e-Kafkas Journal of Educational Research e-KJER Research Article

A Comprehensive Review of Technological Pedagogical Content Knowledge (TPACK)

Tuğçe Karaduman[1] Berrin Akman[2]

To cite this article:
Karaduman, T. & Akman, B. (2024). A Comprehensive review of technological pedagogical content knowledge (TPACK)**.** *e-Kafkas Journal of Educational Research*, *11*, 141-159. doi:10.30900/kafkasegt.1282126

Research article **Received: 12.04.2023** **Accepted: 22.04.2024**

Abstract

This systematic review, encompassing 36 studies, investigates the Technological Pedagogical Content Knowledge (TPACK) framework within diverse educational settings. A PRISMA method was followed to carry out the systematic review. The majority of the reviewed studies focus on pre-service and in-service teachers, highlighting the multifaceted nature of TPACK research. A comprehensive analysis considers demographic variables, technology-related elements, and methodological approaches, revealing a spectrum of methodologies, characteristics, and emerging patterns. Predominantly, non-probability sampling methods were featured in the reviewed studies, indicating a call for standardized sampling techniques to facilitate cohesive comparisons and comprehensive synthesis of findings. The findings suggest that future research should prioritize developing well-defined research questions and data management practices to ensure the accuracy and reliability of the findings. Furthermore, future studies should continue to explore the complex relationships between TPACK and various aspects of instructional practices, as well as the potential impact of TPACK on student learning outcomes. By building on these findings and employing rigorous research methods, future studies can continue to advance our understanding of the role of TPACK in shaping effective instructional practices, ultimately contributing to the improvement of teaching and learning in the digital age. However, the study's focus on articles published in journals hosted by ULAKBIM and conducted in Turkey, as well as the exclusion of non-empirical research, may have limited the generalizability of the findings to other contexts and populations. Additionally, the lack of explicit information on data cleaning procedures and the presence of missing data from the studies reviewed might affect the accuracy and reliability of the findings.

Keywords: TPACK, Education, Teacher Education, Systematic Review.

[1] Corresponding Author, tskaraduman@gmail.com, Hacettepe University

[2] Author, Hacettepe University

Introduction

Technological Pedagogical Content Knowledge (TPACK) stands as a critical framework within the realm of educational research, profoundly impacting instructional practices across diverse educational contexts. This systematic review embarks on a comprehensive exploration of TPACK's multifaceted nature, aiming to dissect its implications for both pre-service and in-service educators. The purpose of this review is to demonstrate insights from empirical studies delving into the complex intersections of technology, pedagogy, and content knowledge. Drawing from these studies, our endeavor is to summarize the effects of TPACK on instructional practices and educational outcomes. This introduction aims to provide a summarized overview of the text, emphasizing the comprehensive nature of the review and the focus on empirical studies. Throughout this exploration, particular emphasis will be placed on the empirical studies' backgrounds, targeted to offer a nuanced understanding of the contextual factors shaping TPACK's implementation and impact within different educational environments. By grounding this review in empirical evidence, it aims to outline the intricate connections between TPACK and effective instructional methodologies, showing the way for informed advancements in teaching and learning paradigms.

In today's fast-developing technology, daily life is affecting every field, including education. Technology has become an important aspect of enhancing learning for today's students (Horne, 2010). In this age of information, not only the availability but also the necessity of various technologies must be taken very seriously. Despite the potential risks of technology for young children, educators believe that by crafting developmentally appropriate activities within technology-driven environments, they can offer a diverse range of positive learning opportunities for young learners (Keengwe & Onchwari, 2009). Wang and Hoot (2006) observe a shift among early childhood educators, noting that educators have moved beyond the basic inquiry of whether technology suits young children's development. Instead, their focus has shifted towards exploring how information and communication technology can be optimally utilized to support and enhance children's learning and growth. The potential impact of educational technology on early education can be substantial, yet its actual realization hinges on the specific choice of technology and the manner in which it is employed (Saracho, 2019). In light of these, the studies suggesting the positive effects of technology use in early childhood on cognitive development, as well as social learning shows that the issue is needed to be addressed at younger ages (Clements, 1994; Clements & Sarama, 2002, 2003). Furthermore, it is claimed that the technology usage in education creates a more productive learning environment than the traditional methods (Morrison & Lowther, 2010). To provide children with the opportunity to achieve their greatest potential, teachers can leverage various technologies. By captivating student interest and organizing learning within a technology-rich environment, students can benefit from a developmentally appropriate learning style. However, simply introducing technology into the classroom isn't sufficient to encourage learning by and with the technology.

The goal of educators might be to include existing technologies in education for a more productive way of learning. A theory in instructional design and technology that specifically underscores the importance of establishing connections between elements of a new concept and linking that concept with students' prior knowledge is generative learning theory (Grabowski, 2003). Generative learning theory emphasizes the students' active role in the process of constructing knowledge. Although, teachers are expected to use educational technology effectively, for the improvement of learning and teaching; technology must be used effectively (Fisher & Waller, 2013). From an instructional design perspective, activities that promote generative learning offer principles for educators to create learning environments that consider both learning and instructional strategies (Wang & Hoot, 2006). There are studies that show teachers are aware of technological advancements and their use in the classroom. Wang (2020) says that the use of technology in the classroom has increased by 363% from 2010 to 2017. In 2010, the number of technological devices used in class was 3 million, while in 2017 it has risen up to 14 million (Bushweller, 2017). In addition to this, it is founded that teachers are aware of technological progress and classroom necessity. It is claimed that 74% of the teachers participating in the study used technology to support teaching-learning processes and knowledge transfer and to increase learning motivation (Murray, 2017). Although it is said that teachers use technology mainly to prepare lesson plans and web-based games, it is understood that teachers accept technology as a supportive element.

It is expectable teachers can see technology as a facilitator tool. However, there may also be some negative consequences of technology use. In this context, teachers are required to be careful not to let the time spent in front of screens reach a level that threatens the health of students (Scoggin & Vander Ark, 2018). This requires a certain amount of technological "pre-knowledge" for a teacher to integrate the technology successfully in the educational process. This pre-knowledge, as expected, does not provide an effective result for the technology usage in education alone. Technological competence includes practical, conceptual (Wilson et al., 2020) and technological knowledge necessary to effectively teach a subject, concept or theme. This corresponds to the term of technological pedagogical content knowledge (TPACK). Due to the increase in the use of technology in education, the role of technological, pedagogical and content knowledge (TPACK) in supporting effective teaching and learning has attracted interest of the researchers. However, it's proposed that teachers' proficiency in TPACK may not fully account for effective technology-integrated instruction. The TPACK model has undergone recent updates to incorporate research-supported findings, now including XK (Contextual Knowledge) to highlight the importance of contextual elements within the framework (Mishra, 2019).

The field of Technological Pedagogical Content Knowledge (TPACK) encompasses three main areas: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). The interactions between these three areas result in Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK). The concept of TPACK is formed by the integration of these three concepts (Mishra & Koehler, 2006). Technological knowledge refers to understanding the capabilities and limitations of different technologies, as well as how to use them effectively. Pedagogical knowledge refers to understanding teaching and learning theories and practices, including how to design and implement effective instruction strategies. Content knowledge refers to understanding the concepts, facts, and skills related to a specific subject area (Shulman, 1986; 1987). Technological content knowledge directs to an understanding how technology can be used to support and enhance teaching and learning within a specific subject area. TPACK knowledge refers to understanding how technology might be used to generally support and enhance teaching and learning. Pedagogical content knowledge links to understanding how to effectively teach and assess content within a specific subject area. Technological Pedagogical Content Knowledge (TPACK) represents the integration of all of these components and represents the knowledge and skills needed to effectively use technology to support teaching and learning (Koehler & Mishra, 2008).

In general terms, TPACK provides a useful framework for teachers to understand how technology, instruction, and content knowledge can be integrated to support the complex and interconnected nature of teaching and learning. TPACK is an important concept in education, particularly in the context of early childhood education. TPACK represents the knowledge and skills that teachers require to effectively integrate technology into their teaching and learning practices. It includes understanding how to use technology to support the learning goals and objectives of the curriculum, as well as how to use technology to effectively teach and engage students. Studies that attempt to explain TPACK suggest that it is the interaction of these components that make it important for teacher education and professional development.

There are several reasons why TPACK is important in education. Technology has increasingly become prevalent in society and a part of daily life (Schwab, 2017). Especially, there has been an increased inclination towards technology, exacerbated by the Covid-19 pandemic that affected the entire world (Venkatesh, 2020). As children are growing up in a digital world, so it is important to support them in using technology in a conscious, controlled, and effective way. A recent OECD report highlighting the aftermath and effects of Covid-19 on education and learning found that most students feel adept at utilizing educational technologies. Around 75% expressed confidence in using systems like online learning platforms and video conferencing tools across the OECD member countries. Yet excessive technology used for leisure may negatively impact academic performance. Specifically, the data shows that students concentrating on devices during math lessons scored 15 points lower than those less distracted by technology, while one hour daily of technology usage for learning related activities resulted in 14 points increase in math scores (OECD, 2023). By teaching children how to use technology as a learning and communication tool, they can develop the skills they need to be successful in the modern world (Bulger et al., 2018; CDW, 2022). It is also claimed that TPACK can make contributions to the

education process from different angles (Koehler & Mishra, 2009). When children have chance to practice and access to technology in their learning, they can become more motivated and engaged in the learning process. Teachers can help students learn and develop in meaningful and engaging ways by using technology. To support the education of young children and integrate technology into teaching practices effectively, educators should develop their TPACK skills (Benson & Ward, 2020).

Furthermore, a significant trend involves the integration of artificial intelligence (AI) and adaptive learning technologies. This tendency reshapes traditional teaching methods, offering personalized and effective learning experiences by taking the pressure away from teachers to possess exhaustive knowledge, enabling them to dedicate more time to supporting students (Akgün & Greenhow, 2022). Wang et al. (2021) explored the implications of AI-driven adaptive learning revealing that educators incorporating these technologies reported a deeper understanding of student needs and refined instructional strategies. Adaptive learning tools facilitated real-time data analysis, empowering teachers to make informed decisions about content delivery and student interventions (Wang & Zhao, 2020). Another study emphasizes the significance of teachers possessing not only technological knowledge (TK) but also a deep understanding of the pedagogical benefits and ethical implications associated with AI integration in education. It advocates for a more holistic approach, proposing an evolved framework named Intelligent-TPACK, which integrates ethical considerations into the existing TPACK model to guide ethical integration of AI-based tools in education (Celik, 2023). As the integration of AI and adaptive learning technologies in TPACK studies represents a significant shift in educational paradigms, emphasizing the role of technology in personalizing learning experiences gains more importance. By analyzing AI curricula and resources, the findings emphasize that K-12 teachers teaching AI necessitate TPACK for constructing, preparing environments, and facilitating project-based classes centered on problem-solving with AI technologies.

Regarding the rising numbers of research carried out about TPACK in literature, TPACK has its place in Turkish research in the scope of education. This particular study would provide an in-depth analysis off existing research on the framework, its impact on both teacher education and teaching practices, learning outcomes of the students. The article would synthesize the existing literature on TPACK to identify the gaps in the literature. This would allow us to suggest recommendations for future studies and practices about TPACK.

Theoretical Background

The growing focus on incorporating technology into education has spurred the creation of the Technological Pedagogical Content Knowledge (TPACK) framework. This framework aims to address the intersection of technological, pedagogical, and content knowledge, and their interplay in the educational context. It focuses on supporting effective teaching and learning practices. This framework highlights the importance of teachers' understanding of how to seamlessly incorporate technology into their instruction. However, possessing TPACK alone does not guarantee successful teaching; self-efficacy also plays a vital role in enhancing a teacher's ability to use technology effectively and improve student outcomes (Mishra & Koehler, 2006).

Self-efficacy, as theorized by Albert Bandura (1986), refers to an individual's confidence in their capabilities to successfully complete a task or achieve a goal. It is a primary driver of motivation and behavior and can influence an individual's perceived control over their environment and available resources. High self-efficacy has been associated with greater persistence in overcoming challenges and achieving objectives (Bandura, 1997). In the context of teaching, a teacher's belief in their capacity to effectively use technology is an example of self-efficacy.

Bandura's social cognitive theory (1986; 1997) posits that individuals actively shape their own learning by engaging with or ignoring the situations they encounter. This approach differs from behaviorism, which emphasizes only environmental influences on learning. Bandura (1997) contends that individuals also contribute to their environment and the learning experiences of others.

TPACK has become a popular and effective framework for describing technology integration in education since its introduction by Mishra and Koehler (2006). While some researchers have criticized the framework (Cox & Graham, 2009; Bowers & Stephens, 2011), others have explored its application in specific subject areas, such as science education (Sheffield et al., 2015). The practical implications of

TPACK remain a topic of interest, especially given the increased reliance on distance education during the pandemic (Harris & Hofer, 2011; Yeh et al., 2021).

Recent studies have investigated various aspects of TPACK, including its relationship with teacher performance (Tosuntas et al., 2021), the impact of microteaching practices on TPACK development (Mutlu et al., 2019), and its relevance to early childhood education (Altun, 2019). However, systematic analyses of TPACK research have highlighted areas that require further investigation, such as the need for longitudinal studies on teachers' actual application of TPACK in practice (Moreno et al., 2019) and the development of more diverse measurement techniques for assessing TPACK (Yigit, 2014). Additionally, some studies have explored the assessment of TPACK (Abbitt, 2011; Archambault, 2010; Chai et al., 2013), while others have employed case studies to gain deeper insights into the TPACK framework and its implementation (Mouza & Krachmer-Klein, 2013; Tai & Crawford, 2014).

In conclusion, the TPACK framework, self-efficacy, and social cognitive theory provide valuable perspectives on the integration of technology in education. Further research on these topics, particularly on the practical implications and assessment of TPACK, will contribute to a deeper understanding of how to effectively use technology to enhance teaching and learning.

Significance of the Research

The significance of this partial replication and systematic review study lies in its potential to provide an updated, comprehensive, and unbiased understanding of the current state of knowledge on the specific topic under investigation. By extending the analysis to more recent publications and employing supplementary tools for a thorough assessment, this research offers valuable insights that can inform decision-making processes and guide future research. Furthermore, the study's methodological adaptations not only validate the robustness of the initial results but also contribute new perspectives and insights to the existing body of knowledge. Ultimately, the findings of this study will serve as a solid foundation for researchers, practitioners, and policymakers seeking to advance the field and address emerging challenges and opportunities.

Moreover, utilizing journal review rubrics and concentrating on empirical research with primary data will reinforce the study's findings' rigor and strength. The implementation of random sampling in this study will help to ensure that the conclusions are representative of the broader population of pertinent articles, thus enhancing the applicability of the results.

This research will provide helpful insights for educators, policymakers, and researchers by summarizing the current state of knowledge on TPACK and identifying potential avenues for future exploration. By building upon the work of the original authors and integrating novel methodological approaches, this study holds the potential to significantly enrich our knowledge of TPACK and its practical implementations in the continuously evolving educational environment.

Method

This research is a partial replication and systematic review study that aims to systematically and comprehensively define, evaluate, and synthesize existing research on TPACK. Systematic reviews are designed to minimize bias and provide a detailed overview of evidence on a specific topic (Petticrew & Roberts, 2006). They offer a comprehensive summary of information that serves as a valuable resource for decision-making. To conduct a systematic review, researchers implemented the PRISMA methodology which involves: defining inclusion and exclusion criteria for study selection, conducting a comprehensive search of literature, assessing quality and relevance of identified studies, extracting and synthesizing findings, and discussing the evidence-based results (Moher et al, 2009). This research utilizes the framework from Baran and Canbazoğlu-Bilici (2015) as a foundation while incorporating modifications and additions to further explore and build upon their initial work.

This research is a partial replication and systematic review study that aims to systematically and comprehensively define, evaluate, and synthesize existing research on TPACK or research question while building upon the methodology outlined in Baran and Canbazoğlu-Bilici (2015). The rationale for this approach is to validate and expand upon the original findings by adapting certain aspects of the initial work. This allows for contributing new insights to the existing body of knowledge while assessing the robustness of the original results.

Our study differs from the original work (Baran & Canbazoğlu-Bilici, 2015) in several ways including selection criteria:

1. Due to the increased number of publications, we employed a random sampling technique to select a subset of articles for analysis, unlike the original authors who worked with the entire population of relevant articles.
2. Our research does not emphasize distinction of transformative and integrative models of TPACK.
3. The analysis focuses on journal articles published between 2014 and 2022, as opposed to the original study, which examined articles published from 2005 to 2013.
4. The population includes only the articles published in journals hosted by ULAKBIM and those conducted in Turkey.
5. The study includes only empirical research that utilizes primary data.

These methodological differences have been carefully considered and implemented to offer a fresh perspective on the original findings while acknowledging the contributions of the original authors. By incorporating these adaptations and refining the methodology, this research is expected to provide a more robust evaluation of the current state of knowledge on the topic and contribute valuable insights for future research.

Study Inclusion and Exclusion Criteria

Screening process was carried out by two researchers and study eligibility were determined through three stages (See Table 1; Moher et al., 2009).

Table 1.

Article Screening Process.

Screening Stage	Frequency of Articles (f)	Percentage of Screened Articles (%)
Title	228	100%
Title & Abstract	172	75%
Full Text	36	16%

The initial stage was to query ULAKBIM database. It has been reviewed several TPACK review studies to determine search terms (Baran & Canbazoğlu-Bilici, 2015; Voogt et al. 2013; Yeh et al., 2021; Yılmaz & Bal, 2022). The final searching keywords were "technological pedagogical content", "technological pedagogical content knowledge", "teknolojik pedagojik", "teknolojik pedagojik alan", "tpab", "tpack", and "tpck". The results were limited to the articles whose abstracts include above mentioned search terms. The year range was between 2014 and 2022. All the search results were joined and in total 810 articles have been founded. After removing duplicates 228 articles remained. Of these, 203 articles were within the scope of education and/or teaching. Then the authors created selection criteria:

1. Data source was in Turkey.
2. It was an empirical study using primary data. All kinds of review studies were excluded.
3. The focus was on in-service and/or pre-service teachers.
4. The purpose of the study was related to TPACK.

Selection criteria yielded 172 results. The abstracts of all of these articles screened by two researchers and the researchers arrived on a consensus to determine to select 159 articles. In order to examine all of the articles comprehensively, the researchers decided to decrease the number of the screened articles. For that purpose, the researchers randomly select 36 articles for systematic review. In statistics, a common percentage used for random sampling is 5% (Cochran, 1977). In the case of selecting only five percent of the population, it's possible that this sample may not be large enough to accurately capture the variability of the population. For instance, in similar studies 30-40 articles are included. To be relevant to existing literature, nearly 20% of the articles are included in the study (See Figure 1).

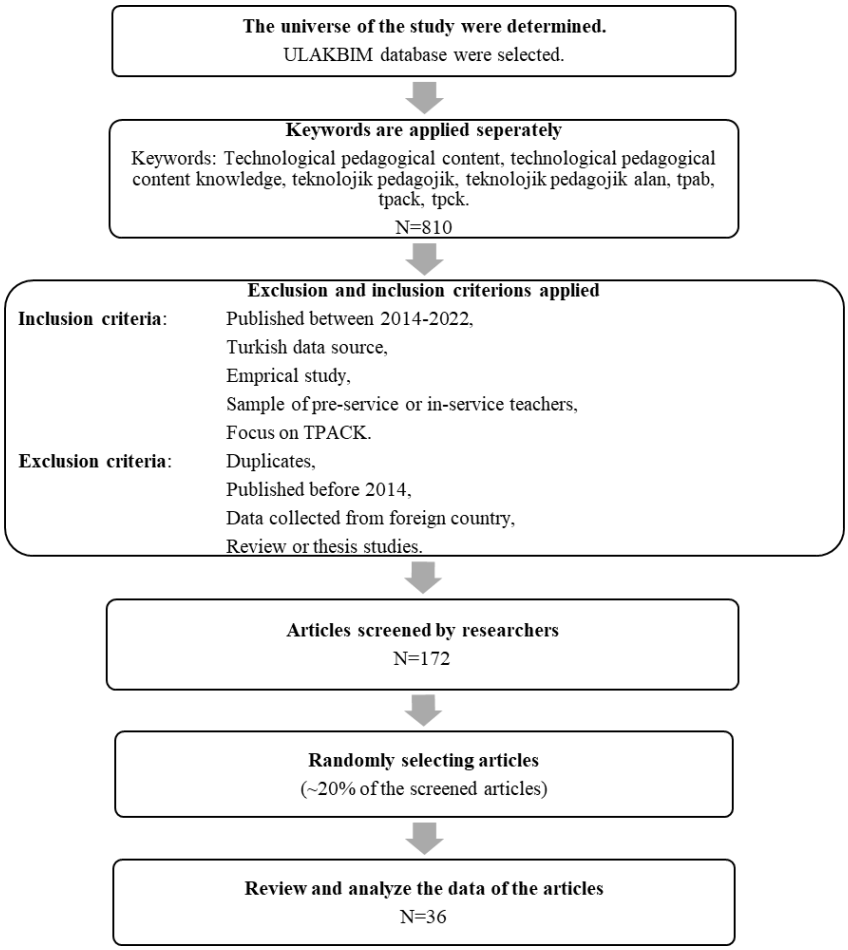

Figure 1. Article Selection Process

Literature Analysis

The articles were analyzed using content analysis method which was determined to be suitable for the study criteria. A classification method was prepared by examining the relevant research in the field (Petticrew & Roberts, 2006). After this classification, a descriptive analysis was conducted. Descriptive content analysis is a type of literature review that systematically evaluates research in a research field in order to describe tendencies and results (Suri & Clarke, 2009).

The researchers developed an analytical framework for analyzing articles. Then, the researchers read all articles and created a preliminary coding scheme, which was refined by another researcher after reviewing two articles to ensure trustworthiness. The coding finalized by negotiating until reaching a complete consensus. The contents were summarized according to the categories and subcategories as shown in the Table 2.

Table 2.

Article Analysis Categories

Sampling	Method	Data Analysis
Study group	Research questions	Demographic variables
Sample size	Research design	Data cleaning
Sampling method	Data collection tools	Outcome measure
	Explanation of measurement tools	

After examining each article thoroughly, the details were entered into an MS Excel spreadsheet. The researchers merged their examinations and conducted cross-comparisons between examined similarities

and differences. Data reporting was completed by using tables and figures to present findings rather than any statistical analysis due to the nature of research methodology employed for the study.

Research Questions

1. What are the characteristics of the study groups in the existing literature on TPACK and instructional practices across different subject areas and educational contexts?
2. How do the research methodologies, tools, and scales employed in the studies on TPACK and instructional practices differ, and what are the trends and patterns observed in the use of these methods and tools?
3. How do demographic factors and technology-related variables feature in the studies on TPACK and instructional practices, and what is the extent of their consideration and analysis in these studies?
4. What are the sampling techniques and sample sizes used in the studies on TPACK and instructional practices, and how do they influence the outcomes and generalizability of the findings?
5. How do the studies on TPACK and instructional practices address missing data and data cleaning procedures, and what are the implications for the accuracy and reliability of their findings?
6. What are the study contexts and outcomes investigated in the existing literature on TPACK and instructional practices?

Findings

This section presents the findings from a comprehensive review of 36 studies focusing on the Technological Pedagogical Content Knowledge (TPACK) framework and instructional practices in different educational contexts. The findings provide insights into the various study groups, research methodologies, tools and scales employed, as well as the handling of missing data, study contexts, and outcomes. The objective of this chapter is to shed light on the different approaches, characteristics, and trends observed in the reviewed studies, offering a detailed understanding of the current state of research on TPACK and instructional practices.

Study Group

Table 3.

Distribution of study groups by subject area

Study Group	Frequency (f)	Percentage (%)
In service	17	47.22%
Multiple Groups	6	16.67%
Math	2	5.56%
ECE	2	5.56%
Elementary	2	5.56%
Science	2	5.56%
Physical Ed.	1	2.78%
Geography	1	2.78%
Chemistry	1	2.78%
Pre-service	18	50.00%
Science	6	16.67%
Multiple Groups	4	11.11%
Elementary	3	8.33%
Math	2	5.56%
ELT	1	2.78%
Geography	1	2.78%
Administrators	1	2.78%

As shown in Table 3, a total of 36 studies were examined. Among these studies, 18 collected data from pre-service teachers, 17 from in-service teachers, and 1 from school leaders. The majority of the in-service studies (n=6) gathered data from teachers across various subject areas, while the majority of the studies (n=6) conducted with pre-service teachers collected data specifically from science education teachers.

In the reviewed studies, various demographic factors were considered or mentioned. Approximately 61% of the studies focused on gender, while age was addressed in 22% of the studies, and experience was discussed in 14% of the studies. However, there were also 25% of the studies where demographic information was not provided or analyzed.

In addition to demographics, some studies explored internet usage (25%), computer use (33%), technology ownership (36%), and educational technology usage (8%). Many of these studies considered multiple factors together, such as internet usage, computer use, and technology ownership. However, it is worth noting that 25% of the studies did not delve into any of these aspects.

Overall, the demographic factors and technology-related variables in the reviewed studies varied, with some studies providing a more comprehensive view of the participants, while others were more limited in scope.

Study Design

The breakdown of the research methods, tools, and scales used in 36 studies is as follows: 16.67% (6 studies) used mixed methods, 13.89% (5 studies) were qualitative, and 66.67% (24 studies) were quantitative. Various tools and scales were employed, with some studies using multiple methods or tools. Graham et al. (2009) was referenced in 8 studies, while Sahin (2011) was used in 6 quantitative studies. Notably, 11.11% (4 studies) used semi-structured interviews. Some specific tools and scales, such as TPACK self-efficacy scale by Schmidt et al, (2009; 5 studies), TPACK SES scale by Horzum, Akgün, and Öztürk (2014; 2 studies), TPACK-EFL Survey, TPACK DEEP by Kabakci Yurdakul et al. (2012), and TSES by Tschannen-Moran and Woolfolk Hoy (2001) were also referenced by some studies. Furthermore, semi-structured interviews were employed as a secondary data collection tool in several studies, demonstrating its versatility in complementing other research methods. In addition to semi-structured interviews, other qualitative tools were employed, such as peer reflective discussion forums, focus group interviews, coding the class assignments and presentations and lesson plans.

Table 4.

Distribution of Referenced TPACK Scales

Scale Name	Year	Developer	Frequency (f)
TPACK Self Confidence Scale	2009	Graham et al.	8
TPACK Scale	2011	Sahin	6
TPACK Self-efficacy Scale (SES)	2009	Schmidt	5
TPACK DEEP	2012	Kabakci et al.	2
TPAB-ÖDÖ	2016	Kartal, Kartal, & Uluay	2
TPACK SES	2014	Horzum, Akgün, & Öztürk	2
IWB-based TPACK Questionnaire	2012	Jang & Tsai	1
TPACK-EFL	2015	Baser, Kopcha & Ozden	1
Technology in Education SES	2014	Dogru	1
TPAB Özyeterlik Ölçeği	2016	Balcin & Ergun	1
TPACK-SES	2013	Canbazoğlu-Bilici et al.	1

In the reviewed studies, 58.33% of the articles provided explanations of the measures employed, while 8.33% gave information on both the original scale and the current study's reliability scores. However, 8.33% of the studies did not offer sufficient information on the measures used. In 2.78% of the articles, the measures were not provided, whereas in 5.56% of the cases, the current study's measures were given, but not the original scale. Additionally, 2.78% of the studies only provided the original scale, without mentioning the current study's measures. Lastly, 13.89% of the articles employed qualitative measures.

Out of the 36 studies, a majority (77.78%) employed a convenience sampling method, which is a non-probability sampling technique. In addition, purposive sampling, another non-probability sampling method, was utilized in 19.44% of the studies. Only one study (2.78%) used cluster sampling, a probability sampling approach. Overall, non-probability sampling methods were predominantly favored in the reviewed studies.

The reviewed studies display a variety of sample sizes (See Table 5). For the mixed-methods studies (16.67% of the total), sample sizes ranged from 24 to 436 participants. In the qualitative studies (13.89%), the sample sizes were smaller, with a range of 5 to 80 participants. Quantitative studies, representing 66.67% of the total, had a wider range of sample sizes, from 25 to 1,169 participants. Lastly, there was a single quantitative quasi-experimental study (2.78%) with a sample size of 35 participants. This indicates a diverse array of sample sizes across the different research methodologies employed in the reviewed studies.

Missing data details were addressed to varying degrees. For missing values, it was found that 25% (n=7) of the studies mentioned missing values, while the majority, 69.4% (n=24), did not mention them. In addition, 5.6% (n=5) of the studies were qualitative and, thus, did not specifically discuss missing values. None of the articles examined in this review provided explicit information on their data cleaning procedures.

In the analysis of the studies, it was found that 77.78% (n=28) of them explicitly provided research questions, while 22.22% (n=8) did not clearly mention research questions or hypothesis of the study. This indicates that a majority of the studies included clear research questions, whereas a smaller proportion lacked this important element in their research design.

Table 5.

Distribution of Sample Sizes by Research Methodology

Research Methodology	Frequency of Studies (f)	Percentage (%)
Mixed methods	6	16.67%
0-49	2	5.56%
50-99	1	2.78%
More than 100	3	8.33%
Qualitative	5	13.89%
0-49	4	11.11%
50-99	1	2.78%
Quantitative	24	66.67%
Less than 100	3	8.33%
100-199	6	16.67%
200-299	6	16.67%
300-399	2	5.56%
400-499	2	5.56%
More than 500	6	16.67%
Quantitative (quasi-exp.)	1	2.78%
0-49	1	2.78%

Study Context and Outcomes

The review study analyzed various aspects related to TPACK and instructional practices. This comprehensive systematic review synthesized findings from 36 studies that analyzed various aspects related to technological pedagogical content knowledge (TPACK) and instructional practices across educational contexts. The predominant focus was on TPACK scores (n=27, 75%) as a key measurable outcome for assessing TPACK development, with a subset also investigating impacts on instructional practices (n=5, 13.9%) and educator opinions, needs assessments, and attitudes related to effective technology integration (n=4, 11.1%).

The majority of studies were situated in teacher training environments (n=22, 61.1%), including both pre-service teacher preparation coursework as well as in-service professional development workshops. This context allowed for analysis of how foundational knowledge of TPACK is initially developed by educators in training, as well as how seasoned teachers further enhance skills. The remaining studies (n=14, 38.9%) collected data in active K-12 or postsecondary educational settings, providing additional insights into how cultivated TPACK translates into daily teaching practices, student impacts, and institutional technology integration challenges.

Regarding specific data collection methodology, an overwhelming majority leveraged likert-scale questionnaires (n=31 studies, 86.1%) to gather wide-ranging perceptual data on educators' self-assessed TPACK abilities and growth areas. Open-ended interviews offered qualitative insights (n=8 studies, 22.2%) into participant experiences developing technological knowledge situated in content-driven pedagogy. A limited number of studies employed focus groups for group discussion dynamics and direct analysis of class assignments or lesson plans (n=2, 5.6%) for revealed artifacts of TPACK in practice. A subset combined closed and open-ended questionnaires with interviews or focus groups for mixed-methods approaches (n=8 studies, 22.2%) and data triangulation.

In summary, while predominantly focusing on teacher training contexts, the reviewed body of scholarship featured diverse research designs and data collection methods to rigorously explore various facets of TPACK cultivation alongside translations to daily instructional practices across educational settings. This provides a robust evidence base for synthesis. Further targeted analysis of trends across findings is warranted to determine high-potential directions for both research and practice.

Discussion, Conclusion, and Suggestions

This comprehensive review of 36 studies investigating the Technological Pedagogical Content Knowledge (TPACK) framework and instructional practices in various educational contexts has provided valuable insights into the current state of research on this topic. The findings of this review reveal diverse approaches, characteristics, and trends, offering a detailed understanding of the ways researchers have explored TPACK and its impact on instructional practices.

The majority of the reviewed studies focused on pre-service and in-service teachers, with a few investigating school administrators. Considering that Baran and Canbazoğlu-Bilici's (2015) study only included 6 studies conducted with in-service teachers (20%), we can see that our data shows that almost 50% of the studies in our review were conducted with in-service teachers. The studies examined various demographic factors, including gender, age, and experience, as well as technology-related variables, such as internet usage, computer use, technology ownership, and educational technology usage. This diversity in the study groups and the factors considered highlights the multifaceted nature of TPACK research, which requires attention to the complex interplay between teacher characteristics, technology, and instructional implementations.

In a recent TPACK review study Yeh et al. (2021) discusses the limitations of using self-reported surveys to determine individual teachers' TPACK levels. The authors suggest that relying solely on self-reported TPACK data may not provide an accurate reflection of a teacher’s instructional quality. Similarly, while self-reported data can provide some insights, it may not be sufficient to accurately measure teachers’ TPACK proficiency (Koehler et al., 2012). While collaborative discourse has shown promise in enhancing collective TPACK, getting data regarding teachers’ personal TPACK development is crucial. It is suggested that future studies should emphasize more experience-based perspective and identify effective strategies.

Accordingly, the reviewed studies in this particular research employed a range of approaches in terms of methodology, with the majority using quantitative methods, followed by mixed-methods and qualitative approaches. This finding is relatively consistent with another review study where the majority of the studies utilized empirical research with quantitative methods as their systematic process and qualitative studies were also commonly used, while mixed methods were used to a lesser extent (Moreno et al, 2019). This indicates a growing recognition of the need to combine various research methods to gain a comprehensive understanding of TPACK and instructional practices. The studies employed various tools and scales to assess TPACK, including some widely-used measures such as the TPACK self-efficacy scale and TPACK Scale. This highlights the importance of establishing reliable and valid

measures to assess TPACK and its various components, which can facilitate the comparison of findings across different studies and contexts.

This study also investigated how reliability levels were reported in TPACK studies, and found that detailed information was given in majority studies, while small number of studies did not provide such information. Another review study similarly found that 64 studies provided detailed information on reliability levels, 24 studies only gave superficial information, and 11 studies did not provide any information at all (Yolcu et al., 2022).

A majority of the reviewed studies utilized non-probability sampling techniques, such as convenience and purposive sampling, which may limit the generalizability of the findings. Future research could benefit from employing probability sampling techniques to enhance the representativeness and generalizability of the study samples. Additionally, the sample sizes varied greatly across the studies, indicating a need for more consistency in sampling procedures to facilitate comparison and synthesis of findings.

The analysis of the studies revealed that a significant proportion did not explicitly address missing data or data cleaning procedures. This suggests that future research should pay greater attention to data management practices to ensure the accuracy and reliability of the findings. Furthermore, some studies lacked clear research questions or hypotheses, indicating that future research should prioritize developing well-defined research questions to guide the investigation of TPACK and instructional practices.

The reviewed studies predominantly focused on TPACK scores as an outcome measure, with some investigating instructional practices, opinions, needs assessments, and attitudes. This suggests that future research should continue to explore the complex relationships between TPACK and various aspects of instructional practices, as well as the potential impact of TPACK on student learning outcomes. A notable recommendation arising from this review involves conducting further data analysis to gather additional insights. While the reviewed studies provided valuable insights, a deeper analysis of the interplay between specific TPACK components and their effects on student achievement could offer a more nuanced understanding. Additionally, findings presented in the reviewed studies were often contextualized within specific educational settings, limiting their broader applicability. To enhance the informativeness of findings, future research should aim for more generalizable and transferable conclusions, facilitating their relevance across diverse educational landscapes.

In conclusion, this review has provided a comprehensive overview of the current research landscape concerning the TPACK framework and instructional practices across diverse educational contexts. The findings illuminate various approaches, methodologies, and trends, underscoring the imperative for future research to address the identified gaps and inconsistencies. By leveraging these findings and employing rigorous research methods, forthcoming studies can further enhance our comprehension of the role of TPACK in shaping effective instructional practices, ultimately contributing to the improvement of teaching and learning in the digital age.

Limitations

Systematic reviews possess inherent limitations. When the prescribed stages are not meticulously followed, ensuring fairness and reliability in research findings becomes challenging. Hence, the decisions made by researchers regarding research methodologies, such as PRISMA, are crucial. To overcome mistakes such as inadequate keyword selection or incorrect data sources that might exclude essential studies, researchers follow the path outlined in the methodology section and manually eliminate irrelevant studies. In social sciences, there's a risk of subjective interpretation, potentially impacting impartiality. Although synthesizing a limited number of studies can yield a comprehensive overview, it might compromise the robustness of conclusions due to the restricted scope of synthesized research. Addressing these risks and proposing solutions is imperative in systematic literature analysis. Despite efforts to transparently evaluate search system capabilities based on evidence-based criteria, the study's boundaries inevitably constrain its comprehensiveness. It's vital to highlight both strengths and weaknesses, as it provides a valuable evaluation, recognizing that the researchers' experience can be shaped by various technical and situational factors.

The present study has several limitations that should be taken into consideration when interpreting the findings. The study's focus on articles published in journals hosted by ULAKBIM and conducted in Turkey may have resulted in a biased sample, limiting the generalizability of the findings to other contexts and populations. As a systematic review, this study relied on the data collection and reporting from the original 36 source studies rather than gathering any primary data first-hand. As such, it is limited by any issues with how the source studies were conducted or by the accuracy of their documented findings. Secondly, the study's exclusion of non-empirical research, such as literature reviews and theoretical papers, may have excluded valuable insights from the analysis. Thirdly, the use of a random sampling technique to select a subset of articles for analysis may have resulted in a sample that is not representative of the entire population of relevant articles. Furthermore, the use of a single database for article selection may have resulted in the exclusion of relevant studies published in other databases. Additionally, the lack of explicit information on data cleaning procedures and missing data of the studies reviewed might affect the accuracy and reliability of the findings.

Acknowledgment

Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

Author Contributions: The authors contributed to the article equally, with both involved in conceptualization and validation. Corresponding author handled the methodology and analysis. Additionally, both authors participated in writing, reviewing, and editing. Berrin Akman provided supervision and project administration.

Funding: This research received no funding.

Institutional Review Board Statement: Ethical approval was not sought for this systematic review as it involves analyzing previously published research and does not involve the collection of new data from human subjects.

Data Availability Statement: Data generated or analyzed during this study are available from the authors upon request.

Conflict of Interest: The authors declare that they have no conflicts of interest to disclose.

References

Akgün, S. & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. AI Ethics, 2, 431–440 (2022). https://doi.org/10.1007/s43681-021-00096-7

Altun, D. (2019). Investigating Pre-Service Early Childhood Education Teachers' Technological Pedagogical Content Knowledge (TPACK) Competencies Regarding Digital Literacy Skills and Their Technology Attitudes and Usage. *Journal of Education and Learning, 8*(1), 249-263. doi:10.5539/jel.v8n1p249

Archambault, L. M. & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education. 55,* 1656-1662.

Abbitt, J. T. (2011). Measuring Technological Pedagogical Content Knowledge in Preservice Teacher Education. *Journal of Research on Technology in Education, 43*(4), 281-300. doi:10.1080/15391523.2011.10782573

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, New Jersey: Prentice Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W. H. Freeman & Company: New York

Baran, E. & Canbazoğlu Bilici S. (2015). Teknolojik Pedagojik Alan Bilgisi (TPAB) Üzerine Alanyazın İncelemesi: Türkiye Örneği. [in Turkish]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 30*(1), 15-32.

Benson, V. & Ward, S. (2020). Teachers' readiness to use technology in the classroom. *Technology, Pedagogy and Education, 30*(1), pp.137-156. https://doi.org/10.1080/1475939X.2020.1851752

Bowers, J. S. & Stephens, B. (2011). Using technology to explore mathematical relationships: A framework for orienting mathematics courses for prospective teachers. *Journal of Mathematics Teacher Education, 14*, 285-304.

Bulger, M., Mayer, R., Metzger, M., & Blumenfeld, P. (2018). Knowledge and processes that predict proficiency in digital literacy. *Reading and Writing, 31*(7), 1531–1553. https://doi.org/10.1007/s11145-017-9752-2

Bushweller, K. C. (2017). Classroom technology: Where schools stand. Technology counts. *Education Week, 36*(35)

Chai, C. -S. Koh J. H. -L., & Tsai C. -C. (2013). A Review of Technological Pedagogical Content Knowledge. *Educational Technology & Society, 16*(2), 31-51.

Clements, D. H. (1994). "The Uniqueness of the Computer as a Learning Tool: Insights from Research and Practice." In June L. Wright and Daniel D. Shade (Eds), Young Children. Active Learners in a Technological Age. National Association for the Education of Young Children.

Clements, D. H. & Sarama, J. (Eds.). (2002). Early Childhood Corner: The Role of Technology in Early Childhood Learning. *Teaching children mathematics, 8*(6), 340-343.

Clements, D. H. & J. Sarama. (2003). Strip mining for gold: Research and policy in educational technology - A response to "Fool's Gold." *Educational Technology Review, 11*(1).

Cochran, W. G. (1977). *Sampling Techniques.* 3rd Edition, John Wiley & Sons, New York.

Cox, S. & Graham C. R. (2009) Diagramming TPACK in practice: using and elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends, 53*, 60–69.

CDW (2022). The COVID-19 Pandemic and the Transformation of Education. CDW. Retrieved from https://www.cdw.com/content/cdw/en/research/covid-19-pandemic-transformation-of-education.html

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

Fisher, D. M. & Waller, L. R. (2013). The 21st century principal: A study of technology leadership and technology integration in Texas K-12 schools. The Global eLearning Journal, 2(4), 1-44.

Grabowski, B. L. (2003). Generative learning contributions to the design of instruction and learning. In D. H. Jonassen (Ed.), Handbook of research for educational communications and technology. 2nd edition. 719-743. Hillsdale, NJ: Lawrence Erlbaum Associates.

Graham, R. C., Burgoyne, N., Cantrell, P., Smith, L., St. Clair, L., & Harris, R. (2009). TPACK Development in Science Teaching: Measuring the TPACK Confidence of In-service Science Teachers. *Tech-Trends, 53*(5), 70-79. doi: 10.1007/s11528-009-0328-0.

Harris, C. B. & Hofer, M. (2011). Technological Pedagogical Content Knowledge (TPACK) in Action. Journal of Research on Technology in Education. doi: 10.1080/15391523.2011.10782570

Horne, M. (2010). A new role for CTE. Techniques: Connecting Education and Careers, *85*(4), 10–11.

Horzum, M. B., Akgün, Ö. E., & Öztürk, E. (2014). The psychometric properties of the technological pedagogical content knowledge scale. *International Online Journal of Educational Sciences, 6*(3). https://doi.org/10.15345/iojes.2014.03.004

Keengwe, J. & Onchwari, G. (2009). Technology and Early Childhood Education: A Technology Integration Professional Development Model for Practicing Teachers. *Early Childhood Education Journal*, *37*, 209–218. https://doi.org/10.1007/s10643-009-0341-0

Mishra, P. (2019). Considering Contextual Knowledge: The TPACK Diagram Gets an Upgrade. *Journal of Digital Learning in Teacher Education, 35*, 76-78. https://doi.org/10.1080/21532974.2019.1588611

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

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group, (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine, 151(4), 264-269.

Morrison, G. R. & Lowther, D. L. (2010). Educational technology research past and present: Balancing rigor and relevance to impact school learning. *Contemporary educational technology*, *1*(1), 17-35.

Kabakci Yurdakul, I., Odabasi, H.F., Kilicer, K, Coklar, A. N., Birinci, G., & Kurt, A.A. (2012). The development, validity and reliability of TPCK-deep: A technological pedagogical content knowledge scale. *Computers & Education, 58*(3), 964-977. doi: 10.1016/j.compedu.2011.10.012

Koehler, M. J. & Mishra, P. (2008). Introducing TPCK. AACTE Committee on Innovation and Technology. The handbook of technological pedagogical content knowledge (TPCK) for educators (pp. 3–29). Mahwah, NJ: Lawrence Erlbaum Associates.

Koehler, M. J. & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70

Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In R. N. Ronau, C. R. Rakes, & M. L. Niess (Eds.), Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches (pp. 16–31). Hershey, PA, USA: IGI Global.

Moreno, J. R., Montoro, M. A., & Ortiz Colón, A. M. (2019). Changes in teacher training within the TPACK model framework: A Systematic Review. *Sustainability, 11*, 1870; doi:10.3390/su11071870

Mouza, C. & Karchmer-Klein, R. (2013). Promoting and assessing pre-service teachers' technological pedagogical content knowledge (TPACK) in the context of case development. *Journal of Educational Computing Research, 48*(2),127-152

Murray, C. (2017, Dec 13) 74 percent of educators support the use of technology in schools. EdTech Magazine online. https://edtechmagazine.com/k12/article/2013/02/survey-74-percent-educators-support-use-technology-schools

Mutlu, Y., Polat, S., & Alan, S. (2019). Development of preservice mathematics teachers' TPACK through micro teaching: Teaching the VuStat program. *International Journal of Technology in Education and Science (IJTES), 3*(2), 107-118.

OECD (2023), *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*, PISA, OECD Publishing, Paris, https://doi.org/10.1787/53f23881-en.

Petticrew, M. & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide.* Malden USA: Blackwell Publishing.

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *Turkish Online Journal of Educational Technology, 10*(1), 97-105.

Saracho, O. N. (2019). *Handbook of Research on the Education of Young Children*. 4th Edition. Routledge, NY. https://doi.org/10.4324/9780429442827

Schmidt, D., Baran, E., Thompson, A., Mishra, P., Koehler, M.J., & Shin, T. (2009). Technological Pedagogical Content Knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. Paper presented at the *2009 Annual Meeting of the American Educational Research Association*. April 13-17, San Diego, California.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.

Scoggin, D. & Vander Ark, T. (2018). Should we limit 'Screen Time' in school? Education Next, 18(1), 54-63.

Sheffield, R., Dobozy, E., Gibson, D., Mullaney, J., & Campbell, C. (2015). Teacher education students using TPACK in science: a case study, *Educational Media International.* doi: 10.1080/09523987.2015.1075104

Suri, H. & Clarke, D. (2009). Advancements in research systhesis methods: From a methodologically inclusive perspective. *Review of Educational Research, 79*(1), 395-430.

Schwab, K. (2017). *The fourth industrial revolution.* Crown Publishing Group.

Tai, S. D. J. & Crawford, D. (2014). Conducting classroom observations to understanding TPACK: Moving beyond self-reported data.

Tosuntas, Ş. B., Cubukcu, Z., & Beauchamp, G. (2021). A new model for the factors that affect interactive whiteboard usage of teachers and its effect on performance. *Education and Information Technologies, 26*(3), 3575–3592. doi:10.1007/s10639-021-10428-z

Tschannen-Moran, M., & Woolfolk, H. A. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education, 17*, 783-805.

Venkatesh, V. (2020). Impacts of COVID-19: A research agenda to support people in their fight. International Journal of Information Management, 55. https://doi.org/10.1016/j.ijinfomgt.2020.102197

Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & Van Braak, J. (2013), Technological pedagogical content knowledge–a review of the literature. J. Comput. Assist. Learn. 29, 109–121.

Wang, J. G. H. (2020). Developing teachers technological, pedagogical, and content knowledge (TPACK) through design thinking and community of practice. Dissertations. 43. Retrieved from https://scholarworks.sjsu.edu/etd_dissertations/43

Wang, Y., Liu, C., & Tu, Y. F. (2021). Factors affecting the adoption of AI-based applications in higher education. Educational Technology & Society, 24(3), 116–129.

Wang, Y., & Zhao, P. (2020). A probe into spoken English recognition in English education based on computer-aided comprehensive analysis. International Journal of Emerging Technologies in Learning (iJET), 15(3), 223–233.

Wang, X. C., & Hoot, J. L. (2006). Information and communication technology in early childhood education. Early Education and Development, 17(3), 317–322.

Wilson, M. L., Ritzhaupt, A. D., & Cheng, L. (2020). The impact of teacher education courses for technology integration on pre-service teacher knowledge: A meta-analysis study. *Computers & Education, 156*, 1–16. https://doi.org/10.1016/j.compedu.2020.103941

Yeh, Y., HoChan, K. K., & Hsu, Y.-S. (2021). Toward a framework that connects individual TPACK and collective TPACK: A systematic review of TPACK studies investigating teacher collaborative discourse in the learning by design process. *Computers and Education, 171*. doi: 10.1016/j.compedu.2021.104238

Yılmaz, R., & Bal, A. P. (2022). Examination of the studies made on technological pedagogical content knowledge in the years of 2010-2021. *Gaziantep Üniversitesi Eğitim Bilimleri Dergisi, 6*(2), 54-70.

Yigit, M. (2014). A review of the literature: how pre-service mathematics teachers develop their technological, pedagogical, and content knowledge. *International Journal of Education in Mathematics, Science and Technology, 2*(1), 26-35.

Yolcu, H., Kaya Durna, D., Akan, A., & Uluçınar Sağır, Ş. (2022). Analysis of studies on pedagogical content knowledge and technological pedagogical content knowledge by meta-synthesis method. *Educational Academic Research, 46*, 106-121.

Appendix 1. Reviewed Studies

Açıkgül, K. & Aslaner, R. (2015). İlköğretim matematik öğretmen adaylarinin TPAB Güven algilarinin incelenmesi. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 17*(1), 118-152. doi: 10.17556/jef.04990

Aksan, A. N. & Kutluca, A. Y. (2021). Investigation of preschool teachers' use of technology in teaching in terms of technology selfefficacy levels. *Kastamonu Eğitim Dergisi , 29* (3) , 611-626 . Retrieved from https://dergipark.org.tr/en/pub/kefdergi/issue/64754/738068

Akgündüz, D. & Bağdiken, P. (2018). Fen bilimleri öğretmenlerinin teknolojik pedagojik alan bilgisi özgüven düzeylerinin incelenmesi. *Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi, 38*(2), 535-566. doi: 10.17152/gefad.357224

Akyıldız, S. & Altun, T. (2018). Sınıf öğretmeni adaylarinin teknolojik pedagojik alan bilgilerinin (TPAB) bazi değişkenlere göre incelenmesi. *Trakya Üniversitesi Eğitim Fakültesi Dergisi, 8*(2), 318-333. doi: 10.24315/trkefd.322749

Akyüz, D. (2016). Farklı öğretim yöntemleri ve sınıf seviyesine göre öğretmen adaylarinin TPAB analizi. *Turkish Journal of Computer and Mathematics Education (TURCOMAT), 7*(1), 89-111. doi: 10.16949/turcomat.75768

Akyüz, H. İ., Pektaş, M., Kurnaz, M. A., & Memiş, E. K. (2014). Akıllı tahta kullanimli mikro öğretim uygulamalarinin fen bilgisi öğretmen adaylarinin TBAP'larına ve akilli tahta kullanima yönelik algilarina etkisi. *Cumhuriyet Uluslararası Eğitim Dergisi, 3*(1), 1-14. doi: 10.30703/cije.321331

Aşık, A., Eroğlu İnce, B. H., & Şarlanoğlu Vural, A. (2018). Investigating learning technology by design approach in pre-service language teacher education: Collaborative and reflective experiences. *Eğitimde Nitel Araştırmalar Dergisi, 6*(1), 37-53. Retrieved from https://dergipark.org.tr/tr/pub/enad/issue/36482/413836

Aydın Günbatar, S., Yerdelen Damar, S., & Boz, Y. (2017). Teknolojik pedagojik alan bilgisi (TPAB) kavraminin yakindan incelenmesi: İlköğretim fen bilgisi öğretmen adaylarinin TPAB'ının modellemesi. *İlköğretim Online, 16*(3), 917-934. DOI: 10.17051/ilkonline.2017.330232

Bahçivan, E., Aydın, F., & Yener, D. (2015). Fen bilgisi öğretmen adaylarinin teknolojik pedagojik alan bilgisi öz güvenleri ve benlik kurgulari arasindaki ilişkilerin incelenmesi: Abant Izzet Baysal Üniversitesi örneği. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 15*(2), 1-12. doi: 10.17240/aibuefd.2015.15.2-5000161310

Bakaç, E. & Özen, R. (2017). Öğretmen adaylarinin materyal tasarimi öz-yeterlik inanç düzeylerinin teknolojik pedagojik alan yeterlikleri bağlaminda incelenmesi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 18*(2), 613-632. Retrieved from https://dergipark.org.tr/en/pub/kefad/issue/59416/853301

Balçın, M. & Ergün, A. (2018).Fen bilgisi öğretmen adaylarinin sahip olduklari teknolojik pedagojik alan bilgisi (TPAB) özyeterliklerinin belirlenmesi ve çeşitli değişkenlere göre incelenmesi. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, 0*(45), 23-47. doi: 10.21764/maeuefd.311316

Bayrak, N. & Bayrak, G. (2021). Eğitimde teknoloji kullanimi içerikli hizmet içi eğitim kurslarinin öğretmenlerin teknolojik pedagojik alan bilgisi özgüvenine etkileri. *Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, 18*(1), 1009-1041. doi: 10.33711/yyuefd.957385

Çar, B. & Aydos, L. (2022). Beden eğitimi ve spor öğretmenlerinin teknolojik pedagojik alan bilgisi yeterliliklerinin sinif yönetimi davranişlari açisindan incelenmesi. *Beden Eğitimi ve Spor Bilimleri Dergisi, 24*(1), 1-9. Retrieved from https://dergipark.org.tr/tr/pub/ataunibesyo/issue/69207/910931

Çelik, İ., Hebebci, M. T., & Şahin, İ. (2016). Role of use of online case study library in technology integration: A study based on TPACK. *Gaziantep University Journal of Social Sciences, 15*(3), 739-754. doi: 10.21547/jss.256698

Cesur Özkara, E., Yavuz Konokman, G., & Yanpar Yelken, T. (2018). Eğitimde teknoloji kullanimi hizmetiçi eğitimine katilan öğretmenlerin TPAB özgüvenlerinin incelenmesi. *Amasya Üniversitesi Eğitim Fakültesi Dergisi, 7*(2), 371-412. Retrieved from https://dergipark.org.tr/en/pub/amauefd/issue/41157/416332

Çiftçi, T. & Dikmenli, Y. (2018). Coğrafya ve sosyal bilgiler öğretmen adaylarinin teknolojik pedagojik alan bilgisi özdeğerlendirme düzeylerinin farkli değişkenlere göre incelenmesi. *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (28), 1-30. doi: 10.14520/adyusbd.332816

Demir, T. & Fırat Durdukoca, Ş. (2018). Pedagojik formasyon eğitimi sertifika programina devam eden öğrencilerin teknolojik pedagojik alan bilgilerinin çeşitli değişkenlere göre incelenmesi. *Uluslararası Türkçe Edebiyat Kültür Eğitim (TEKE) Dergisi, 7*(2), 1253-1275. Retrieved from https://dergipark.org.tr/tr/pub/teke/issue/38234/442087

Demircioğlu, G., Yadigaroğlu, M., & Demircioğlu, H. (2016). Kimya öğretmenlerinin teknolojik pedagojik alan bilgisine (TPAB) yönelik hizmet içi eğitim (HİE) ihtiyaçlarinin belirlenmesi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 10*(2), 156-185. doi: 10.17522/balikesirnef.277487

Dikmen, C. H. & Demirer, V. (2022). The role of technological pedagogical content knowledge and social cognitive variables in teachers' technology integration behaviors. *Participatory Educational Research, 9*(2), 398-415. doi: 10.17275/per.22.46.9.2

Doğan, A. & Doğan, İ. (2022). İlkokullarda Görev yapmakta olan okul yöneticilerinin teknolojik pedagojik alan bilgisi (TPAB) yeterliliklerinin farkli değişkenler açisindan değerlendirilmesi. *Journal of Multidisciplinary Studies in Education, 6*(2), 39-53. Retrieved from https://dergipark.org.tr/tr/pub/jmse/issue/70097/1119414

Doğru, E. & Aydın, F. (2018). Coğrafya öğretmenlerinin teknolojik pedagojik alan bilgisi (TPAB) hakkindaki düşünceleri ve bunu kullanma durumlari. *Eğitim Kuram ve Uygulama Araştırmaları Dergisi, 4*(2), 88-100. Retrieved from https://dergipark.org.tr/en/pub/ekuad/issue/38280/448918

Gökbulut, B. (2021). Öğretmenlerin teknostres ve teknopedagojik yeterlikleri arasindaki ilişki. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 22*(1), 472-496. Retrieved from https://dergipark.org.tr/en/pub/kefad/issue/60452/929603

Güler, Ç. & Bilici, S. (2016). Ortaöğretim öğretmenlerinin TPAB düzeylerinin öğretim teknolojilerini kullanma durumlarina göre incelenmesi. *İlköğretim Online, 15*(3), 0-0. doi: 10.17051/io.2016.05210

İnce Aka, E., Doğan, A., & Sert Çıbık, A. (2018). Öğretmen adaylarinin teknolojik pedagojik alan bilgisi öz güvenlerinin değişiminin incelenmesi. *e-Kafkas Journal of Educational Research, 5*(1), 1-9. doi: 10.30900/kafkasegt.341868

Karakuyu, Y. & Karakuyu, A. (2016). Motivasyon ve öz-yeterliğin sinif öğretmeni adaylarinin teknolojik pedagojik alan bilgilerine (TPAB) katkisi. *Uşak Üniversitesi Eğitim Araştırmaları Dergisi, 2*(1), 89-100. doi: 10.29065/usakead.232415

Karalar, H. & Altan, B. A. (2016). Sinif öğretmeni adaylarinin teknolojik pedagojik alan bilgisi yeterliklerin ve öğretmen özyeterliklerinin incelenmesi. *Cumhuriyet Uluslararası Eğitim Dergisi, 5*(5), 15-30. doi: 10.30703/cije.321422

Karatas, A. & Akgün, Ö. E. (2018). Lise öğretmenlerinin fatih projesi'ni uygulamaya yönelik teknolojik pedagojik alan bilgisi yeterliliklerinin incelenmesi. *Medeniyet Eğitim Araştırmaları Dergisi, 1*(4), 10-30.
Retrieved from https://dergipark.org.tr/en/pub/mead/issue/43089/516893

Kayaalp, F., Gökbulut, B., Meral, E., & Başcı Namlı, Z. (2022). The effect of digital material preparation training on technological pedagogical content knowledge self-confidence of pre-service social studies teachers. *Journal of Theoretical Educational Science, 15*(3), 475-503. doi: 10.30831/akukeg.1061527

Kose, F. (2021). TPAB modeli kapsaminda öğretmenlerin tpab becerilerinin geliştirilmesi: Bir çaliştay örneği. *İnönü Üniversitesi Eğitim Fakültesi Dergisi, 22*(3), 2509-2530. doi: 10.17679/inuefd.1016001

Mutluoğlu, A. & Erdoğan, A. (2016). Examining primary mathematics teachers' technological pedagogical content knowledge (TPACK) levels according to their preferred teaching styles. *OPUS International Journal of Society Researches, 6*(10), 102-126. Retrieved from https://dergipark.org.tr/en/pub/opus/issue/22701/242324

Özdurak Sıngın, R. H., & Gökbulut, B. (2020). Okul öncesi öğretmenlerinin teknopedagojik yeterliklerinin belirlenmesi. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 20*(1), 269-280. doi: 10.17240/aibuefd.2020.20.52925-556477

Sarıtepeci, M. & Durak, H. (2017). Examining different variables of TPACK level of teachers attending the FATIH Project interactive classroom management course. *Participatory Educational*

Research, Special Issue 2016(4), 161-170. Retrieved from https://dergipark.org.tr/tr/pub/per/issue/47596/601276

Sungur Alhan, S. (2020). Harmanlanmış öğrenme ortamina yönelik fen bilimleri öğretmen adaylarinin görüşleri. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 22*(2), 397-414. Retrieved from https://dergipark.org.tr/en/pub/erziefd/issue/56611/633189

Topçu, E. & Masal, E. (2020). Matematik öğretmenlerinin teknolojik pedagojik alan bilgisi öz-değerlendirme algilarina bir bakiş. *Gazi Eğitim Bilimleri Dergisi, 6*(1), 147-167. Retrieved from https://dergipark.org.tr/tr/pub/gebd/issue/53429/692711

Üredi, L. & Ulum, H. (2020). Matematik eğitimi sürecinde sinif öğretmenlerinin teknolojik pedagojik alan bilgisine (TPAB) ilişkin görüşleri. *OPUS International Journal of Society Researches*, *16* (29 Ekim Özel Sayısı), 3642-3669. doi: 10.26466/opus.766702

Yağcı, M. (2016). Pedagojik formasyon eğitimi öğretmen adaylarinin teknopedagojik eğitim yeterliliklerinin çeşitli değişkenler açisindan incelenmesi. *Kastamonu Eğitim Dergisi, 24*(3), 1327-1342. Retrieved from https://dergipark.org.tr/en/pub/kefdergi/issue/22607/241625