Research Article https://doi.org/10.12973/eu-jer.10.4.2045

European Journal of Educational Research
Volume 10, Issue 4, 2045 - 2054.
ISSN: 2165-8714
http://www.eu-jer.com/

# Research Trends in Technological Pedagogical Content Knowledge (TPACK): A Systematic Literature Review from 2010 to 2021

**Irwanto Irwanto***
Universitas Negeri Jakarta, INDONESIA

*Received: August 1, 2021 ▪ Revised: September 8, 2021 ▪ Accepted: October 2, 2021*

**Abstract:** In recent years, integrating technology into education continues to attract more attention along with the rapid growth of information and communication technology. In the literature, teachers' technological pedagogical content knowledge (TPACK) plays an essential role in successfully integrating technology into teaching and learning contexts. This study aims to provide a comprehensive view of prior literature and some possible directions for researchers and educators for further TPACK studies. A total of 106 papers were chosen from the Springer database and synthesized. Frequency of annual publications, number of documents with and without TPACK in the title, research methods, number of authors, major contributed countries, most cited papers, and most productive journals in TPACK research were reviewed. The results showed that TPACK has continued to receive attention from researchers in the past decade. Among the reviewed publications, each of the 53 documents included the term TPACK in the title and abstract. To date, qualitative methods were more frequently adopted in TPACK research than quantitative, mixed, and non-empirical methods. Most papers published in TPACK research have two authors. When ranked by country, the US has the highest contribution compared to other countries in this field, followed by Turkey, Australia, Singapore, and Taiwan. The authors with the most cited papers were Min-Hsien Lee and Chin-Chung Tsai with 210 citations. Based on the number of articles published in TPACK, *The Asia-Pacific Education Researcher* and *TechTrends* seemed to be the most contributing journal in this field.

**Keywords:** *Literature review, research trends, systematic analysis, technological pedagogical content knowledge.*

**To cite this article:** Irwanto, I. (2021). Research trends in technological pedagogical content knowledge (TPACK): A systematic literature review from 2010 to 2021. *European Journal of Educational Research*, *10*(4), 2045-2054. https://doi.org/10.12973/eu-jer.10.4.2045

## Introduction

Historically, the technological pedagogical content knowledge (TPACK) framework—which first appeared as TPCK—is an extension of the pedagogical content knowledge (PCK) proposed by Shulman (1986). With the rise and rapid development of information and communication technology (ICT) which is widely recognized as successful in enhancing students' twenty-first century skills, this framework was later expanded to include technology (Mishra & Koehler, 2006). Theoretically, TPACK is defined as a conceptual framework that emphasizes "connections among teachers' understanding of content, pedagogy, and technology interact with one another to produce effective teaching" (Koehler et al., 2013, p. 101). It clearly appears that TPACK plays a fundamental role in teachers' successful integration of technology into their instructions today (Koehler & Mishra, 2008). In brief, this theory reveals that constructive teaching and learning in the digital era needs to emphasize the complex interaction between content, pedagogy, and technological knowledge (Willermark, 2018). Previous literature claimed that the use of technology is an appropriate way to enhance effective teaching and learning (Voogt et al., 2009; Williams et al., 2004). Interestingly, since its introduction in 2005, TPACK continues to receive much attention from educators and has become a center for teacher professional development (Chai, Chin, et al., 2013; Voogt et al., 2012).

TPACK is seen as a coherent set of knowledge and skills that teachers need to implement effective ICT in the classroom (Koehler et al., 2007; Mishra & Koehler, 2006). In general, the TPACK framework consists of three major knowledge components; content knowledge (CK), technology knowledge (TK), and pedagogical knowledge (PK). CK is related to any subject-matter knowledge, PK refers to the use of effective teaching methods to catalyze student learning, and TK includes various technologies to develop teaching practices in the classroom. These three types of knowledge intersect

* **Correspondence:**
Irwanto Irwanto, Department of Chemistry Education, Universitas Negeri Jakarta, Jakarta, Indonesia. ✉ irwanto@unj.ac.id

with each other and form four other knowledge components; technological content knowledge (TCK), technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPACK). TCK refers to how teachers use technology to represent learning content, for example, chemistry teachers use ChemDraw to visualize the shape of a molecule. PCK is related to how teachers deliver subject matter through pedagogical reasoning so that it can be accessed by students. TPK refers to how teachers use technology to communicate with students and engage them actively during instruction. Finally, TPACK is related to how teachers use technology to make it easier for students to learn subjects and facilitate them to find any resources and conduct scientific investigations. In the previous literature, TPACK was intended to overcome the difficulties often faced by teachers in integrating technology into the curriculum (Sahin, 2011; Wang et al., 2004). In other words, TPACK aims to help teachers enhance a technological habit of mind, where they are encouraged to use computation and communication tools in order to help students understand concepts and relate them to the real world (Bowers & Stephens, 2011). The theoretical framework of TPACK has been considered as the proper solution to solve complex problems when teachers integrate ICT into their classrooms (Chai, Chin, et al., 2013).

Literature studies on TPACK have been documented in recent years. For instance, Voogt et al. (2012) conducted a systematic literature review of 56 studies from four databases published from 2005 to September 2011. They explored the theoretical basis and the practical use of TPACK. Also, Willermark (2018) conducted a systematic literature review of 107 documents from the SSCI database in the period 2011-2016. The study analyzed a variety of approaches and instruments to investigate teacher TPACK. Then, Rodríguez Moreno et al. (2019) conducted a systematic review of 37 papers from the Web of Science and Scopus databases between 2005 and 2013. Their study focused on analyzing publications related to TPACK, such as public, topic, main results, and methodological design. Recently, Soler-Costa et al. (2021) conducted a bibliometric review of 471 articles from the Web of Science database during 2006-2019. They explored the significance and evolution of the TPACK concept. It is clear that the increasing volume of studies in TPACK requires a systematic synthesis. It should be noted that previous studies identified TPACK publications up to 2019. By involving the latest peer-reviewed journal articles related to TPACK, the current review is intended to complement past literature studies.

Information on research trends and possible directions in the TPACK may help researchers and educators understand research developments in this area and then plan for future investigations. Accordingly, the current study aims to analyze recent statuses and provide extensive overviews of TPACK research between 2010 and mid-2021. For this purpose, journal articles published by Springer were identified. As we know, Springer is a global publisher that publishes millions of scientific documents in various disciplines, one of which is related to the educational field. To the best of my knowledge, no study explores the development and direction of TPACK research using a systematic review until mid-2021. Thus, the current study provides a comprehensive and accurate view in this field to assist researchers and educators around the world in conducting research related to TPACK and publish their papers in the future. To this end, the research questions set out in this study are:

1. What are the annual publications trends in the TPACK field during 2010-2021?
2. How are publication patterns of documents with and without TPACK included in the title in the last 12 years?
3. How did the research methods of published papers in the academic journals vary from 2010-2021?
4. How is the distribution of the articles reviewed in terms of the number of authors in the 2010-2021 period?
5. Which countries contributed the most to the publications in the academic journals vary from 2010-2021?
6. What are the research trends of highly-cited papers published in academic journals between 2010 and 2021?
7. Which academic journals publish papers related to TPACK more frequently in the 2010-2021 period?

## Methodology

### *Research Design*

In this systematic review, a protocol developed by Wu (2013) was used to achieve the proposed objectives. The researcher then conducted a comprehensive search for all journal papers about TPACK from the Springer database (https://link.springer.com/) for the 2010-2021 period. Document search was carried out on June 8, 2021.

### *Inclusion Criteria*

The researcher set specific criteria for including documents in the current study. For instance, papers should be written in English and published in journal papers between January 2010 and June 2021. As a note, books or book chapters, conference proceedings, editorial materials, and corrections were excluded from the analysis.

### *Data Analysis*

The terms used in the search for sample papers included “TPCK”, or “TPACK”, and “technological pedagogical content knowledge” to obtain related articles. To ensure that the target papers were relevant to the research objectives, the researcher identified the titles, abstracts, and keywords of the papers manually. In this study, the sample papers were only taken from the Education discipline. Based on the initial search, there were 317 papers spread over 37

subdisciplines. The researcher then read each paper and double-checked all documents to ensure that the target papers fit with the criteria and there were no duplications. To select the final articles for review, the researcher first checked the titles, then the abstracts, and finally the full text. After filtering the data, 211 articles–which did not match the topic under analysis–were eliminated.

In the selection process, the researcher read the full text of all the papers assisted by a research assistant. In order to provide an accurate and comprehensive systematic review, we discussed the relevance of the manuscripts to the main research questions of whether they met the inclusion criteria. If there was any doubt whether the document met the inclusion criteria, the researcher then conducted an independent evaluation. As a result, a total of 106 contributions met the inclusion criteria and were selected for review. Aiming to make a decision, all final samples were identified, including the number of authors, years of publication, names of journals, nationality of the first author, and research methods adopted. It should be noted that each article was assigned to only one research type.

## Results

Specifically, this section presents the results of the analysis of selected papers from the Springer database during the 2010–2021 timespan. The results are presented in seven parts, covering the number of annual publications, publication trends with and without TPACK included in paper titles, research methods, patterns in the number of authors, 15 most productive countries, 15 most cited papers, and top 10 journals with the highest number of papers in TPACK research.

### *Distribution of Publications in TPACK by Year*

The first research question is analyzed in Figure 1. Figure 1 reflects the growth in TPACK publications in the period January 2010 to June 2021.

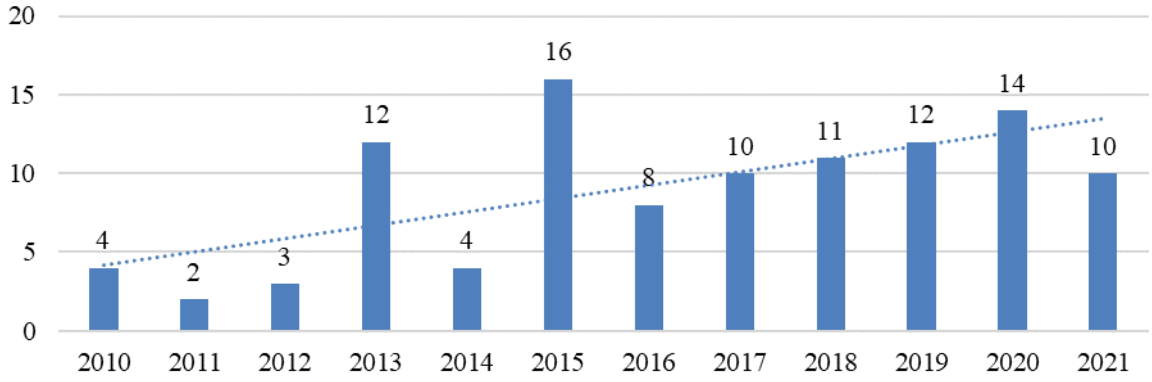


*Figure 1. Number of Published Papers Relating to TPACK in the Literature*

Taking into account the annual volume of the TPACK research, the results of the analysis indicate that the number of papers in this field has fluctuated. The peak of publications in TPACK research was in 2015, where the number of publications from Asia (9 papers) was higher than the US ($n$ = 2), Europe ($n$ = 2), Africa ($n$ = 2), and Australia ($n$ = 1). In 2011 and 2012, it can be revealed that there were relatively few articles published in scientific journals, two and three papers respectively, and then there was a rapid growth in 2013, with a total of 12 documents. However, in 2016 the reviewed articles decreased by 50% before increasing by a total of 20% in 2017. In the past 6 years, the number of TPACK studies has steadily increased, especially from 2016 to 2020. Specifically, there were 65 publications, representing 61% of the total publications between 2016 and 2021. When analyzed by year, until June 2021, the number of publications in this area reached 10 papers and the researcher predicts that this topic will continue to receive attention from researchers worldwide. Since there is an urgent need to integrate technology into pedagogical content knowledge among researchers and educators, it is likely that there will be more publications in TPACK in the future.

### *Frequency of the Term "TPACK" Used in Document Titles*

In order to address the second research question, Figure 2 presents the trend of articles with and without TPACK in the title over the past 12 years.

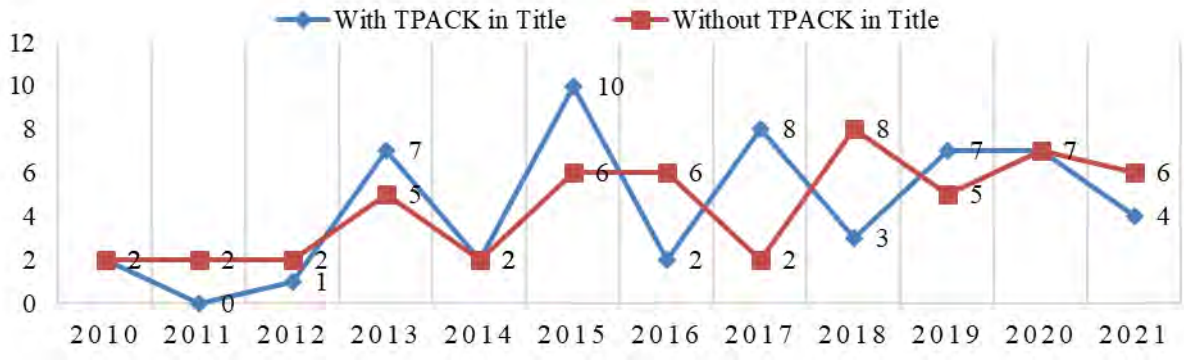


*Figure 2. Number of Publications with and without TPACK in Title*

The distribution of papers with and without TPACK in titles fluctuated from early 2010 to mid-2021. The highest number of articles with TPACK in titles was 10 in 2015 (an 80% increase from the previous year) and the number of articles without TPACK in titles (in abstract and/or keywords) was 8 in 2018. However, the number of publications shows a more positive trend as reviewed articles, both with and without TPACK in the title, increase gradually from 2016–2020, and potentially increase rapidly in 2021.

*Distribution of Research Methods*

Aiming to respond to the third research question, Figure 3 illustrates the frequency of research methods adopted in TPACK research during the years 2010-2021.

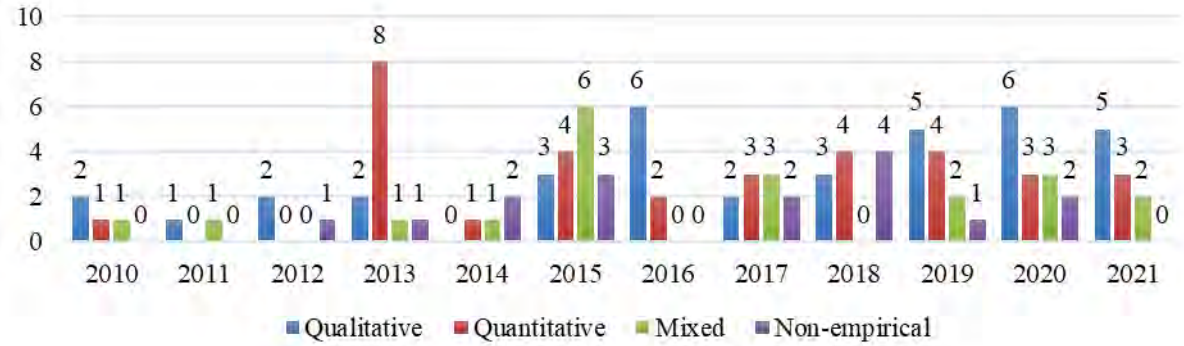


*Figure 3. Distribution of Research Methods Used in TPACK Research by Year*

According to Figure 3, although quantitative approaches have dominated TPACK research, trends in qualitative methods seem to be used consistently. In terms of the number of publications, in 2013, quantitative research designs were the most popular among TPACK researchers. In general, regarding the frequency of the research methods analyzed from 2010 to 2021, quantitative studies (27; 25.47%) have the highest ranking, followed by qualitative (26; 24.53%), mixed (15; 14.15%), and non-empirical (14; 13.21%) studies in sequence. However, in the last 5 years, there has been a shift in the trend of research types used by researchers. To date, qualitative methods ($n$ = 21) were more frequently employed in TPACK research than quantitative ($n$ = 17), mixed ($n$ = 10), and non-empirical ($n$ = 9) methods.

*Number of Authors in TPACK Publications*

In order to answer the fourth research question, Figure 4 presents information about the number of authors in TPACK research according to year (2010 to 2021).

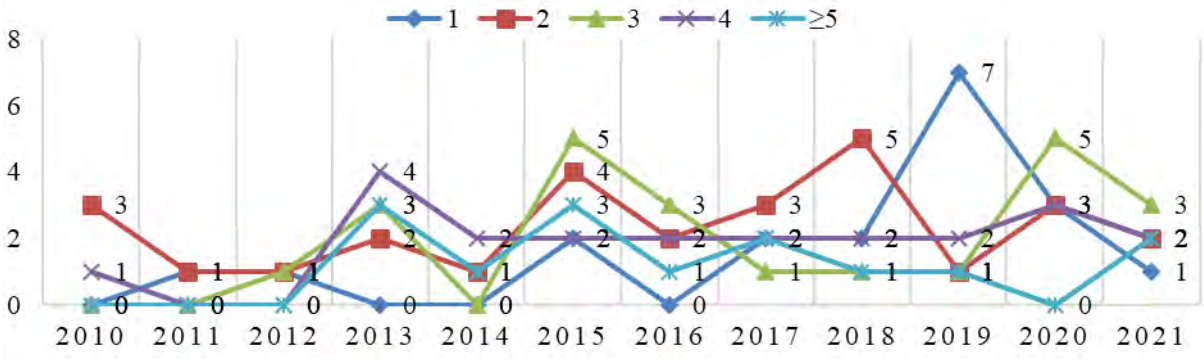


*Figure 4. Number of Authors in TPACK Research by Year*

When analyzed by year, in 2019, the number of single-author articles was the most, reaching the peak with 7 papers. In addition, the number of four author papers stagnated between 2014 and 2019 before finally increasing in 2020. The increase also occurred in papers with two authors from 2016 to 2018. This implies that collaboration in research on TPACK mostly comes from groups of authors who work in at least 2 affiliates. As can be seen from Figure 4, overall among 106 papers, less than one-fifth (17.92%; *n* = 19) of papers are single-authored and the most frequent papers published in TPACK research have 2 authors (26.42%; *n* = 28). Interestingly, more than half (55.56%; *n* = 59) of publications were written by at least 3 authors between 2010 and 2021.

*Most Productive Countries in TPACK Research*

Aiming to identify the most productive countries in the TPACK field according to the fifth research question, the researcher scored each paper manually. Table 1 presents the top 15 countries (from 26 different countries) with the number of articles published in TPACK research worldwide in the period 2010-2021.

*Table 1. Ranking of the Top 15 Countries in TPACK Research*

| Rank | Country | *N* of Papers | Percentage (%) |
|---|---|---|---|
| **1** | US | 34 | 32.08 |
| **2** | Turkey | 12 | 11.32 |
| **3** | Australia | 10 | 9.43 |
| **4** | Singapore | 9 | 8.49 |
| **5** | Taiwan | 8 | 7.55 |
| **6** | China | 4 | 3.77 |
| **7** | Netherlands | 3 | 2.83 |
| **8** | Cyprus | 2 | 1.89 |
| **8** | Germany | 2 | 1.89 |
| **8** | Greece | 2 | 1.89 |
| **8** | Israel | 2 | 1.89 |
| **8** | South Africa | 2 | 1.89 |
| **8** | Sweden | 2 | 1.89 |
| **8** | Thailand | 2 | 1.89 |
| **15** | Belgium | 1 | 0.94 |
| **Other Countries** | | | 10.38 |

In this review, the total number of documents analyzed is 106. The maximum score for each paper is 1 and is only given to the country of the first author. Based on the analysis provided, it can be seen that the US (32.08%) has the highest contribution than other countries in this field, followed by Turkey (11.32%), Australia (9.43%), Singapore (8.49%), and Taiwan (7.55%). As shown in Table 1, there are 7 countries with 2 papers each. In relation to the most productive countries, it can be seen that research related to TPACK is frequently reported in developed countries. In general, it was found that the top 15 countries contributed almost 90% of the total publications in TPACK in the last 12 years.

*The Most Valuable Paper in TPACK Studies*

Table 2 visualizes the 15 most cited papers in TPACK research between 2010 and 2021. As a note, the number of citations was obtained from the Springer database. In order to address the sixth research question, the papers are then sorted by the highest number of citations in the TPACK field.

*Table 2. Top 15 Cited Papers in TPACK*

| Rank | Citations | Year | Authors | Title |
|---|---|---|---|---|
| 1 | 210 | 2010 | Lee, M.-H., & Tsai, C.-C. | Exploring teachers' perceived self-efficacy and technological pedagogical content knowledge with respect to educational use of the world wide web |
| 2 | 91 | 2010 | Jang, S.-J., & Chen, K.-C. | From PCK to TPACK: Developing a transformative model for pre-service science teachers |
| 3 | 74 | 2013 | Lin, T.-C., Tsai, C.-C., Chai, C. S., & Lee, M.-H. | Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK) |
| 4 | 66 | 2013 | Koh, J. H. L., Chai, C. S., & Tsai, C.-C. | Examining practicing teachers' perceptions of technological pedagogical content knowledge (TPACK) pathways: A structural equation modeling approach. |
| 5 | 56 | 2011 | Khan, S. | New pedagogies on teaching science with computer simulations |
| 6 | 51 | 2015 | Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H.-Y. | Technological pedagogical content knowledge (TPACK) and design thinking: A framework to support ICT lesson design for 21st century learning |
| 7 | 40 | 2013 | Maeng, J. L., Mulvey, B. K., Smetana, L. K., & Bell, R. L. | Preservice teachers' TPACK: Using technology to support inquiry instruction |
| 8 | 38 | 2014 | Lee, C.-J., & Kim, C. | An implementation study of a TPACK-based instructional design model in a technology integration course |
| 9 | 35 | 2011 | Bowers, J. S., & Stephens, B. | Using technology to explore mathematical relationships: A framework for orienting mathematics courses for prospective teachers |
| 10 | 29 | 2013 | Annetta, L. A., Frazier, W. M., Folta, E., Holmes, S., Lamb, R., & Cheng, M.-T. | Science teacher efficacy and extrinsic factors toward professional development using video games in a design-based research model: The next generation of STEM learning |
| 11 | 28 | 2013 | Drijvers, P., Tacoma, S., Besamusca, A., Doorman, M., & Boon, P. | Digital resources inviting changes in mid-adopting teachers' practices and orchestrations |
| 11 | 28 | 2015 | Pringle, R. M., Dawson, K., & Ritzhaupt, A. D. | Integrating science and technology: Using technological pedagogical content knowledge as a framework to study the practices of science teachers |
| 13 | 25 | 2013 | Thomas, T., Herring, M., Redmond, P., & Smaldino, S. | Leading change and innovation in teacher preparation: A blueprint for developing TPACK ready teacher candidates |
| 13 | 25 | 2015 | Yeh, Y.-F., Lin, T.-C., Hsu, Y.-S., Wu, H.-K., & Hwang, F.-K. | Science teachers' proficiency levels and patterns of TPACK in a practical context |
| 15 | 23 | 2010 | Trautmann, N. M., & MaKinster, J. G. | Flexibly adaptive professional development in support of teaching science with geospatial technology |
| 15 | 23 | 2013 | Chai, C. S., Chin, C. K., Koh, J. H. L., & Tan, C. L. | Exploring Singaporean Chinese language teachers' technological pedagogical content knowledge and its relationship to the teachers' pedagogical beliefs |

Based on Table 2, the distribution by the first author's country is as follows: the US ($n$ = 7), Taiwan ($n$ = 4), Singapore ($n$ = 3), Canada ($n$ = 1), and the Netherlands ($n$ = 1). Among those top 15 cited papers, 7 of them were published in the *Journal of Science Education and Technology*. On this list, the authors with the most cited papers were Min-Hsien Lee and Chin-Chung Tsai with 210 citations. Their Work, published in *Instructional Science* in 2010, received an average of 17.50 citations per year. This study focused on how to develop a Technological Pedagogical Content Knowledge-Web (TPCK-W) Survey to investigate teachers' self-efficacy with regard to their TPCK-W and to evaluate their attitudes toward web-based learning. Then, they were followed by Syh-Jong Jang and Kuan-Chung Chen with a total of 91 citations. This study referred to how to integrate technology into pedagogical content knowledge of pre-service science teachers to further enhanced their TPACK. Interestingly, all four authors were from Taiwan. Furthermore, when identified by research methods, there were 6 documents using a quantitative approach, 4 documents each using qualitative and mixed-methods, and only 2 documents using non-empirical methods. This finding is also confirmed by Figure 2 that quantitative studies have been used extensively by researchers and educators in TPACK over the last decade.

*Number of Publications by Journal*

The latest research questions are analyzed in Table 3. Table 3 below provides a summary of the top 10 academic journals with the highest number of papers from 2010 to 2021.

*Table 3. Top 10 Journals with the Highest Number of Papers*

| Rank | Journal | *N* of Papers |
|---|---|---|
| **1** | The Asia-Pacific Education Researcher | 17 |
| **1** | TechTrends | 17 |
| **3** | Educational Technology Research and Development | 14 |
| **4** | Journal of Science Education and Technology | 12 |
| **5** | Technology, Knowledge and Learning | 6 |
| **6** | Journal of Computers in Education | 5 |
| **7** | Instructional Science | 3 |
| **8** | Journal of Mathematics Teacher Education | 3 |
| **9** | ZDM | 3 |
| **10** | International Journal of Science and Mathematics Education | 2 |
| **10** | International Journal of Technology and Design Education | 2 |
| **10** | Journal of Computing in Higher Education | 2 |
| **10** | Journal of Science Teacher Education | 2 |
| **10** | Mathematics Education Research Journal | 2 |
| **10** | Research in Science Education | 2 |

Aiming to evaluate the number of publications by journal, Table 3 describes the top 10 journals (out of 28 peer-reviewed journals) with the highest number of articles related to TPACK in the last 12 years. Based on the number of articles published in TPACK, *The Asia-Pacific Education Researcher* and *TechTrends* appeared to be the most productive journals in this field, each with 17 papers. In addition, there were 3 journals with 3 papers each (e.g., *Instructional Science*) and 6 journals with 2 papers each (e.g., *International Journal of Science and Mathematics Education*). Meanwhile, the remaining journals only published 1 paper (e.g., *Asia Pacific Education Review*). Specifically, in *The Asia-Pacific Education Researcher,* there were 5 papers written by authors affiliated with Taiwanese institutions.

## Discussion

The current study has successfully presented a comprehensive view of the previous literature and some possible directions for researchers and educators for further TPACK studies. As a result, it is clearly seen that there is an increase in the volume of publications related to TPACK by year. The current finding is in line with previous studies (e.g., Chai, Koh, et al., 2013; Rodríguez Moreno et al., 2019; Rosenberg & Koehler, 2015; Soler-Costa et al., 2021; Wu, 2013; Xue & He, 2021). For example, Rosenberg and Koehler (2015) conducted a systematic review of 193 publications on TPACK from 2005-2013 and reported that there was a rapid increase in the number of papers over the years. In addition, Wu (2013) conducted a systematic review of 24 articles from the Social Science Citation Index (SSCI) database between 2002 and 2011. He revealed that TPACK research increased rapidly from 2009. Recently, in a bibliometric review, Soler-Costa et al. (2021) analyzed 471 documents in TPACK from the Web of Science database during 2006-2019. They pointed out that the volume of publications about TPACK is increasing sharply in this period. With respect to the highest number of publications, Willermark (2018) conducted a systematic literature review on 107 studies related to TPACK published between 2011 and 2016. She also found that the highest number of papers was published in 2015, with 32 documents (almost 30%). Tseng et al. (2020) also conducted a review study of 51 articles published from 2011 to 2019 and reported that the peak of publication was in 2015, where most of the studies were conducted in Asia and the Middle East. This indicates that TPACK research has received great attention from researchers and educators around the world over the last decade. In addition, the theoretical framework of TPACK tends to be complete and many researchers and educators have applied TPACK (Xue & He, 2021). Thus, the number of publications in TPACK is predicted to increase significantly throughout the year.

With regard to the second research question, the number of publications with and without TPACK in the title varied, however, the trend is likely to increase from 2015 to 2018. It is clear that this increase may be due to the enhancing interest of researchers in TPACK. Furthermore, researchers and educators in the field of TPACK quickly respond to and adapt to advances in information and communication technology. In a bibliometric review, Xue and He (2021) analyzed 844 articles related to TPACK from the Web of Science database between 2009 and November 2020. They noted that the growth of publications in this field has been increasing rapidly overall, with the peak of publication being in 2015. The current findings are also supported by a study conducted by Rodríguez Moreno et al. (2019), where the number of publications in TPACK increased dramatically from 2014 to 2017.

In relation to the third research question, it was found that quantitative methods were the most popular among TPACK researchers and educators. The reason for this may be the fact that, because the sample size is generally considered representative of the population, quantitative studies can reach high audiences, can be replicated within the larger population, and allow the researchers to generalize findings (Borrego et al., 2009). Overall, the current review shows that the number of papers using both quantitative and qualitative approaches each year increases between 2014 and 2021. Review studies conducted over the last decade on the use of quantitative approaches in TPACK research support the current findings (e.g., Rodríguez Moreno et al., 2019; Willermark, 2018; Wu, 2013). For instance, Rodríguez Moreno et al. (2019) analyzed 37 articles published between 2014 and 2017 from the Web of Science and Scopus databases using a systematic review. They reported that the most widely adopted research methodology designs were quantitative methods (43.24%), followed by qualitative (40.24%) and mixed (16.21%) methods. In a similar vein, Wu (2013) also investigated research trends of 24 articles in TPACK published in selected journals in the period 2002-2011. He summarized that the most frequently employed research methods sequentially were quantitative (45.8%), qualitative (41.7%), and mixed (12.5%) methods. Supportively, Willermark (2018) also explained that among 107 studies, quantitative methods (46.7%) were most preferred, followed by mixed (41.1%) and qualitative (12.1%) methods. The results suggest that various research methods have been used by TPACK researchers over the last decade, where quantitative and qualitative designs are preferred among them.

With respect to the number of authors in TPACK research by year, it was found that articles with two authors are the most published in this field. The current findings parallel the study conducted by Chai, Koh, et al. (2013). They found that of the 75 papers reviewed, the majority of documents were written by 2 authors (31; 41.33%), 24 papers with at least 3 authors, and 20 papers with single authors. Supportively, Rodríguez Moreno et al. (2019) reported that out of 37 studies, a total of 14 papers (37.84%) were two authored, more than half of publications (20; 54.05%) were written by at least 3 authors, and only 3 papers (8.11%) were single-authored. This indicates that there is an increase in academic cooperation on TPACK research among researchers and educators around the world. As suggested by Wai-Chan (2017), international research collaboration enables researchers to maximize the benefits of their inputs and magnify their outputs and also to exchange ideas and combine their views to solve complex problems.

In terms of the most productive countries in TPACK, the US was ranked first among 36 countries. The result echoes the previous literature. For example, in a study, Chai, Koh, et al. (2013) analyzed 74 papers related to TPACK from 2003 to 2011. They found that most of the research in this area was conducted in North America (65.0%, $n$ = 49), followed by Europe and the Mediterranean (16.7%; e.g., Turkey, 4; Israel, 3; Cyprus, 2), and Asia Pacific (17.6%; e.g., Singapore, 5; Taiwan, 4; Australia, 3). A possible reason for the high number of publications from the US may be related to the high budget for research and development. In the fiscal year 2021, the National Science Foundation received a budget of $8.49 billion (an increase of 2.5% from the previous year), of which about 80% of research and education funds is typically distributed to universities (Harris, 2021). This implies that more research in TPACK should probably be conducted beyond the US taking into account different cultural contexts.

In addition, the current study suggested that the most productive authors were Min-Hsien Lee and Chin-Chung Tsai and followed by Syh-Jong Jang and Kuan-Chung Chen. In the literature, the number of citations is generally assumed to be a measure of the usefulness or influence of a publication; it means that the more citations, the greater the impact of the research (Aksnes et al., 2019). Thus, this indicates that the two papers written by all Taiwanese authors had a great impact on TPACK research in the past 10 years.

According to the number of publications by journals, *The Asia-Pacific Education Researcher* and *TechTrends* appeared to be the most productive journals in TPACK research. A possible reason may be that *The Asia-Pacific Education Researcher* published empirical and theoretical studies in the field of education that emphasized the successful experiences of education systems in the Asia-Pacific Region. In *TechTrends,* the US—where this journal was originally published—is the most productive country in this field with 16 papers. As the name implies, this journal published high-quality papers related to educational communication and technology in order to provide up-to-date information for researchers and practitioners. *The Asia-Pacific Education Researcher* and *TechTrends* have also been started their publication life in 1992 and 1957, respectively.

## Conclusion

In summary, the review of the 106 studies published between 2010-2021 in TPACK showed that research in this area has moved forward over time. Since 2010, literature on TPACK has gradually appeared in the Springer database. This clearly shows that, overall, the number of papers published increased rapidly during this period. In particular, the highest number of articles was published in 2015, followed by 2020. Among the sample papers, it was found that the acronym TPACK was included as often as in the title or in the abstract and/or keywords, with 53 papers each. In the last 12 years, the research methods most commonly used among TPACK scholars are qualitative, quantitative, mixed, and non-empirical methods, respectively. Furthermore, it seems that the most frequent papers published in TPACK research have 2 authors. In fact, more than half of the publications were written by at least 3 authors during 2010-2021. To date, studies related to TPACK are frequently reported in developed countries, where the US was ranked first among 26 countries. Other countries outside the top 15 countries only contributed about 10% of the total publications

in this field in the last decade. With respect to the most valuable papers in TPACK research, the paper with the highest citations was written by Min-Hsien Lee (National Taiwan Normal University) and Chin-Chung Tsai (National Taiwan University of Science and Technology) with 210 citations, followed by Syh-Jong Jang and Kuan-Chung Chen (both from Chung-Yuan Christian University) with 91 citations. It was shown in the results that, of the 28 peer-reviewed journals analyzed, *The Asia-Pacific Education Researcher* and *TechTrends* were the most productive academic journals publishing articles related to TPACK in this period, with 17 documents each.

## Limitations

This present review provides a thorough synthesis of prior literature and some possible directions for researchers and educators for further TPACK studies. This study may provide deeper insights for pre-service and in-service teachers to use TPACK in order to plan their professional development programs in a holistic way. Although the results from this literature review provide an extensive overview, there are limitations that should be considered. First, the current study is limited to journal articles related to TPACK published in the Springer database; thus, the results may differ when compared with other scientific databases. Note that editorial sections, comments, book chapters, book reviews, etc., were not included for analysis. Then, it should also be noted that the current study is limited in terms of time span.

## Recommendations

According to the aforementioned limitations, the researcher suggests that more types of articles should be included and a longer period of time should be utilized in literature review studies in the future. This is intended to provide a more holistic view of scientific information about TPACK.

## References


Aksnes, D. W., Langfeldt, L., & Wouters, P. (2019). Citations, citation indicators, and research quality: An overview of basic concepts and theories. *SAGE Open, 9*(1), 1–17. https://doi.org/10.1177/2158244019829575

Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed research methods in engineering education. *Journal of Engineering Education, 98*(1), 53–66. https://doi.org/10.1002/j.2168-9830.2009.tb01005.x

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*(4), 285–304. https://doi.org/10.1007/s10857-011-9168-x

Chai, C. S., Chin, C. K., Koh, J. H. L., & Tan, C. L. (2013). Exploring Singaporean Chinese language teachers' technological pedagogical content knowledge and its relationship to the teachers' pedagogical beliefs. *The Asia-Pacific Education Researcher, 22*(4), 657–666. https://doi.org/10.1007/s40299-013-0071-3

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.

Harris, L. A. (2021). *The national science foundation: An overview.* Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R46753

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Eds.), *The handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3–29). Routledge.

Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2013). The technological pedagogical content knowledge framework. In M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 101–111). Springer.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education, 49*(3), 740–762. https://doi.org/10.1016/j.compedu.2005.11.012

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Rodríguez Moreno, J., Agreda Montoro, M., & Ortiz Colón, A. (2019). Changes in teacher training within the TPACK model framework: A systematic review. *Sustainability, 11*(7), 1870. https://doi.org/10.3390/su11071870

Rosenberg, J. M., & Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *Journal of Research on Technology in Education, 47*(3), 186–210. https://doi.org/10.1080/15391523.2015.1052663

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

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102%2F0013189X015002004

Soler-Costa, R., Moreno-Guerrero, A. -J., López-Belmonte, J., Marín-Marín, J. -A. (2021). Co-word analysis and academic performance of the term TPACK in web of science. *Sustainability, 13*(3), 1481. https://doi.org/10.3390/su13031481

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

Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & van Braak, J. (2012). Technological pedagogical content knowledge - a review of the literature. *Journal of Computer Assisted Learning, 29*(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Voogt, J., Tilya, F., & Van den Akker, J. (2009). Science teacher learning for MBL-supported student-centered science education in the context of secondary education in Tanzania. *Journal of Science and Education and Technology, 18*(5), 428–429. https://doi.org/10.1007/s10956-009-9160-8

Wai-Chan, S. (2017). International research collaboration creates higher impact. *Nordic Journal of Nursing Research, 37*(2), 59–60. https://doi.org/10.1177/2057158517706259

Wang, L., Ertmer, P. A., & Newby, T. J. (2004). Increasing preservice teachers' self-efficacy beliefs for technology integration. *Journal of Research on Technology in Education, 36*(3), 231–250. https://doi.org/10.1080/15391523.2004.10782414

Willermark, S. (2018). Technological pedagogical and content knowledge: A review of empirical studies published from 2011 to 2016. *Journal of Educational Computing Research, 56*(3), 315–343. https://doi.org/10.1177/0735633117713114

Williams, M., Linn, M. C., Ammon, P., & Gearhart, M. (2004). Learning to teach inquiry science in a technology-based environment: A case study. *Journal of Science Education and Technology, 13*(2), 189–206. https://doi.org/10.1023/B:JOST.0000031258.17257.48

Wu, Y.-T. (2013). Research trends in technological pedagogical content knowledge (TPACK) research: A review of empirical studies published in selected journals from 2002 to 2011. *British Journal of Educational Technology, 44*(3), E73–E76. https://doi.org/10.1111/j.1467-8535.2012.01349.x

Xue, C., & He, W. (2021). Research hotspots and trends on TPACK in WOS based on visual analysis. *Open Journal of Social Sciences, 9*(2), 305–321. https://doi.org/10.4236/jss.2021.92021