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Overview of the TPACK Model in Digital Learning: A Bibliometric Analysis

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Abstract

This bibliometric analysis provides an overview of the Technological Pedagogical Content Knowledge (TPACK) model of digital learning. The TPACK Model refers to integrating three types of knowledge: technological, pedagogical, and content knowledge, to effectively integrate technology in learning and teaching. Using a comprehensive search strategy, it identified 123 relevant articles from the Scopus database in fiscal years 2013 – 2022. The results reveal that articles and journals focused on learning and technology dominate in terms of citations. Furthermore, Scopus database publishing journals are dominated by Q1 rankings. Meanwhile, the UK became the country with the most significant articles. The results of the VOSviewer visualization revealed that seven clusters showed that digital learning requires technology, various good tools, and the development of educator proficiency levels. This study provide insights into TPACK research trends and patterns, which may inform future research direction and practice in a digital learning environment. Teachers can apply TPACK to digital learning well; it is crucial to be equipped with digital competencies first before he becomes professional educator through preservice training because TPACK is closely related to technological knowledge and pedagogy that will make teachers skilled and creative in applying learning with the help of digital technology.

K*eywords:* *TPACK; Digital Learning; Digital Technology; Bibliometric Analysis*

Introduction

In recent years, the rapid development of mobile technology and learning with technology increasingly attracted the attention of educator (Kajonmanee et al., 2020; Spiteri et al., 2020). Most educational institutions have integrated technology with teaching to enhance their learners' learning experience (Goradia, 2018). New learning technologies are being used to improve learner engagement and academic outcomes. Furthermore, the development of modern knowledge and globalization have also changed the needs of 21st-century learners (Mclay et al., 2019). Therefore, 21st-century pedagogy stems from the need to provide opportunities for learners to develop the competencies and skills needed in the current era.

The use of technology and pedagogical innovation in education is one of the alternatives that can make education more successful (Tømte et al., 2015; Wekerle et al., 2020; Nasir et al., 2023). This innovation can be known as TPACK (Technological, Pedagogic, Content, Knowledge). TPACK does not recognize hierarchies other than presenting a holistic model that combines knowledge about technology,

pedagogy, and content related to the effective use of technology in the classroom (Falloon, 2020). TPACK, as defined by Mishra & Koehler (2006), is a teacher's comprehensive knowledge of technology (TK), pedagogy (PK), and content (CK) that goes beyond each knowledge component individually (TK, PK, CK), as well as collectively (PCK, TCK, TPK). Given the foregoing, it is considered knowledge of how various digital technologies can favorably or adversely effect the depiction of clearly different content and the learning process.

Many researchers have focused on the importance of TPACK. Ammande et al. (2020) claimed in their research that while educators' knowledge of TPACK is at a "good" level, it can be increased to produce greater results by planning more learning activities or workshops. Furthermore, it was emphasized by, (Drugova et al., 2021; Wekerle et al., 2020; Maeng et al., 2013) that technical mastery was crucial in teacher education programs. Technology in learning requires activities that directly incorporate it in addition to being conceptually integrated. Referring to these researchers' reviews, we are interested in looking further into how TPACK models in digital learning using bibliometric analysis. Some previous studies have used the topic of TPACK by conducting bibliometric analysis, but none have tried to provide an overview of TPACK in digital learning because digital learning is closely related to the TPACK model (Goradia, 2018; Drugova et al., 2021). The following are previous bibliometric analysis studies using the keyword TPACK.

Table 1. Previous Research Using Bibliometric Analysis of TPACK Topics

No.	Author	Article Title
1	Hyung-Ying Lee et al, Chi-Yang Chung, & Ge Wei, (2022)	Research on Technological Pedagogical and Content Knowledge: A Bibliometric Analysis From 2011 to 2020
2	Nadi Suprapto, Sukarmin, Rinie Pratiwi Puspitawati, Erman, Dian Savitri, Chih-Hsiung Ku, Husni Mubarok, (2021)	Research trend on TPACK through bibliometric analysis (2015-2019)
3.	Rebeca Soler-Costa, Antonio-José Moreno-Guerrero, José-Antonio Marín-Marín, Jesús López-Belmonte, and José-Antonio Marín-Marín, (2021)	Co-Word Analysis and Academic Performance of the Term TPACK in Web of Science

In the TPACK framework, pedagogy, technology, and content are all interwoven, which was developed to integrate technology with teacher expertise (Soler-Costa et al., 2021). Bustamante (2020) claims that the purpose of TPACK is to describe and demonstrate instructors' knowledge and abilities concerning integrating digital learning tools. According to several studies (Elas et al., 2019; Bustamante, 2020; Baran et al., 2019), educational content knowledge is the context in which learners make the most progress. Moreover, the improvement is more pronounced in pedagogical knowledge-related areas than in technology- or content-related areas. However, the changes are more subtle in places lacking pedagogical expertise (Soler-Costa et al., 2021). In simple terms, it is evident from this research that teachers in training need ongoing competence evaluation and feedback. This is important to help them advance their understanding, abilities, and attitudes toward using digital learning in the classroom (Habibi et al., 2019; Goradia, 2018).

The urgency of the TPACK model for teaching and learning by utilizing digital technology is a fact. This study intends to provide an overview of this model by utilizing publications on the Scopus database and offering a clear framework with bibliometric analysis-based research. The novelty of this

study, compared to previous studies (Lee et al., 2022; Suprapto et al., 2021; Soler-Costa et al., 2021), focuses on modeling the development of research on TPACK topics. This paper specifically makes use of performance analysis and scientific mapping of articles pertaining to the chosen constructs. In order to conduct efficient research, this study adheres to the analytical framework of various impact articles.

Materials & Methods

This research uses a bibliometric analysis method related to the TPACK model in digital learning. According to Broadus (1987), bibliometrics is the application of statistical and mathematical techniques to books and other forms of media. The type of bibliometric analysis used is descriptive bibliometrics, which describes the characteristics of literature. One of the many uses of bibliometric analysis is identifying new patterns in publications such as articles and journals. Performance analysis and mapping are two subcategories of bibliometric analysis methodologies (Donthu et al., 2021). As shown in Figure 1, we modified the science mapping approach Aria & Cuccurullo (2017) recommended for this study.

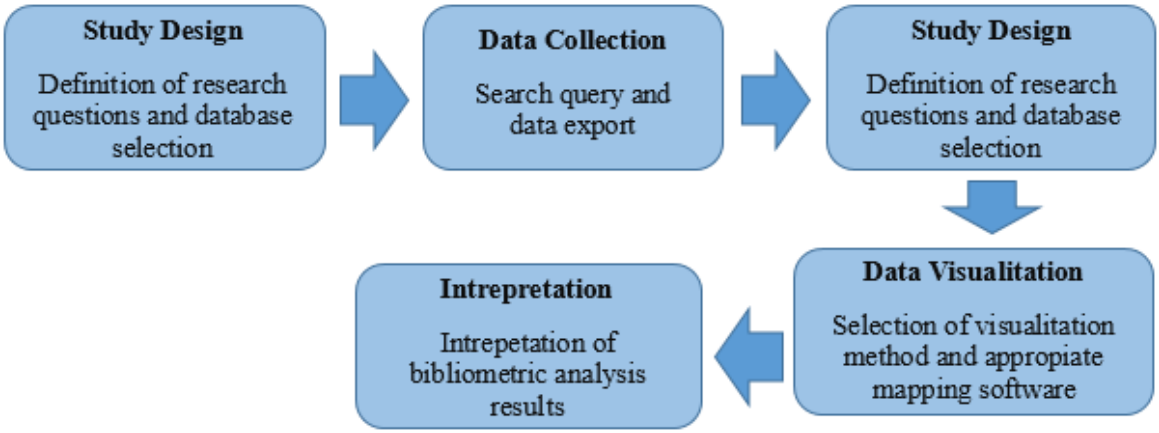

Figure 1. Protocol for Science Mapping

We accessed Scopus (http://www.scopus.com) on 15 March 2023 to obtain a database of articles for bibliometrics. Scopus is one of the bibliographic databases that has received wide recognition as a source of bibliometric data in various studies. This data is stored in Microsoft Excel for data processing and RIS for use in VOSviewer software. The following research questions were posed to direct the bibliometric inquiry.

RQ1. How did the discussion on the TPACK model in digital learning grow?
RQ2. Which authors have had the greatest impact on research into the TPACK model of digital learning?
RQ3. Which journals have the greatest impact on TPACK model variables in digital learning?
RQ4. What are the most relevant keywords, and what co-occurrence patterns can be found in the TPACK model of digital learning?

Results and Discussion

The bibliometric analysis findings of this study refer to (Donthu et al., 2021). There are two types of analysis: performance analysis, which looks at things like how many articles are published each year, which ones receive the most citations, which journals have the most articles, which countries have the most articles per capita, and science mapping, which looks at things like Circles Network Visualisation, Frames Overlay Visualisation, and Density Visualisation. Data from article search results on the Scopus

database using keywords were collected using the Scopus database. The consultation query in Scopus is as follows: ("pack" AND "digital" AND "learning") AND ("ar" AND "SOCI" AND "English" AND "j"), and the year of publication of the article between 2013 - 2022. Based on the results of data searches through the Scopus database, 123 articles were obtained, which are the population of this study. From the 123 articles, the author screened the relevant keywords. Furthermore, the researcher also limited it to keywords that followed social research, then 73 articles were obtained, which became the research sample. The development of article publications on this topic has fluctuated, as presented in the following figure:

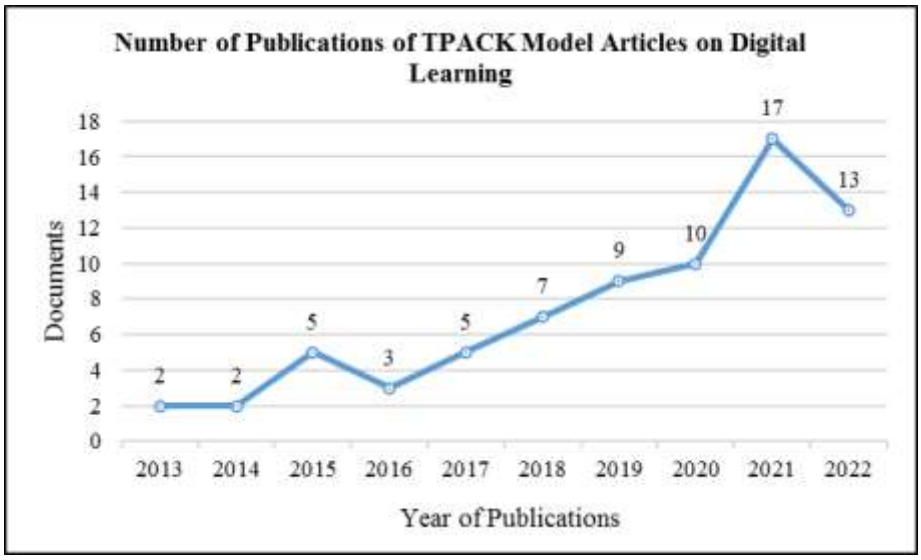

Figure 2. Number of Publications of TPACK Model Articles on Digital Learning

Based on Figure 2, the number of articles from 2013 to 2016 is not too fluctuating; The quantity of articles has increased and decreased, although the changes are not really noticeable. From 2016 through 2021, there was a considerable rise, reaching a peak in 2021. In 2021, the highest number of articles was obtained, namely 17 articles. Meanwhile, from 2021 to 2022, the number of article publications has decreased. Even though the covid-19 outbreak still hit the world in 2021 and 2022, the trend of writing articles has decreased. The shape of the graph in Figure 1 resembles the graph in the research of Nasir et al. (2023), which explains that the accumulation of publications per year forms an exponential growth curve in the period 2013 to 2022 and Putri et al. (2022) in the period 2012-2022. The shape of this graph also resembles the graph in the research of Zou et al. (2022), which was conducted from 2000 to 2020.

Articles in Scopus-indexed journals are often used as reference material in other studies. More citations or citations of an article means that the research results are widely used as references in other studies. The Scopus database search results show 1010 citations from 73 articles from 2013-2022. Table 2 lists the articles that have received the most citations.

Table 2. Articles with the Highest Number of Citations

No	Author	Title	Year	Journal	Citations	Impact Factor	Quartile
1	Falloon, G.	From digital literacy to digital competence: the teacher digital competency (TDC) Framework	2020	Educational Technology Research and Development	155	5.580	1
2	Tømte, C., Enochsson, A.-B., Buskqvist, U., Kårstein, A.	Educating online student teachers to master professional digital competence: The TPACK framework goes online	2015	Computers and Education	84	11.182	1
3	Spiteri, M., Chang Rundgren, S.-N.	Literature Review on the Factors Affecting Primary Teachers' Use of Digital Technology	2020	Technology, Knowledge, and Learning	79	4.440	1
4	Maeng, J.L., Mulvey, B.K., Smetana, L.K., Bell, R.L.	Preservice Teachers' TPACK: Using Technology to Support Inquiry Instruction	2013	Journal of Science Education and Technology	68	3.419	1
5	Hsu, C.-Y., Tsai, M.-J., Chang, Y.-H., Liang, J.-C.	Surveying in-service teachers' beliefs about game-based learning and perceptions of technological pedagogical and content knowledge of games	2017	Educational Technology and Society	56	2.633	1

Articles on the Scopus database about the TPACK model in digital learning are written in international journals. The following table lists the five journals with the most papers published in them.

Table 3. Journals with the Most Articles

No	Journal	Total Article	Citations
1	Education and Information Technologies	3	21
2	Educational Technology Research and Development	3	206
3	Computers and Education	3	137
4	Journal of Research on Technology in Education	3	48
5	Journal of Music Technology and Education	3	7

Table 3 shows the trend of Scopus-indexed journals with the most articles on the TPACK model in digital learning. The journals have the highest number of published articles, with three articles each. The five journals in Table 3 can be used as the best publication references related to the TPACK model in digital learning.

Scopus-indexed reputable journals have a ranking system, namely Quartile (Q). Q1, Q2, Q3, and Q4 are rankings of how great and influential a Scopus-indexed journal is in a scientific field. The the higher the rank of a journal smaller the Q value. The Q value of Scopus-indexed reputable journals can be traced through https://www.scimagojr.com by selecting the Journal Rankings menu. From the search results on the Journal Rankings menu, the Quartile (Q) value and the country of origin of an article are obtained. Then the classification of journals based on the Q value is carried out as follows.

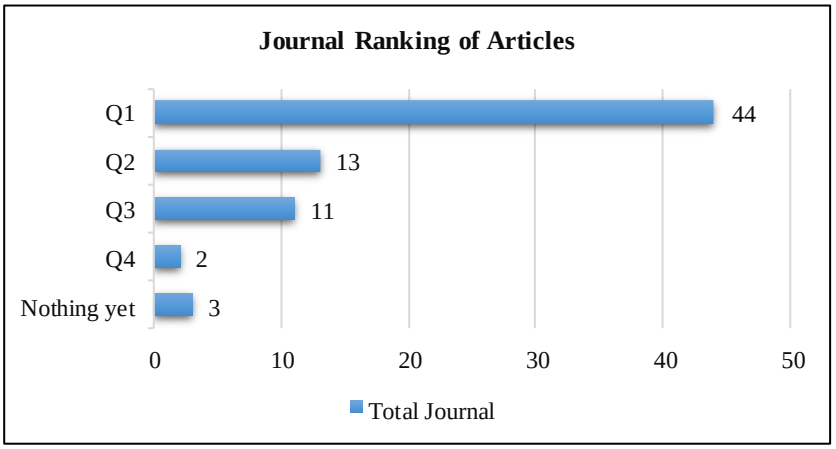

Figure 3. Quartile Journal Ranking of TPACK Model Articles on Digital Learning

Based on the data from Figure 3, the most TPACK model articles on digital learning were written in journals ranked Q1 with 44 articles. This also indicates that writing articles about the TPACK model in digital learning is an essential and exciting topic, and the articles' quality is excellent. So that in the future, it is essential to study and conduct research related to this topic. Journals occupy the second position with Quartile Q2 scores of 13 journals. Journals occupy the third position with Q3 scores of 11 articles. The third position is occupied by journals that do not have a Quartile value, with a total of 3 articles, and the last position is occupied by Q4 journals, with a total of 2 articles.

In the journal rankings menu, information about the country of origin of the journal is also obtained. The following figure presents the countries of origin of journals that write articles about the TPACK model in digital learning.

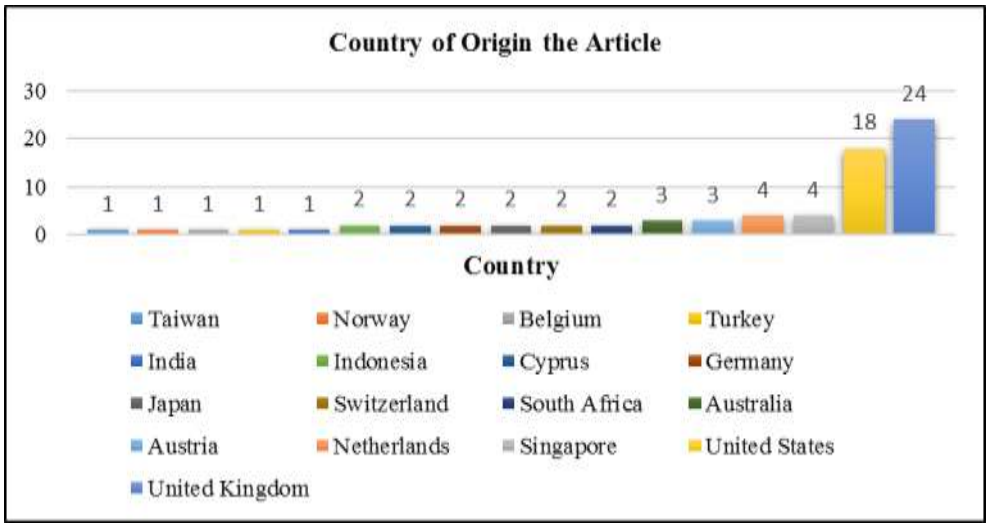

Figure 4. Journal Country of Origin from TPACK model Article on Digital Learning

With 24 papers published between 2013 and 2022, Figure 4 demonstrates that the United Kingdom is the most productive nation in terms of article publications. The second most published article is from the United States, the third and fourth are from Singapore and the Netherlands, followed by other countries. The diagram shows that the data search recorded 17 countries that published articles on TPACK in digital learning according to the keywords.

The Scopus database results are stored as RIS, which is then used in the VOSviewer software to obtain bibliometric analysis results. After the RIS data is entered into the VOSviewer software, 303 keywords are obtained. By selecting the minimum number of occurrences of repeated words used as two words, the results obtained 38 words close to the term, as shown in Figure 5.

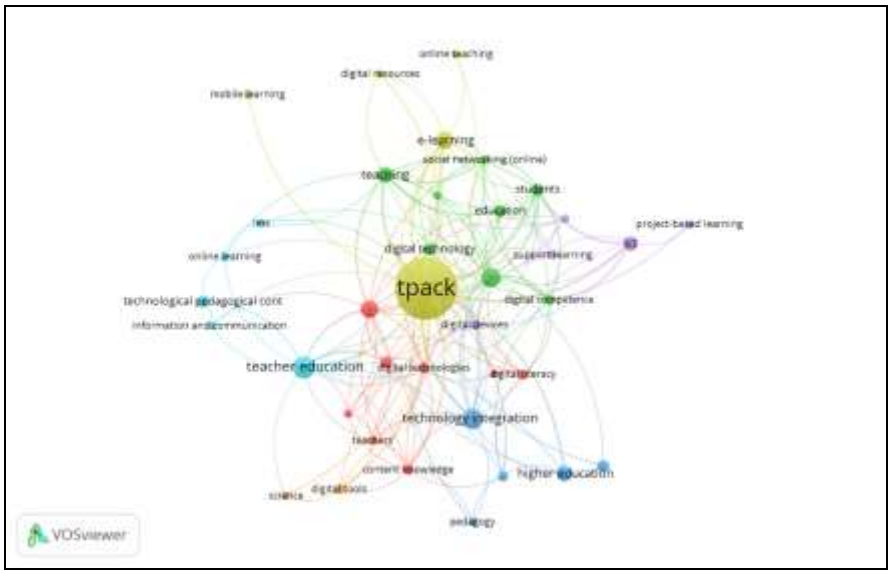

Figure 5.Circles Network Visualization

The results of Circles Network Visualisation of VOSviewer software in Figure 5 shows the existence of 7 clusters consisting of 38 themes related to the TPACK model in digital learning, namely:

1. Cluster 1 (red) consists of 8 items describing the scope of technological knowledge: digital literacy, content knowledge, digital technologies, educational technology, teacher professional development, pack model, technological pedagogical content knowledge, and teachers.
2. Cluster 2 (green) consists of 8 items describing teachers' digital training: digital competence, digital technology, education, information and communication technology, social networking (online), students, teacher training, and teaching.
3. Cluster 3 (blue) consists of 5 items describing technology integration: digital learning, higher education, pedagogy, technology, and technology integration.
4. Cluster 4 (yellow) consists of 5 items describing digital learning models: digital resources, e-learning, mobile learning, online teaching, and pack.
5. Cluster 5 (purple) consists of 5 items describing technology use in learning: digital devices, ICT, preservice teachers, project-based learning, and support learning.
6. Cluster 6 (light blue) consists of 5 items describing technology-age teacher education, namely: online learning, information and communication technologies (ICT), teacher education, LMS, and technological pedagogical content knowledge (pack).
7. Cluster 7 (orange) consists of 2 items describing digital learning tools: digital tools and science.

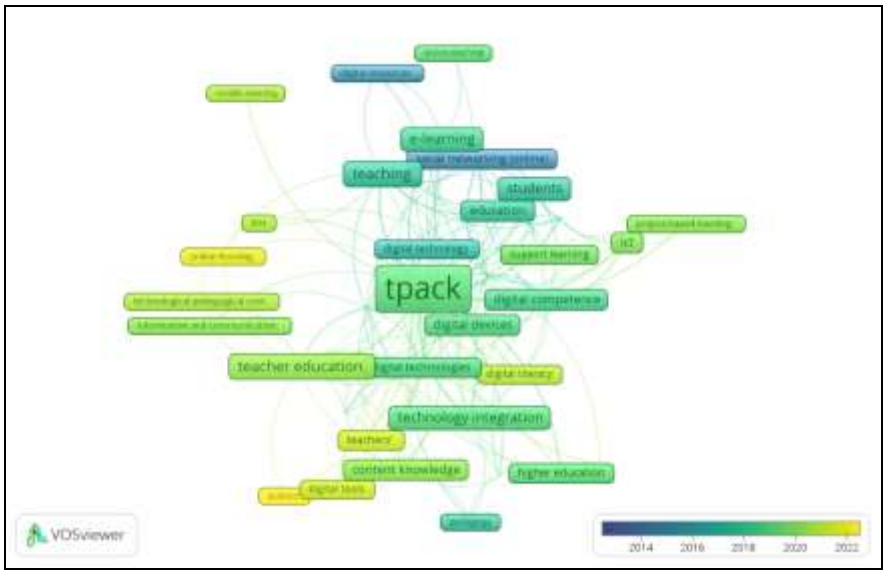

Figure 6. Overlay Visualization

The Overlay Visualisation software VOSviewer results in Figure 6 show the Scopus database's trend for article writing subjects by year. From 2013 to 2022, purple, blue, tosca, dark green, light green, and yellow themes will be popular in article writing. This means that the themes "online learning," "science," and "TPACK model" in yellow and "digital tools," "teachers," "digital literacy," "technological pedagogical content knowledge," and "LMS" in light green are the latest themes related to the TPACK model in digital learning. These themes can be a novelty reference for future research.

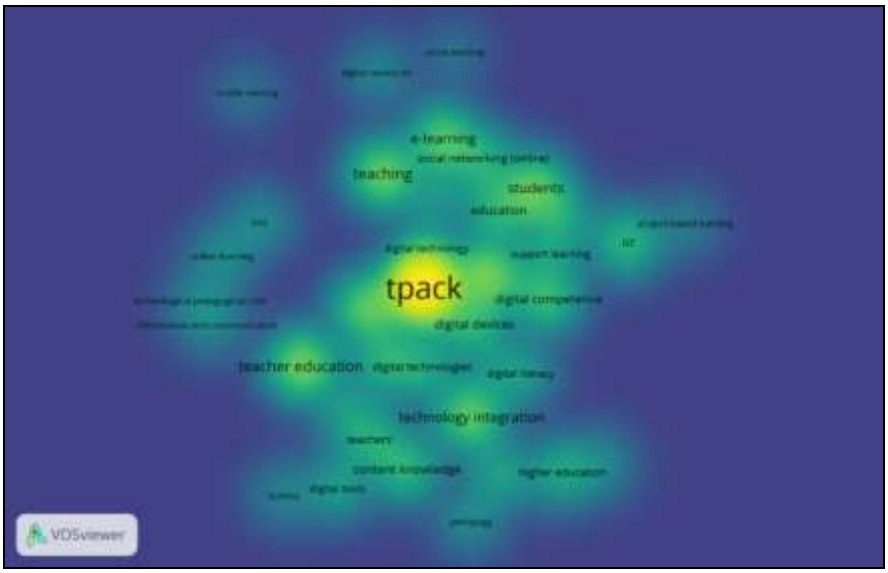

Figure 7. Density Visualization

The Density Visualisation results of VOSviewer software in Figure 7 show the density. Bright yellow coloration indicates study theme density. More study has been done if the color of the theme is brighter. The theme is less thoroughly investigated the paler the color. The darkly colored themes, including "online learning," "digital tools," "digital literacy," "digital technologies," "LMS," "online teaching," "digital resources," and "information and communication technology" are a topic that can be used as a reference for future research.

TPACK study was carried out by several scholars employing bibliometric analysis (Suprapto et al., 2021; Soler-Costa et al., 2021; Lee et al., 2022). However, it must still provide an overview of TPACK in digital learning. The author continues previous researchers who conducted TPACK research on technology-based learning (Habibi et al., 2019; Tømte et al., 2015; Yang et al., 2021). The results of the study (Soler-Costa et al., 2021) imply that the perceptions and beliefs of learners and teachers regarding the TPACK model provide the potential for its application in the digital learning space and, according to Falloon (2020) help build a broader conceptualization of digital competence.

It can be seen in the publication trend in the last ten years (2013-2022) that the number of articles on the Scopus database on the topic of TPACK in digital learning is increasing. This is clear evidence that integrated learning technology is necessary for the evolution of learning (Nasir et al., 2023). In the 21st century, innovation in education and rapid technological advancement are inseparable (Goradia, 2018). When viewed in Table 2, most publications and types of cited journals focus on learning and technology.

Referring to the results of the Scopus database, which were further analyzed using Vosviewer, 303 keywords were produced, which the researchers sorted by two times the keywords repeatedly appeared, resulting in 38 keywords relevant to the topic of TPACK in digital learning. According to the visualization findings, the emergence of TPACK in digital learning gave rise to seven groups denoted by different colors based on the level of manifestation. Clustering is denoted by color, while image labels denote frequently appearing keywords or terms. While clustering is utilized to obtain understanding or an overview of bibliometric clustering, image mapping gives a complete picture of the bibliometric network (Rodriguez et al., 2016). The topic of TPACK model on digital learning has a strong connection and is directly integrated with the concept of online learning, digital tools, digital literacy, digital technologies, LMS, online teaching, digital resources, information, and communication technology.

After conducting a bibliometric analysis of this study, the author conducted a content analysis of the seven clusters formed to find the picture in Figure 5. The TPACK framework described by, Mishra & Koehler (2006) describe teachers' knowledge of using technology for learning purposes. Effective technology integration occurs in areas where teachers' technological knowledge, pedagogical knowledge, and content knowledge interact. TPACK is a way of thinking that can assist educators in making plans for efficient technology integration in technology, pedagogy, and content rather than focusing on mastery of specific technologies. In contrast, TPACK recognizes the interconnectedness of pedagogy, technology, and conceptual content knowledge in teacher education programs (Falloon, 2020). Rarely do these connections appear in course design or instructional methods (Ndongfack, 2015). He asserts that many teacher education programs have inherent structural problems that prevent the development of TPACK integrative knowledge.

If a teacher needs to gain some knowledge base of the TPACK framework, they should learn it to become proficient (Kajonmanee et al., 2020). Introducing TPACK explicitly to learners, modeling technology integration, and facilitating learners' engagement in building collaborative courses are all recommended when developing TPACK-based learning models for teachers in the technological age (Tseng et al., 2022). Quality teacher education and training should start with the preservice training program (Al-Abdullatif, 2019; Habibi et al., 2019; Maeng et al., 2013). This stage is crucial as it ensures that teachers are competent before entering the classroom (Chaipidech et al., 2022). The TPACK-in-Action concept that integrates TPACK competencies has been applied in various pieces of training (Mai, 2022). To promote efficient teacher learning, this approach places a strong emphasis on the knowledge, professionalism, and awareness of sociocultural viewpoints of educators.

Software-based adaptive or personalized learning systems are the latest methods to model TPACK learning (Harris, 2016). As a technological advancement to improve learning innovation, Angeli et al. (2015) developed a self-adaptive learning model called e-TPACK to promote the growth of TPACK learning. AI technology can offer innovative learning models (Alawani, 2019). The field of research on intelligent learning environments has shown tremendous growth over the past 30 years (Hwang & Fu, 2020). One strategy is providing students with unique learning experiences based on their learning profiles and preferences, or "personalized learning" (Hwang, 2014). The benefits of employing technology to customize learning experiences to learners' preferences have been underlined by recent studies on personalized learning (Chaipidech et al., 2022). This technology was developed using rules that can intervene and customize TPACK-based learning models. It is machine-centered adaptation.

The TPACK model offers an analytical framework for incorporating technology during learning. They must understand what this instructional approach means and how they can improve teaching and learning by incorporating technology (Maeng et al., 2013) concerning the utilization of digital media from the view of the TPACK model. According to Prapulla et al. (2020), digital learning is divided into technological and pedagogical knowledge components. Technical skills to create learning by utilizing various digital media are called technological knowledge. Pedagogical knowledge aims to produce practical and creative instructors (Chaipidech et al., 2022). For example, e-learning systems, learning management systems (LMS), content management system (CMS) tools, and digital learning environments are common terminologies used to define educational programs (Chansanam et al., 2021). These portals enable students to interact with all instructors and classmates via text, chat, video meetings, or a variety of specialized applications while viewing course materials in several media (such as text, images, photographs, and sound).

Conclusion

The findings may assist some researchers employ this model in the teaching-learning process, the researchers may claim unequivocally in the study's conclusions. Although this digital learning model helps distribute pedagogical knowledge, educators also need digital expertise and various complementary

materials to achieve the best results. In the publication trend in the last ten years (2013-2022), the number of articles in the Scopus database on TPACK in digital learning increased, but 2022 it decreased slightly. 2021 can be claimed as the year with the highest number of Scopus-indexed publications. Articles and journals focusing on learning and technology dominate in terms of citations. Furthermore, journals published in the Scopus database are dominated by Q1 rankings, indicating essential and exciting topics, and the quality of the articles is outstanding. In terms of journal publishers, the United Kingdom is the country with the most articles. The results of the VOSviewer visualization revealed that seven clusters indicated that digital learning requires technology, a variety of valuable tools, and the development of educators' proficiency levels. In addition, there are opportunities for further research related to TPACK in digital learning.

Based on the results of this study, the researcher claims that the bibliometric analysis of TPACK images on digital learning published in Scopus-indexed journals from 2013 to 2022 can be used as a reference for developing TPACK model learning research in the future. However, the researcher realizes this research is still minimal, so the researcher recommends two things. Firstly, in the future, this research should include more than just Scopus-indexed journals with a more extended period. Second, more in-depth research is needed on integrating the seven components of TPACK in digital learning and the application of TPACK-based AI. Working through multiple levels of professional development to combine technology, curriculum, and pedagogy is one way teachers can build the abilities to use technology effectively in the classroom. For teachers to integrate TPACK-based learning, they must be equipped with digital competencies before they become professional educators through preservice training because TPACK is closely related to technological and pedagogical knowledge that will make teachers skillful and creative in impleenting learning with the help of digital technology.

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