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Research trend on TPACK through bibliometric analysis (2015-2019)

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ABSTRACT

This paper aims to analyze the scientific trend of research on Technological Pedagogical Content Knowledge (TPACK) through bibliometric study and explore how the contribution of Indonesian researchers in the Scopus database from 2015 to 2019. The sample was composed of 2075 documents in total. The results revealed that scientific publication on TPACK has been increasing. United States contributed the most documents on TPACK as well as Singapore's institutions dominated in this area. Meanwhile, Indonesia put its two representative's institutions: Universitas Sebelas Maret and Universitas Pendidikan Indonesia, among the big ten institutions in the world. All Indonesian documents produced by teacher-producing universities and public universities. United States and Taiwan have also contributed to the most productive authors of TPACK. Then, the visualization of research trend on TPACK resulted in four major clusters: i) TPACK as a system; ii) TPACK in relating to its scale; iii) TPACK in connecting with quantitative parameters; and iv) TPACK under beliefs, intention, and technology acceptance. The research findings could aid related researchers to recognize the trend of TPACK research and recommend directions for further research.

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1. INTRODUCTION

The era of the 4th generation industrial revolution, or what is known as the 4.0 industrial revolution, directs all areas of life to digital technology, artificial intelligence, big data, and robotic. There is no exception in education; entering the world 4.0 industrial revolution, education is required to construct learning that involves technology. Education 4.0 is a term used by education experts to describe how to implement cyber technology into learning [1]. Education 4.0 requires teachers to master technology to be integrated into the learning process. The teacher's ability to master technology in learning can be seen through the Technological Pedagogical Content Knowledge (TPACK) owned by the teacher. TPACK is a theoretical framework for integrating technology, pedagogy, and subject matter in learning. It is substantial to

examine the three elements of TPACK knowledge and the interactions between each TPACK element and their relationships with the industrial revolution 4.0 [2].

The ability of TPACK is crucial for prospective teachers because they have to teach all subject matters. Prospective teachers who have TPACK abilities can integrate technology in the learning process is following the learning material and the appropriate learning strategy according to the characteristics of students [3]. The use of technology in the learning process is beneficial for students in understanding subject matter, especially mathematics and science. It is common knowledge that some mathematics and science materials are abstract. The task of prospective teachers is to design abstract learning to be more concrete, contextual, or more realistic according to the students' level of thinking through technology. Effective teachers are expected to exploit the potential of technology to develop student understanding, stimulate interest in learning, and improve student skills.

TPACK is a framework for researchers and education practitioners, in an effort to package and develop learning models in order to achieve learning objectives through a better process. Knowledge of technology, pedagogy, and content knowledge, should be collected in a teacher or prospective teacher [2], [3]. Despite the importance of TPACK, there have been few attempts to gather data about the worldwide scientific production of TPACK. One of the methods used by researchers is a literature review with bibliometric analysis.

The bibliometric analysis provided a precise method to evaluate the contribution of a paper to the advancement of knowledge [4]-[6]. Bibliometric indicators, including research fields, document sources, publication outputs, document sources, language sources, distribution of countries and institutions, top authors, number of citations, and author keywords, have been frequently used to analyze the trends [4]-[8]. This study aims to analyze the trends of TPACK research in the last five years (2015-2019) to help educational researchers comprehend the landscape of global TPACK. Through this research, the researchers explored some parameters or interrelationships among variables on TPACK, such as the product of TPACK, the use of research design in TPACK, TPACK and beliefs, TPACK relating to gender and science, technology, engineering, and mathematics (STEM), the most influenced researcher of TPACK, and the policy about TPACK. Thus, this study focused on the research trend on technological pedagogical content knowledge on interval 2015-2019 with six research questions:

i) To what extent did the publication output, document sources, and language sources of TPACK in 2015-2019?
ii) To what extent did the distribution of publication of TPACK across countries and institutes in the world?
iii) Who were the top authors in researching of TPACK in the world?
iv) How did the publication patterns of TPACK base on source titles?
v) How did the visualization results of the research trend of TPACK?
vi) To what extent did the contribution of Indonesian researchers on researching TPACK?

2. LITERATURE REVIEW

2.1. Overview of technological pedagogical content knowledge

TPACK is teacher knowledge and competence that Shulman first developed in 1986-1987 [9]. TPACK describes scientific insights in technology, education, and fields of study and their use in learning [3], [9], [10]. TPACK framework can be seen in Figure 1(a). Furthermore, the most influential on TPACK, [9] describe TPACK in more detail on its elements, including TK, CK, PK, PCK, PTK, and TPK, which subsequently form TPACK as shown in Figure 1(b).

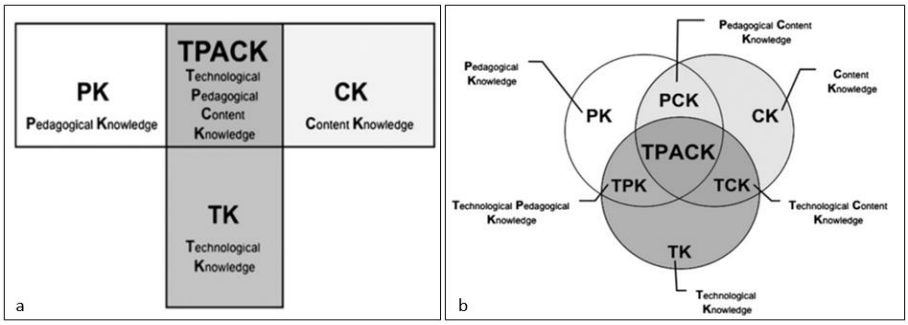

Figure 1. The TPACK framework [3], [9]

In developed countries, teacher competence is known as TPACK [11]-[13]. TPACK consists of three essential components, namely Pedagogical Knowledge (PK), Content Knowledge (CK), and Technological Knowledge (TK). The three components form a specific subject pedagogy, including TPK, TCK, and PCK, forming TPACK.

The TPACK framework is increasing in use by education and educational technology researchers worldwide who were interested in issues related to technology integration. Recently, "a conceptual model called technological pedagogical content knowledge (TPACK) was introduced to the educational research community" [14]. Researchers have involved the model with significant initial enthusiasm, as evidenced by the rapid growth of special interest groups and TPACK strands at the educational association and conferences. Many researchers recognize the broad appeal and potential of the TPACK model.

3. RESEARCH METHOD

The study was utilized a desk study with a bibliometric analysis of papers that we expect provides a valuable reference for future research [4]-[8], [15], [16]. The term bibliometrics was first by Pritchard [17], "hoping that the term would be used explicitly in all studies which seek to quantify the processes of written communication and would quickly gain acceptance in the field of information science" [18]. The researchers optimized Elsevier's Scopus database, the largest academic database in the world. In scientific research, it is crucial to get a broader perspective of research already being conducted concerning relevant content and a bibliometric analysis profile on the research trajectory and dynamics of the research activities worldwide. "TPACK" and "mathematics or physics or chemistry or biology or science education" were used as the filter to search titles, abstracts, and keywords from 2015 to 2019. The search strategy was a title:

"tpack" AND physics OR mathematics OR chemistry OR biology OR science AND (LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015))

The data collection was conducted in October 2020. It was 2075 documents that fulfilled the searching criteria. Microsoft Excel was used to analyze the data. The investigation was conducted to analyze the research trends, including characteristics of publication outputs, document sources, language sources, distribution of countries and institutions, distribution of outputs in subject categories, top authors, top citations, and publication trends from 2015 to 2019. VoSViewer software was used to figure out the research trend on TPACK [19].

4. RESULTS AND DISCUSSION

4.1. Publication output, document sources, and language sources

There were 2,075 papers associated with TPACK research in the Scopus database, including five document sources. The publications devoted to TPACK research throughout 2015 to 2019 are demonstrated in Figure 2. The number of documents of TPACK across the year was increased significantly. It was about 312 articles in 2015 and became double in 2019 (610 articles). It can be predicted that the number of articles in the next five years will increase dramatically.

Meanwhile, the number of articles based on sources indicated the dominance of articles in the journal (1344 documents). It was followed by a book and conference proceeding. The book series and trade journal accounted for the fewest sources of documents. Then, out of a total of 2,075 documents, most articles used English as the language of articles (1997 documents or 96%). The rest documents were using Spanish (3%). While it was in a small number, the documents used Turkish, Russian, Portuguese, and Chinese with a percentage less than 1%.

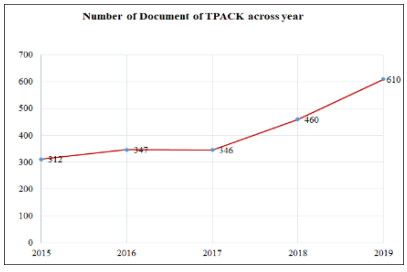

Figure 2. The number of documents on TPACK during 2015-2019

4.2. Publication distribution of countries and institutes

Based on the number of documents across countries, the USA's dominance with 584 documents from 2015 to 2019. The countries such as Australia and Turkey contributed to this topic with 157 and 150 documents, respectively. Meanwhile, with almost the same number, China, Indonesia, and Spain contributed documents between 120-130. The rest of the ten countries that contributed the most to research on TPACK were Taiwan, Malaysia, the UK, and the Netherlands with total of 50-100 documents.

The number of documents of TPACK (2015-2019) across the institution could be seen in Table 1. Singapore places its two institutions in the first and second rank. Nanyang Technological University (NTU), Singapore has ranked first with 44 documents and was followed by the National Institute of Education (NIE), Singapore and National Taiwan Normal University (NTNU), Taiwan. Indonesia has placed two of its representatives (Universitas Sebelas Maret and Universitas Pendidikan Indonesia) among the ten world institutions that have contributed the most to research on TPACK. Meanwhile, other institutions were dominated by the USA and the Netherlands.

Table 1. Number of documents of TPACK (2015-2019) across institution

No	Institution	Number of documents
1	Nanyang Technological University, Singapore	44
2	National Institute of Education, Singapore	39
3	National Taiwan Normal University, Taiwan	33
4	The University of North Carolina at Charlotte, USA	30
5	Michigan State University, USA	26
6	Oregon State University, USA	25
7	University of Twente, Netherlands	23
8	Universitas Sebelas Maret, Indonesia	23
9	Universitas Pendidikan Indonesia, Indonesia	22
10	Universiteit van Amsterdam, Netherlands	21

4.3. Top authors in researching of TPACK

In terms of most productive authors, Chai (29 documents), Polly (25), Tondeur (21), Niess (20), Voogt (20), Koh (16), Zhang (16), Mishra (14), Tsai (12), and Wang (12) were the most productive authors on this topic. Among those top ten authors, the most of them are from the USA. Meanwhile, Chai and Tsai are the representative top authors from Taiwan. Generally, the performance of authors in line with the top citation of the article all years, as indicated in Table 2. For example, Voogt (515 citations) and Tondeur (250 citations) recorded their work with the top five citations until October 2020. Meanwhile, Table 3 depicts the top citation of articles in the duration of 2015-2019. It was listed that authors such as [20]-[23] resulted in their articles as the top 5 citations in 2015-2019.

Table 2. Top citation of article all years

Author(s)	Journal	Number of citations
Schmidt, *et al.* [24]	J. Res. Tech. Educ. 42(2), 123-149	515
Harris, Mishra, and Koehler [25]	J. Res. Tech. Educ. 41(4), 393-416	373
Voogt, *et al.* [26]	J. Comp. Ass. Lear., 29(2), 109-121	261
Tondeur [27]	Comp. & Educ., 59(1), 134-144	250
Graham [14]	Comp. & Educ., 57(3), 1953-1960	248

Table 3. Top citation of article in 2015-2019

Author (s)	Journal	Number of citations
Gil-Flores, *et al.* [22]	Comp. Hum. Behav. 68, 441-449	91
Ghavifekr and Rosdy [21]	Int. J. Res. Educ.& Sci., (2), 175-191	88
Kim, *et al.* [23]	Comp. & Educ, 91, 14-31	83
Angeli, *et al.* [20]	Educ. Tech. & Soc., 19(3), 47-57	76
Valtonen, *et al.* [28]	Comp. & Educ., 81, 49-58	70

4.4. Publication patterns: Source titles (Journal or Proceeding)

Table 4 illustrates the most contribution journal or proceeding on the research of TPACK. Journal of Physics Conference was a leading conference series that contains articles about TPACK. Meanwhile, Computer and Education-Elsevier and Education and Information Technologies-Springer were the leading journals covering TPACK in their content. The remaining journals were Australasian Journal of Educational

Technology, British Journal of Educational Technology, Eurasia Journal of Mathematics, Science, and Technology Education, Technology, Pedagogy and Education, Journal of Educational Computing Research, and TechTrends.

Table 4. Number of documents of TPACK (2015-2019) across source titles

No	Name of Journal or Proceeding	Number of documents
1	J. Phys. Conf. Ser.	63
2	Comp. & Educ.	48
3	Educ. & Inform. Tech.	46
4	Teach. Train. & Prof. Dev. Conc. Meth. Tools & App.	36
5	ACM Int. Conf. Proc. Ser.	28
6	Australasian J. Educ. Tech.	28
7	British J. Educ. Tech.	27
8	Eurasia J. Math. Sci. & Tech. Educ.	23
9	Tech. Ped. & Educ.	23
10	J. Educ. Comp. Res.	22
11	TechTrends	22

4.5. Visualisation of research trends on TPACK based on VoSViewer software

Among those 2,075 papers related to TPACK research in the Scopus database, the researchers visualized the research trends on this topic assisted with VoSViewer software. This effort helps find the novelty of the research on this domain. The findings indicated it was some parameters or interrelationships among variables on TPACK, such as researching on TPACK, PCK, TPACK and service teachers, the product of TPACK, the use of research design in TPACK, TPACK and beliefs, TPACK relating to gender and STEM, the most influenced researcher of TPACK, the policy relating TPACK.

Figure 3 indicates the whole picture research on TPACK. Researchers on the world produced six clusters. Four of six clusters were the significant clusters. The first cluster was TPACK as a system related to the platform and approach guiding the teaching and learning process. The second cluster was TPACK concerning its scale, validity, reliability, and statistics mode. The third cluster was TPACK connecting with quantitative parameters such as test, sample, treatment, and measurement. The fourth cluster indicated TPACK relating to beliefs, intention, and technology acceptance.

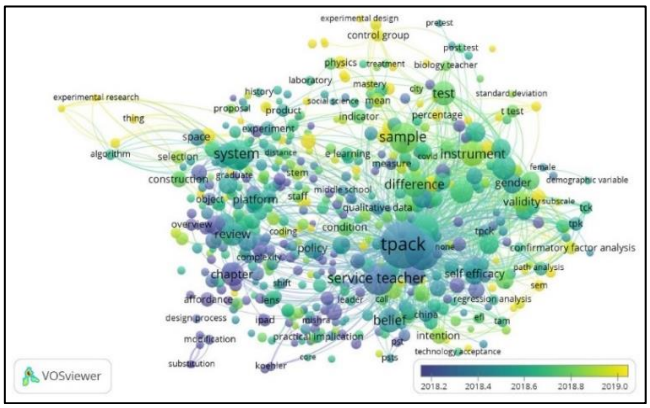

Figure 3. The whole picture of research on TPACK during 2015-2019

If we broke down into the specific connection among variables to capture the trend and novelty of researching TPACK, we found some findings. Figure 4(a) emphasizes that research on TPACK focused on pre-service and in-service teachers. It is logical due to teacher need knowledge concerning technology, pedagogic, and specific content. The development of TPACK for teachers resulted in some product for further validation, as indicated in Figure 4(b).

In terms of the paradigm research used, in the 2015-2019 period, research on TPACK used quantitative and qualitative paradigms as shown in Figure 5(a). However, the positivist paradigm with the type of quantitative research as can be seen in Figure 5(b) still dominates. It can be seen from the picture of how the dominance of tests in researching on TPACK, the selection of samples in the experimental research design in examining TPACK.

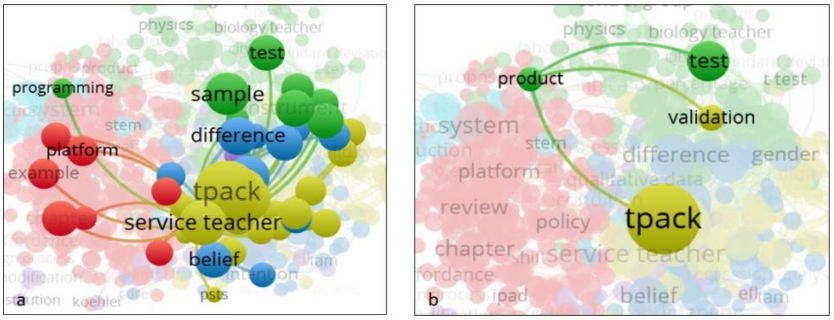

Figure 4. TPACK in relating to service teacher (pre-service and in-service) and its product

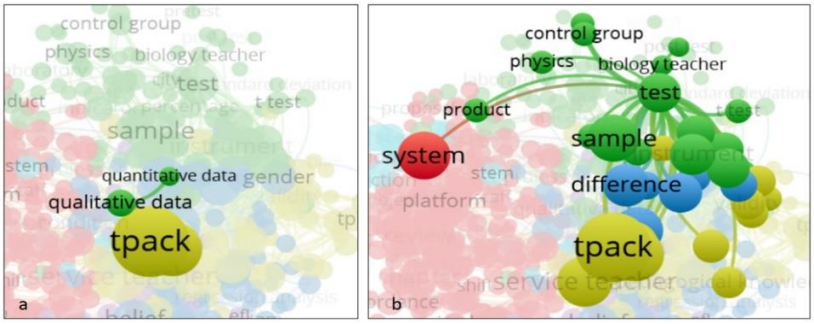

Figure 5. TPACK in relating to research paradigm

Research on TPACK has also related to STEM and gender as shown in Figure 6. Research by Chai [29] reviewed how teacher professional development for STEM education in the Perspectives of TPACK. However, Castéra, *et al.* [30] reported TPACK of teacher educators across gender in six countries in Asia and Europe. Their research indicated there was an independence of gender or academic level and TPACK.

The study of beliefs systems and policies also have an essential part of research on TPACK during 2015-2019. Figure 7 proofs that researchers considered the connection of TPACK and beliefs and TPACK and policy. Teacher' belief is essential in classroom practice because it is the principle that teachers hold to be accurate and the rationale of the attitude in the classroom. In applying the TPACK framework, the teacher has to believe in it [31]. Preservice teachers' TPACK beliefs and attitudes toward simulations were also researched by previous researchers [32]. A systematic review on TPACK has also become a concern among researchers globally. Figure 8 shows the top researcher and its cluster in researching TPACK. Chai and Tondeur have become a leader in each cluster [27], [30]. On the other hand, Mishra and Koehler were the most influenced researchers on TPACK in 2015-2019 [9], [11].

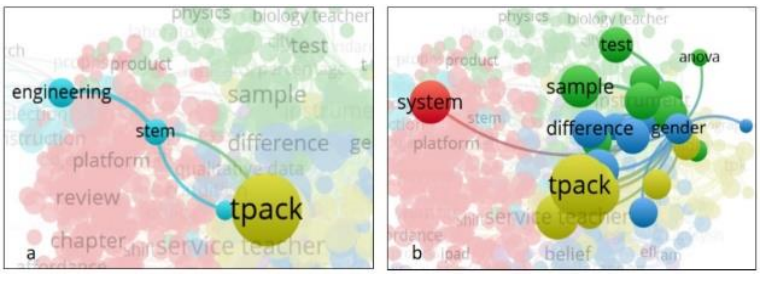

Figure 6. TPACK in relating to STEM and gender

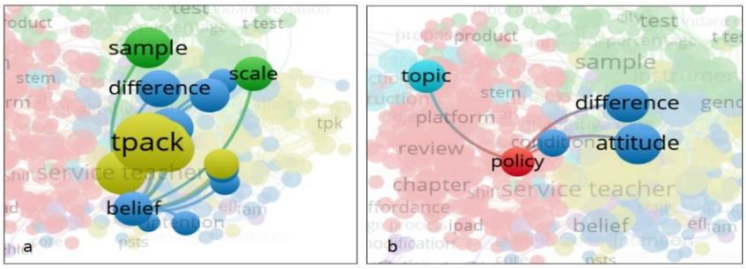

Figure 7. TPACK in relating to beliefs and policy

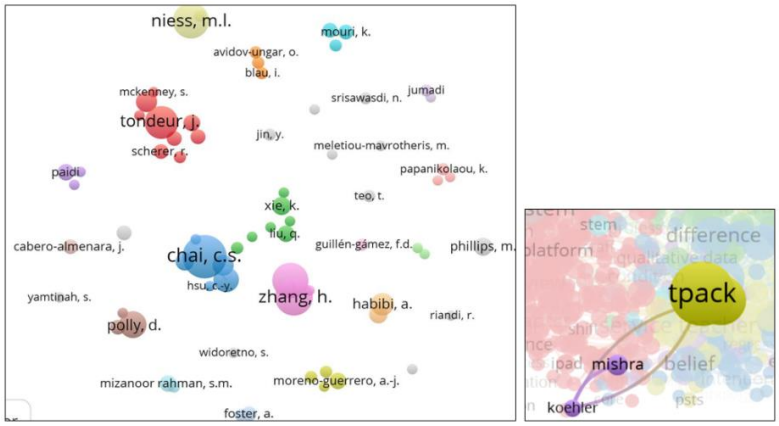

Figure 8. Top researchers and the most influenced researchers on TPACK

4.6. The contribution of Indonesian researchers on TPACK

In total, Indonesia contributed 127 documents related to TPACK in the last five years from 2075 documents. Of this number, it was 64% published in the proceedings or the results of the conference paper, while the remaining 36% is in the form of journal papers.

If researchers in the world produced six clusters related to trends research on TPACK, there were only four clusters produced by Indonesian researchers. The first cluster (red color) was TPACK in relating to skills. Meanwhile, the second cluster (yellow) was TPACK concerning its competence, needs, practice, impact, and challenge. The third cluster (green) was TPACK in connecting with quantitative parameters such as test, value, instrument, assessment, and statistics. The last cluster (blue) indicated TPACK under its component and framework.

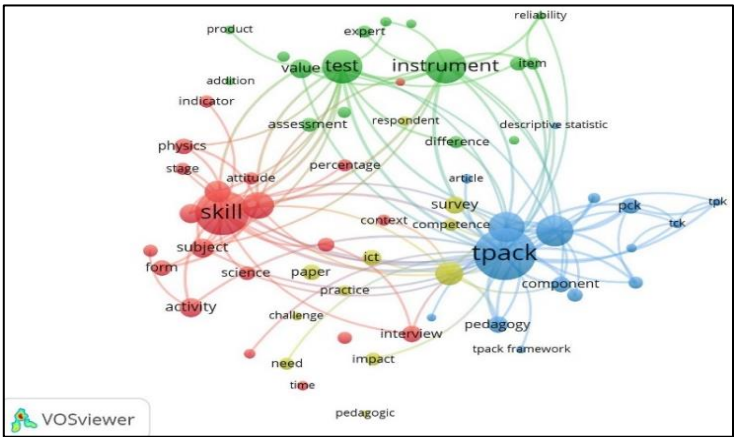

Figure 9. The whole picture of research on TPACK performed by Indonesian researchers during 2015-2019

Table 5 illustrates how the rank of Indonesian institution in producing documents on TPACK. All the top 10 are teacher-producing universities. Except for number seven and ten, all universities above are public universities of documents of TPACK across Indonesian institution (2015-2019). Meanwhile, the top Indonesian researcher on TPACK listed the name such as Paidi (7 documents), Astuti (5), Pradana (5), Riandi (5), Sinaga (5), and Widoretno (5) were the most productive authors in this topic from Indonesia.

It was no different rank from the world in terms of TPACK from Indonesia (2015-2019) source titles; Journal of Physics Conference was a leading conference series that contains articles about TPACK. AIP Conference Proceeding followed this most significant number. Meanwhile, for the journal category, Jurnal Pendidikan IPA Indonesia (number 3), also from Indonesia, is also superior in producing TPACK documents. Table 6 also indicates that Indonesia's contribution to research on TPACK is more in the proceedings than in the journal.

Table 5. Number of documents of TPACK across Indonesian institution (2015-2019)

No	University	Number of documents
1	Universitas Sebelas Maret	23
2	Universitas Pendidikan Indonesia	22
3	Universitas Negeri Yogyakarta	17
4	Universitas Negeri Malang	7
5	Universitas Negeri Jakarta	6
6	Universitas Negeri Semarang	4
7	Universitas Muhammadiyah Surakarta	3
8	Universitas Negeri Surabaya	3
9	Universitas Musamus Merauke	3
10	Surya University	2

Table 6. Number of documents on TPACK from Indonesia (2015-2019) across source titles

No	Name of Journal or Conference	Number of documents
1	J. of Phys. Conf. Ser.	60
2	AIP Conf. Proc.	9
3	J. Pend. IPA Indo.	5
4	Int. J. Innov. Creativity & Change	4
5	IOP Conf. Series Mat. Sci. & Eng.	4
6	Int. J. Learn. Teach. & Educ. Res.	3
7	IOP Conf. Ser. Earth & Env. Sci.	3
8	J. Turkish Sci. Educ.	3
9	5th Int. Conf. on Educ. & Tech. ICET 2019	2
10	Asian EFL J.	2

5. DISCUSSION

Some researches on TPACK have been conducted by several researchers [33]-[38]. However, a few studies focused on systematic review and bibliometric analysis [39]-[41]. The results of this research give a new lens of research trends of TPACK through bibliometric analysis. The authors continued previous researchers' experiences conducting a literature review [42]-[46] to capture all variables related to scientometrics on TPACK. The results of this study complemented the study by Soler-Costa, *et al.* [47], who researched TPACK based on the Web of Science. In contrast, this study used the Scopus database, the most popular database in the world. Therefore, future research can compare data from the Web of Science and Scopus.

In simple, in the last five years (2015-2019), the number of documents of TPACK across the year was increased significantly, most articles used English as the language of articles (1997 documents or 96%) as well as the study performed by Soler-Costa, *et al.* [47]. It was clear the dominance of the USA and followed by Australia and Turkey in this domain. In the middle numbers of documents, China, Indonesia, and Spain have also contributed to research on TPACK. Nanyang Technological University (NTU), Singapore, contributed the most documents on TPACK. Meanwhile, Indonesia has placed two of its representatives (Universitas Sebelas Maret and Universitas Pendidikan Indonesia). This result was also in-lined with the study of Nuangchalerm [34] and Arifin [35]. Indonesian institutions expressed their dominance on the research on TPACK in relating to skills, TPACK concerning its competence, needs, practice, impact, and challenge, TPACK in connecting with quantitative parameters such as test, value, instrument, assessment, and statistics. However, Indonesian institutions should improve their research on TPACK regarding research design, TPACK and beliefs, TPACK relating to gender and STEM, and the policy relating to TPACK.

Chai, Polly, Tondeur, Niess, Voogt, Koh, Zhang, Mishra, Tsai, and Wang were the most productive authors on this topic. These lists have also supported the findings of Soler-Costa, *et al.* [47]. It means both Scopus and Web of Science gave similar map research on TPACK. Journal of Physics Conference was a leading conference series that contains articles about TPACK. Meanwhile, Computer and Education- Elsevier and Education and Information Technologies – Springer were the leading journals covering TPACK in their content. The findings were also indicated that it was some parameters or interrelationships among variables on TPACK, such as researching on TPACK, PCK, TPACK and service teachers, the product of TPACK, the use of research design in TPACK, TPACK and beliefs, TPACK relating to gender and STEM, the most influenced researcher of TPACK, the policy relating TPACK. Indonesia itself contributed 127 documents related to TPACK in the last five years from 2075 documents. All the top ten are teacher-producing universities. It was noted that the authors such as Paidi, Astuti, Pradana, Riandi, Sinaga, and Widoretno were the most productive in this topic from Indonesia.

This study has several limitations as a standard limitation of conducting bibliometric analysis: i) A scholar may produce several units of scientific output (books, journals), but this small work may become seminal for a particular field and significantly impact the scholarship of a discipline. Standard metrics, such as h-index, will have difficulty accounting for such situations; ii) Large research teams across multiple disciplines can produce dozens or hundreds of research papers, each with tens or hundreds of authors. These team members will often exhibit very high impact metrics that may not accurately reflect their advantage on the pitch. This limitation is also related to previous studies, namely [48]-[51]. Therefore, researchers gave three recommendations for future research: i) the following researchers should take into account to two limitations above; ii) It is suggested to compare data from the Web of Science and Scopus in researching TPACK; and iii) It is essential to research on the broader coverage year. For example, research on TPACK in 2011-2020, research on TPACK in 2020-2024, and the prediction of research on TPACK in the future. However, the results of this study can contribute to enriching the treasure trove of special knowledge related to the literature on TPACK.

6. CONCLUSION

Some significant points have been attained on the research trends on TPACK during the period from 2015 to 2019. The number of documents of TPACK across the year was increased, which were dominated by articles in the journal. Considering the countries of origin, it was clear that the dominance of the USA. The number of documents of TPACK across institution indicated the dominance of institution from Singapore. Meanwhile, Indonesia put their two representative's institutions: Universitas Sebelas Maret and Universitas Pendidikan Indonesia, among the big 10 institutions in the world that contributed to researching on TPACK. Taiwan and the USA have also contributed the most productive authors of TPACK. Journal of Physics Conference was a leading conference series that contains articles about TPACK. Meanwhile, Computer and Education-Elsevier were the leading journals covering TPACK in this topic. Regarding the visualization of research trend on TPACK resulted in four major clusters: i) TPACK as a system; ii) TPACK in relating to its scale; iii) TPACK in connecting with quantitative parameters; iv) TPACK under beliefs, intention, and technology acceptance.

Indonesia contributed 127 documents related to TPACK in the last five years from a total of 2075 documents. All these documents most resulted from universities that are teacher producing universities and public universities in Indonesia. It was no different rank from the world in terms of TPACK from Indonesia (2015-2019) across source titles. This research can help related researchers recognize the trend of TPACK research in the world and give directions for further research. Future researchers should pay attention to the three recommendations outlined in the discussion section to overcome the limitations of this study.

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