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Bibliometric Analysis of The Literature on Science, Technology, Engineering, and Mathematic-Pedagogical Content Knowledge (STEM-PCK) for The Years 2011-202

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ABSTRAK

Pembelajaran *Science, Technology, Engineering, and Mathematics* (STEM) sedang banyak dikembangkan dan diteliti akhir-akhir ini. Peranan guru dalam menerapkan pembelajaran ini sangat penting. Mengingat pentingnya peran guru dalam pembelajaran ini, maka penting untuk menganalisis artikel-artikel penelitian untuk mencari hubungan antara *Pedagogical Content Knowledge* (PCK) dan STEM, serta mencari peluang bagaimana pelatihan guru yang efektif untuk meningkatkan STEM PCK guru IPA. Penelitian ini menggunakan metode analisis teks, dan datanya disajikan menggunakan analisis bibliometrik. Pencarian dengan menggunakan kata kunci “STEM pedagogical content knowledge” menggunakan perangkat lunak publish or perish, didapatkan 999 literatur yang terbit pada tahun 2011 sampai tahun 2022. Dari hasil analisis komponen-komponen PCK dan STEM dalam judul dan abstrak menggunakan analisis bibliometrik, peluang penelitian lanjutan dapat diperoleh dengan mengaitkan kata kunci PCK, pedagogical practice, integrasi STEM, PBL, dan pencapaian siswa dalam mengembangkan keterampilan abad 21.

Keywords:
STEM
STEM PCK
Bibliometric

ABSTRACT

Bibliometric analysis of the literature on STEM Pedagogical Content Knowledge for the years 2011-2022. *Analysis of bibliometric literature on Science, Technology, Engineering, and Mathematics (STEM) Pedagogical Content Knowledge spanning 2011-2022. STEM learning is being developed and researched recently. The teacher's role in implementing this learning is very important. Given the importance of the teacher's role in this learning, it is important to analyze research articles to find the relationship between Pedagogical Content Knowledge PCK and STEM, as well as look for opportunities for effective teacher training to improve STEM PCK, science teachers. This research uses the text analysis method, and the data is presented using bibliometric analysis. Searching using the keyword “STEM pedagogical content knowledge” using publish or perish software, obtained 999 kinds of literature published from 2011 to 2022. From the results of the analysis of PCK and STEM components in the title and abstract using bibliometric analysis, further research opportunities can be obtained by linking the keywords PCK, pedagogical practice, STEM integration, PBL, and student achievement in developing 21st-century skills.*

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Introduction

The implementation of learning activities in the classroom requires continuous innovation to answer the challenges of the times. This is necessary so that schools can prepare graduates who can face the changing challenges of the times well. One of the learnings that are now being developed is STEM learning. STEM is an acronym for Science, Technology, Engineering, and Mathematics and is integrated into one learning object and is needed so that students can acquire thinking skills comprehensively (Dugger, 2010). STEM learning can develop students' 21st-century skills because STEM learning is an interdisciplinary approach where the concepts of science, technology, engineering, and mathematics are directly linked to solving real-world problems in contexts that make connections between schools, communities, and global companies, to develop STEM literacy so that students can compete in the new economic era (Pittsburgh, 2009). Articles published in the Web of Science 2013-2018 show that there are several interpretations of STEM learning, and the most common interpretation is the integration of the four disciplines into one learning experience (Martín-Páez et al., 2019).

STEM learning is being widely developed in Asia and is included in one of the curricula to develop teacher professionalism. The results showed that the implementation of STEM learning in Asia was effective at a moderate level in improving student learning outcomes. The STEM learning design that is widely developed in Asia is STEM integrated with the Project-based learning method (Wahono et al., 2020). STEM provides an ideal context to engage students in problem-solving, critical thinking, tool use, curriculum integration, and a variety of other skills because of the potential to explore complex situations and unstructured problems, build prototypes, and observe results. An example would be asking students to determine a solution for cleaning up a contaminated water supply). Therefore, STEM provides a context for integration education at the age of synthetic learning (DeJarnette, 2012).

To develop STEM learning, schools must focus on learning practices that actively involve and support all students in learning and applying science and mathematics (Kloser, 2014). To make this happen, the teacher must be skilled in making STEM learning instructions. These skills can be developed through teacher training. STEM instructional instruction should focus on real-world contexts; by combining all STEM disciplines (interdisciplinary, integrated, or trans-disciplinary) and using project or problem-based learning (LaForce et al., 2016). STEM learning can develop students' 21st-century skills (Lavi et al., 2021). Therefore, it is necessary to develop teacher training programs that develop STEM competencies.

Teachers play an important role in the success of learning and student success (Chval et al., 2008). The teacher as an educator is a profession, so it can only be done by people who are experts in their fields. The expertise of a teacher that distinguishes them from other professions is known as Pedagogical Content Knowledge (PCK). This PCK distinguishes a teacher from one whose speciality is related to content knowledge only. In other words, PCK is a special knowledge that only a teacher has (Shulman, 1986). According to Shulman, there are several domains that affect the way teachers teach, namely knowledge of content, pedagogic knowledge (e.g. knowledge of classroom management strategies), knowledge of curriculum, PCK, knowledge of student learning interests. After Shulman issued the PCK idea, many other experts tried to perfect the concept. (Cochran et al., 1990) defines PCK as "a way to combine pedagogical knowledge and subject matter knowledge, and use them for classroom learning".

Magnusson et al., (2006) developed the ability of teachers' PCK into eight elements, namely: (1) knowledge of instructional strategies designed to obtain effective science learning; (2) knowledge of subject matter and curriculum; (3) knowledge about one's tendency in teaching science; (4) knowledge of assessment; (5) knowledge of students' mastery of the material; (6) knowledge about one's orientation towards teaching (knowledge of the material, beliefs about the material, and how to teach it); (7) knowledge of teacher efficacy for teaching science; and (8) well-adjusted emotional factors.

The PCK concept is the idea of transforming subject matter knowledge for teaching purposes. Therefore, it is important to be able to improve teachers' PCK skills in STEM learning so that the implementation of STEM learning in the classroom can run as expected. Improving teacher competence in STEM learning is important to prepare students to be able to face challenges in the 21st century. There are several ways we can do to improve teachers' PCK skills, one of which is through training. Many recent studies have demonstrated the benefits of developing PCK in training (Duschl & Bybee, 2014). Therefore, teacher training is absolutely necessary to develop in-service teacher PCK.

Nowadays, measuring the quality and quantity of scientific articles is an important requirement because the decision to conduct research largely depends on the benefits of existing research. This measurement can be carried out using bibliometric analysis (Gutiérrez-Salcedo et al., 2018). Bibliometric analysis is used to summarize the literature with certain indicators (Kovács et al., 2015). Bibliometric indicators can measure the effect of a paper on the number of other papers that have cited it (Belter, 2015).

This study aims to find out the relationship between PCK and STEM and find opportunities for how teacher professional training programs are implemented. In the end, increasing teacher competence can be achieved optimally, one of which is increasing the capacity of teachers in understanding and implementing STEM in science learning.

These findings can guide how to develop training programs that can improve the STEM PCK of science teachers through bibliometric analysis. So far, creating a training program is based only on the limited number of literature review data. To get keyword data from more numerous articles (can number in the thousands), bibliometric analysis is used (donthu, 2021). Data from the results of the bibliometric analysis can be used to determine PCK and STEM components through keywords in the title and abstract, so that it can be seen which ones have the potential to be developed. The results of this study are expected to be a reference for how to organize training that can develop good STEM PCK.

Methode

The research applied five stages methods from (Hudha et al., 2020; Murata et al., 2014). They are determining search keywords, gathering initial search results, doing refinement search result, compiling preliminary data statistics, and doing data analysis.

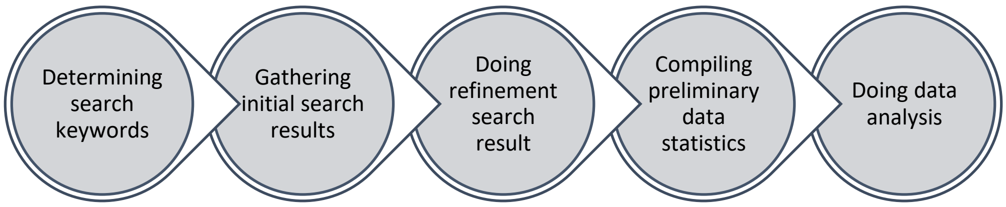

Figure 1. Five-step method bibliometric analysis

1. Determining search keywords

The keyword STEM Pedagogical Content Knowledge was used to conduct a literature search in March 2022. Publish or Perish was chosen because it has been demonstrated to be the most effective technique of finding publications on the Google Scholar (GS), and GS was picked since it is currently the largest data base (Baneyx, 2008). The first search used the PoP software's query language and the keyword 'STEM Pedagogical Content Knowledge.' The search is limited by year, namely from 2011 to 2022, and the maximum number of search results is 1000 articles. Obtained 999 articles, downloaded and saved in *ris format using VOS viewer software. Visualization of research data was obtained from the VOS viewer (Shah et al., 2020).

2. Gathering initial search results

Only 'journals', 'title words', and the years '2011-2022' are included in this search. All significant article information, such as paper titles, author and affiliation names, abstracts, keywords, and references, is compiled in Research Information Systems (RIS) format.

3. Doing refinement search result

The GS database is filtered for appropriate and indexed items. This data excludes proceedings, newspapers, books, book reviews, and book chapters. Only articles from journals were chosen. The file is then saved as a RIS file in order to perform the necessary modifications. The bibliographic program Zotero imports RIS data. The RIS file that results is utilized to conduct further data analysis.

4. Compiling preliminary data statistics

The information gathered was saved in the form of RIS. The complete components of the journal articles (publication year, volume, number, page, etc. were examined at the outset, and if any missing data was discovered, we added it. Data was analyzed so that articles could be categorised by year, publication source, and publisher.

5. Doing data analysis

PoP software was used in this study's bibliometic analysis (Baneyx, 2008). Vosviewer software, on the other hand, is used to analyze and visualize bibliometric networks (Shukla et al., 2020). VOSviewer is employed because of its capacity to work effectively with big data sets and give a variety of visually appealing analyses, investigations, and graphics (van Eck & Waltman, 2010). Vosviewer may also produce keyword maps based on shared networks or create publication, author, or journal maps based on co-citation networks.

VOS viewer is a software that can visualize bibliometric networks developed by the Center for the Study of Science and Technology, Leiden University. The VOS viewer can be used to analyze all types of bibliometric network data, for example, citation relationships between publications or journals, collaborative relationships between researchers, and relationships between scientific publications (Sarkodie & Strezov, 2019).

Results and discussion

VOSviewer is widely used as bibliometric analysis, especially in theme analysis and cluster analysis (Kokol et al., 2018; Yuan et al., 2017), used to identify growth patterns of international literature (Shah et al., 2020).

There are 4748 terms that appear at the beginning of data processing, and 149 meet the threshold. Number of terms tobe selected is 89, and there is 36 items after selected. We dropped some keywords which have the same meaning or not closely related to keywords. The results of network visualization using VOSviewer show that the search results are divided into 5 clusters, and the results are shown in Table 1.

Table 1. Keywords representing each cluster

Cluster 1 (10 items)	**Cluster 2 (10 items)**	**Cluster 3 (7 items)**	**Cluster 4 (6 items)**	**Cluster 5 (3 items)**
Assessment	Engineering	PCK	Career	Technological
Concept	Implication	Pedagogical	Engineering	pedagogical
Content area	Math	Knowledge	design	content
Idea	PBL	Science Education	Integrated STEM	knowledge
Inquiry	Pedagogical strategy	Schulman	Education	Technology
Program	Project	Teacher knowledge	Pedagogical	TPACK
STEM discipline	Science content	Pedagogical	practice	
STEM learning	STEAM	Content Knowledge	STEM content	
STEM teacher	STEM career	Teachers	STEM integration	
Training	STEM subject	pedagogical content knowledge		

To discover the most frequently appearing keywords, the output is evaluated using the PoP program and the VOSviewer software. The quantity of most commonly occurring keywords, on the other hand, is altered to meet the needs of data collecting and analysis. VOSviewer is a program that displays bibliometric maps. This software displays bibliometric mapping on three different visualizations: network, overlay, and density.

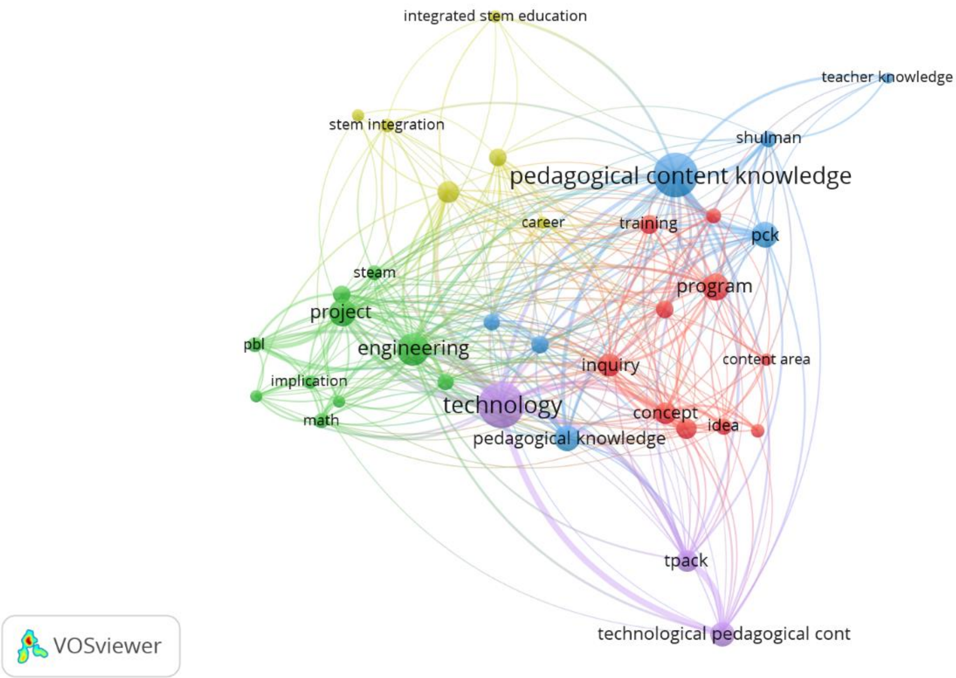

Figure 2. Network visualization with the keyword “STEM pedagogical content knowledge”

Network visualization (Figure 2) shows the relationship between keywords based on articles that have been written and published. Color differences indicate cluster differences. A larger circle indicates that the keyword has a higher number of articles. It makes it easier for researchers to analyze the content of articles, especially those related to "pedagogical content knowledge.

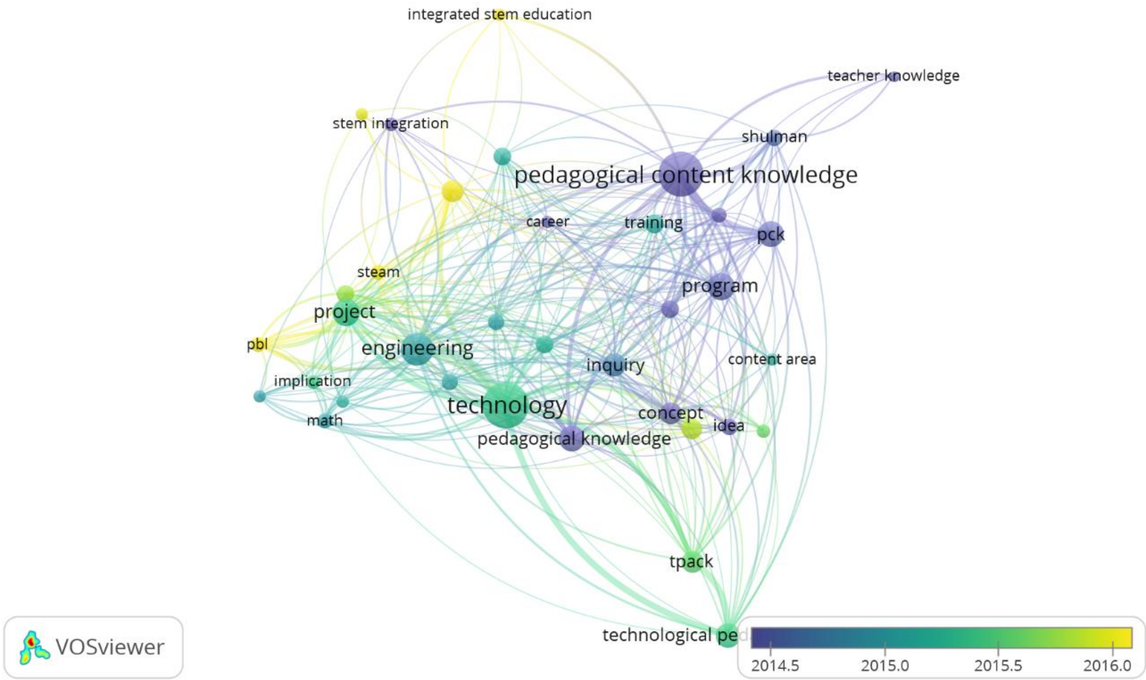

Figure 3. Overlay visualization with the keyword "STEM pedagogical content knowledge"

Based on the overlay visualization analysis (figure 3), it was found that the earliest articles related to STEM PCK were published in mid-2014. It indicates that articles related to STEM PCK keywords were only published in mid-2014 and increased in the following years.

The latest articles (2016 to 2022) are mostly related to the keywords of pedagogical practice, STEM integration, STEAM, and PBL (yellow circle). This data can be used to reference that research trends related to STEM and PCK have a lot to do with these four words. This data can be used to do new research that connects pedagogical practice integration of STEM, PBL, and PCK.

In the density visualization analysis (figure 4), it was found that the most frequently found articles were related to the keywords pedagogical content knowledge, technology pedagogical knowledge, project, and engineering.

From the three data processing results above (Table 1 and Figures 2, 3, and 4), there are many keywords in STEM Pedagogical Content Knowledge articles. Of all the keywords obtained, there are no keywords that mention student achievement in developing 21st-century skills. This opportunity becomes a novelty for further research, namely, developing training that can improve the STEM PCK of science teachers, linking PCK, pedagogical practice, integration of STEM, PBL, and student achievement in developing 21st-century skills.

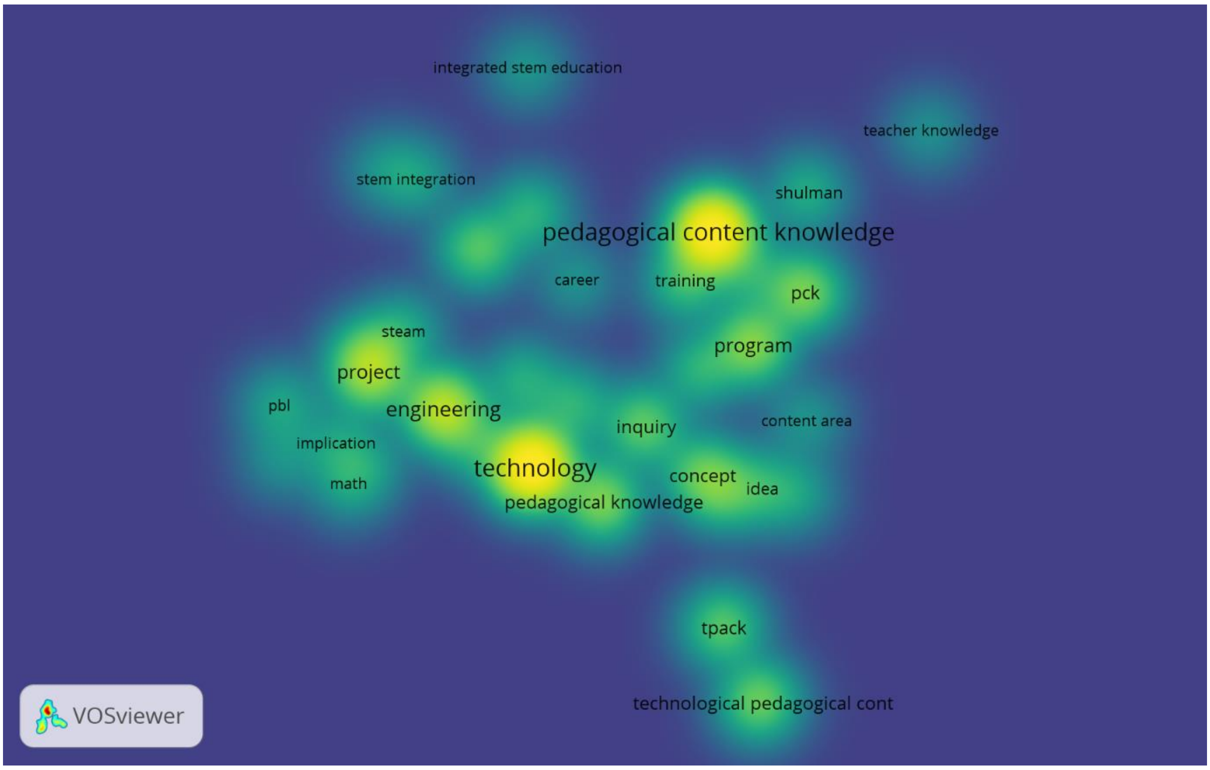

Figure 4. Density visualization with the keyword “STEM pedagogical content knowledge”

Conclusion

Further research on STEM and PCK needs to be developed. The development of teacher PCK STEM can be done through teacher professional development. It is necessary to prepare a good framework so that the professional development of this teacher can run well and be effective in increasing teacher STEM PCK. Teachers play an important role in learning. Therefore, the increase in teacher PCK is expected to improve student learning outcomes.

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