TPACK of Pre-Service Mathematics Teachers in Secondary School: A Literature Review

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Abstract. This systematic review investigates the Technological Pedagogical Content Knowledge (TPACK) of pre-service mathematics teachers in secondary schools by addressing two key research questions: (1) Which journals have published scientific articles in this domain? (2) What is the state of TPACK among pre-service mathematics teachers based on the reviewed articles? Using a litera ture review methodology, the study analyzed 14 relevant articles published between 2020 and 2024 from the Scopus database. The findings highlight the prominent journals contributing to this field and reveal the strengths and weaknesses of TPACK competencies in pre-service teachers. Specifically, while pedagogical and content knowledge are often robust, technological knowledge tends to be underdeveloped. This gap underscores the need for targeted interventions in teacher education programs to enhance TPACK integration in mathematics instruction. The study provides valuable insights for educators, researchers, and policymakers aiming to improve mathematics education through the development of TPACK competencies. It also identifies areas requiring further research, particularly the holistic development of TPACK across diverse educational contexts.

Keywords: TPACK, Pre-service teacher, Mathematics.

1 Introduction

Technological Pedagogical Content Knowledge (TPACK) has become a significant framework for understanding how teachers can effectively integrate technology into their teaching [13]. Ideally, teachers, including pre-service mathematics teachers, are expected to possess adequate TPACK competencies to optimize the learning process in the classroom. TPACK enables teachers not only to understand mathematical content and effective teaching methods but also to know how technology can be utilized to enhance students' understanding of complex mathematical concepts [14].

In reality, various studies show that the TPACK competence of pre-service mathematics teachers still varies, with some pre-service teachers demonstrating a less-than-optimal understanding of how to integrate technology into their teaching [5, 12]. Many pre-service mathematics teachers in secondary schools have strong content knowledge

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but face challenges in effectively and innovatively utilizing technology in their teaching practices [18]. This indicates a gap between the expectation of ideal TPACK competencies and the reality in the field [2].

To address this issue, a comprehensive literature review is needed to identify the current research trends related to the TPACK of pre-service mathematics teachers in secondary schools. So far, research has largely focused on the conceptual development of the TPACK framework and its implementation across various disciplines, including mathematics [15]. Additionally, some studies have examined TPACK development in the context of teacher training or mathematics teaching in general [8, 16]. However, studies that provide an in-depth review of the actual state of TPACK competence among pre-service mathematics teachers in secondary schools, particularly in integrating technology into mathematics teaching, are still limited [4]. Therefore, this study is conducted to fill this gap by providing a more focused literature review on the TPACK competence of pre-service mathematics teachers in secondary schools.

This solution is expected to provide a clear picture of the training and professional development needs of pre-service mathematics teachers in the TPACK domain. The advantage of this solution is that by identifying existing trends and weaknesses, educational institutions and teacher training program developers can design more targeted and evidence-based interventions [3]. This study offers novelty by providing a more specific literature review on pre-service mathematics teachers in secondary schools, which has rarely been the focus of previous research [9].

Through this review, the main research questions will be explored: (1) Which journals have published scientific articles in this field? (2) How are pre-service mathematics teachers' TPACK in secondary schools? By answering these questions, this study is expected to provide significant contributions to the development of TPACK knowledge among pre-service mathematics teachers.

2 Method

This study used the "literature review" method. It aims to define all research related to the specified subject. In other words, the method is used to conduct detailed evaluations and interpretations by reaching various research sources related to the research question [11]. The literature review method is used to identify, review, evaluate, and interpret the available research with specific relevant research questions. Researchers collect journal articles from Scopus. The keywords used are "Preservice teacher" and "TPACK" and "Mathematics". The articles collected are only articles published in the period 2020 to 2024. From the various articles obtained, researchers selected 14 articles that were closely related to the keywords used. The next step, researchers grouped articles related to Preservice mathematics teachers' TPACK.

3 Result and Discussion

In line with the specified criteria, the 14 articles out of a total of 29 articles obtained from the Scopus database included in this literature review have been studied thoroughly to answer the research questions. Based on the results obtained, it shows that most of the scientific articles on TPACK of Pre-Service Mathematics Teachers in Secondary School have been published in reputable journals indexed in Scopus. Detailed information on the distribution of publications based on Scopus quartiles is presented in Table 1.

Table 1. Distribution of publications based on Scopus quartile

Indexation	Frequency	Percentage
Scopus Q1	5	35.7
Scopus Q2	3	21.4
Scopus Q3	4	28.6
Scopus Q4	2	14.3
Total	14	100

Based on Table 2, specifically, 35.7% of the articles were published in Scopus Q1 journals, indicating high-quality research. Meanwhile, 21.4% appeared in Scopus Q2 journals, 28.6% appeared in Scopus Q3 journals and another 14.3% in Scopus Q4 journals. This distribution highlights the significant presence of high-impact publications in the field. This might suggest that the field is vibrant and has a lot of research that is making a substantial impact, either by being widely cited, published in prestigious journals, or contributing significantly to advancing knowledge in that area.

Table 2. Presents the articles included in this study, illustrating the impact of TPACK.

No.	References	Journal	Impact
1.	Kohen, Z., Schwartz-Aviad, L., & Peleg, T. (2023) [3]	International Journal of Mathematical Education in Science and Technology	Positive
2.	Bwalya, A., & Rutegwa, M. (2023) [4]	EURASIA Journal of Mathematics, Science and Technology Education	Positive
3	Yildiz, E., & Arpaci, I. (2024) [5]	Education and Information Technologies	Positive
4	Araújo Filho, R., & Gitirana, V. (2022) [6]	Mathematics Enthusiast	Positive

No.	References	Journal	Impact
5	Ishartono, N., Halili, S. H. B., & Razak, R. B. A. (2023) [9]	International Journal of Information and Education Technology	Positive
6	Yanuarto, W. N., Maat, S. M., Setyanigsih, E., Isnawan, M. G., & Zakaria, M. I. (2023) [17]	Mathematics Teaching Research Journal	Positive
7	Uygun, T., Sendur, A., Dere, R., & Ozcakir, B. (2023) [16]	European Journal of Science and Mathematics Education	
8	Bonafini, F. C., & Lee, Y. (2021) [4]	New Educator	Positive
9	Backfisch, I., Sibley, L., Lachner, A., Kirchner, K. T., Hische, C., & Scheiter, K. (2024) [8]	Teaching and Teacher Education	Positive
10	Hernández-Rodríguez, O., González, G., & Villafañe-Cepeda, W. (2021) [4]	International Journal for Lesson & Learning Studies	Positive
11	Kesornprom, S., Peeyada, P., Cholamjiak, W., Ngamkhum, T., & Jun-on, N. (2023) [3]	Thai Journal of Mathematics	Positive
12	Casler-Failing, S. (2021) [9]	Research in Learning Technology	Positive
13	Aldemir Engin, R., Karakuş, D., & Niess, M. L. (2023) [1]	Education and Information Technologies	Positive
14	Hidayat, R., Zainuddin, Z., & Mazlan, N. H. (2024) [8]	Acta Psychologica	Positive

The literature on TPACK (Technological Pedagogical Content Knowledge) development among pre-service mathematics teachers reveals both converging themes and distinct approaches. These studies contribute to understanding how TPACK can be effectively developed and integrated into mathematics education.

Many studies emphasize the crucial role of integrating technology with pedagogy and content knowledge in developing TPACK. Some studies [12, 18] found that improvements in TPACK largely depend on effective technology integration with peda-

gogical and content components. Kohen et al. [12] highlighted improvements specifically in technology-focused areas, while Yildiz and Arpaci [18] pointed out factors like effort expectancy and social influence as predictors of technology use intentions in educational settings. These studies align in recognizing the importance of technological integration for enhancing mathematics education.

Additionally, studies by Bwalya and Rutegwa [5] and Uygun et al. [16] focus on TPACK self-efficacy and competencies. [4] found moderate self-efficacy among pre-service teachers, with technological knowledge (TK) being the weakest. Uygun et al. [16] showed that specific training, such as the use of Web 2.0 tools, improved TPACK competence, indicating the need for targeted interventions to strengthen technological integration skills.

Differences emerge in the specific contexts and variables studied. Kohen et al. [12] focus on technology integration in a mathematics lab setting, contrasting with Yildiz and Arpaci [18], who examine motivational factors influencing technology use. Bwalya and Rutegwa's study [5] also differs by investigating demographic influences like gender and year of study on TPACK self-efficacy, while Araújo Filho and Gitirana's study [2] emphasizes the developmental aspects of TPACK, focusing on how pedagogical and content knowledge intersect during early teacher training.

Several studies provide unique contributions to TPACK research. Ishartono et al. [9] offer a methodological perspective by identifying effective instruments for measuring TPACK, highlighting the Schmidt's TPACK questionnaire [15] as the most widely used tool. Kesornprom et al. [10] contribute by developing a predictive model for future TPACK levels, offering a strategic approach to enhancing teacher education programs over time.

Backfisch et al. [3] introduce utility-value interventions to support knowledge integration, providing a fresh perspective on enhancing TPACK by addressing the perceived value of its components. Similarly, Hidayat et al. suggest that TPACK components like TK and TCK are vital for discovery learning and multiple representations, emphasizing the need for more comprehensive educational frameworks to integrate these elements [8].

These studies collectively indicate that TPACK development is multifaceted, requiring diverse strategies and interventions. Common themes, such as integrating technology with pedagogy and content, underscore its significance in mathematics education. However, the differences in focus—ranging from specific educational contexts and demographic influences to psychological factors—reflect the need for a holistic approach to developing TPACK competencies.

Overall, while significant strides have been made in understanding TPACK development among pre-service mathematics teachers, a combination of targeted interventions, robust measurement tools, and innovative models is necessary. Future research should integrate these varied approaches to create more effective and sustainable teacher education programs, ultimately equipping future mathematics teachers with comprehensive TPACK skills.

4 Conclusion

The literature review indicates that developing Technological Pedagogical Content Knowledge (TPACK) among pre-service mathematics teachers is essential for effective mathematics education in secondary schools. The integration of technology with pedagogical and content knowledge enhances teaching practices and supports the learning process by making abstract mathematical concepts more accessible and engaging. Various studies highlight that targeted interventions, such as training in specific technological tools and strategies, significantly improve pre-service teachers' TPACK competencies. These findings suggest that comprehensive TPACK development programs could better prepare future educators to integrate technology effectively in their teaching practices, thus fostering more dynamic and effective mathematics instruction.

However, the review also identifies gaps in TPACK research and practice. While several studies provide insights into TPACK development through different methods and instruments, most focus on specific contexts or components, such as technological knowledge (TK) or pedagogical knowledge (PK), rather than a holistic approach. Moreover, there is limited research exploring TPACK integration across diverse educational settings and mathematical topics. Further studies could expand the scope by investigating comprehensive TPACK frameworks and strategies that cater to various teaching contexts and content areas, ultimately enhancing pre-service mathematics teachers' readiness to meet the demands of modern classrooms.

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