

## **GLOBAL INSIGHTS INTO TPACK: A SYSTEMATIC REVIEW OF DEMOGRAPHICS AND THEMATIC PATTERNS AMONG PRE-SERVICE BIOLOGY TEACHERS**

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### **ABSTRACT**

The study aims to analyze the demographic characteristics and trends related to assessment methods and research themes of TPACK among pre-service biology teachers from 2019 to 2024. This research employs a Systematic Literature Review (SLR). The identification and selection of articles follow the PRISMA protocol, utilizing academic databases such as Scopus and Web of Science. The search strategy incorporates relevant keywords and applies eight inclusion and exclusion criteria, resulting in the review of 23 articles. Data extraction is followed by thematic analysis. The finding reveals that the demographic characteristics of studies on TPACK among pre-service Biology teachers shows a variation within a global context with a concentration in Asia and Europe. The research identifies five major themes: (1) The effectiveness of TPACK-development courses in enhancing TPACK competencies (13%), (2) The role of reflection and self-assessment in TPACK development (22%), (3) The integration of TPACK into lesson planning and challenges in real-world application (39%), (4) The influence of cultural and geographical contexts on TPACK development (9%), and (5) The relationship between personal characteristics and successful TPACK development (17%). These findings provide insights into emerging trends and gaps in TPACK research among pre-service biology teachers.

**Keywords:** *Pre-service Biology Teachers, Systematic Literature Review, Thematic Trends, TPACK Development*

## **INTRODUCTION**

The advancement of technology in the 21st century has brought significant changes to various aspects of life, including in Biology education (Kapici & Akcay, 2023; Pondee et al., 2021). Students in the 21st century are highly dependent on technology, which is very different from previous generations, as their lives are surrounded by technology, and they can utilize the technology around them as a source of learning (Paidí et al., 2021; Purwianingsih et al., 2022). The implication of this development is the need for teachers to master technology, especially in creating interactive and innovative learning experiences (Botha & Herselman, 2018; Dewi et al., 2022; Durdu & Dag, 2017). Preparing professional biology teachers has become a research focus aimed at creating qualified teachers for biology education reform in both developing and developed countries (Rochintaniawati et al., 2019; Xie et al., 2017).

Research has shown that biology teachers in various countries still struggle to use technology, such as e-learning, efficiently in their teaching methods (Pondee et al., 2021; Tanak, 2020; von Kotzebue, 2022). The framework that emphasizes the importance of mastering technology, pedagogy, and content simultaneously in the context of learning is TPACK (Technological Pedagogical Content Knowledge) (Mishra et al., 2019). TPACK is a framework that helps teachers understand and integrate technology, pedagogy, and content effectively into the learning process (Shulman, 1986). This concept combines three core elements: Technological Knowledge (TK), which is the understanding of tools and digital technology; Pedagogical Knowledge (PK), which is the knowledge of teaching methods and strategies; and Content Knowledge (CK), which is the deep understanding of the material or content being taught (Loseñara & Jugar, 2023). TPACK emphasizes the importance of teachers integrating these three elements to create effective learning, where technology is used to support pedagogy and content harmoniously.

Mishra and Koehler (2006) described the components as technological pedagogical content knowledge. TPACK is a framework that shows the complex interaction between teachers' knowledge of technology, content, and pedagogy as indicators of their ability to integrate technology (Kabakci & Oklar, 2014) and to design technology-integrated pedagogy courses (Chai et al., 2013).

Based on the results of a systematic review analysis of previous studies, several gaps in the literature were identified. First, regarding the context and participants in the studies, the majority of research was conducted in a general context and not specific to any particular subject area (Bragg et al., 2021; Postholm, 2018; Basma & Savage, 2018; Bascopé et al., 2019; Philipsen et al., 2019; Gast et al., 2017). Although there are reviews related to Science Teacher Education in general (Setiawan et al., 2019; Fernandes et al., 2020; Chai et al., 2019), none have been specific to the Biology context alone. The majority of participants analyzed in the previous research reviews were teachers in general or biology teachers, with fewer studies focusing on biology teacher candidates at higher education institutions. Also, the trend of themes explored in the context of biology education research also needs to be examined. This can be used to recommend future research directions. The research question (RQ) in this systematic review study is that what are the demographic characteristics and trends related to the focus of research from 2019 to 2024?

## **METHODS**

This study employs a Systematic Literature Review (SLR) approach to identify, select, and analyze relevant literature. The article search and identification procedures in this study follow the protocols of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) developed by Moher et al. (2009). The search strategy was carried out using relevant keywords such as "TPACK," "Biology teacher education," "pre-service teacher," "Professional Development," and "pedagogical knowledge." These keywords were combined with Boolean operators (AND, OR) to broaden or narrow the search results. An example search query was: "TPACK OR technological pedagogical knowledge AND biology AND pre-service teacher" AND "Professional Development." The initial search results were downloaded and stored in a reference manager such as Mendeley to facilitate management and removal of duplicates.

Some inclusion and exclusion criteria were applied to ensure the quality and relevance of the studies included in the review including: (1) Publication Year: Studies published within the last 5 years, from 2019 to 2024. (2) Field of Study: The study must be in the field of Biology Education, excluding other subjects such as physics and chemistry. (3) Language of the Article: The article must be published in English. (4) Participants: Only prospective biology teachers were included, excluding experienced biology teachers or general teachers. (4) Databases: Scopus, Taylor, Elsevier, Science Direct, Wiley were used. Google Scholar was excluded. (5) Journals: Articles must be available in full-text and published in peer-reviewed journals.

Article Selection Procedure was conducted by screening the articles based on titles. Articles that are irrelevant or do not meet the inclusion criteria are excluded at this stage. Titles that do not align with the theme are excluded, totaling 400 articles, and duplicate articles are also removed, amounting to 154. In addition, 56 review articles were excluded. Secondly, Articles that pass the initial screening are then examined in full. The researcher reads the articles thoroughly to ensure they meet the inclusion criteria and are relevant to the research questions. The justification for inclusion and exclusion is as follows: the researcher reads the abstracts to quickly assess the relevance of the content. Based on this, 154 articles are excluded. Articles are limited to the past 5 years with the final number is 23 articles.

After the data are extracted, analysis is performed using a thematic analysis approach based on the types of data found. In thematic analysis, qualitative data are analyzed by identifying themes and subthemes emerging from the study findings. This process is conducted by identifying relevant patterns and relationships. The results of the analysis are presented in the form of tables and narratives, providing a comprehensive overview of the findings, main themes, and conclusions that can be drawn from the reviewed literature ensuring that the conclusions drawn from this review are supported by strong evidence from the existing literature.

## **RESULTS AND DISCUSSION**

The extracted data including Demographic characteristics and research themes is shown in Table 1.

**Table 1.** Demographic characteristics and Research Themes of the reviewed research

<i>Authors</i>	<i>Year</i>	<i>Country</i>	<i>Research Themes</i>
Aktaş, et al	2022	Turkey	Effectiveness of TPACK Course
Aumann, et al	2024	Germany	Integration of TPACK
Bwalya, et al	2023	Rwanda	Cultural Influence on TPACK
Dewi, et al	2022	Indonesia	Role of Reflection on TPACK
Irdalisa, et al	2020	Indonesia	Role of Reflection and Self-Assessment
Irmak, et al	2019	Turkey	Impact of Personal Characteristics on TPACK
Jiang, et al	2024	China	Integration of TPACK in Lesson Planning
Kapici, et al	2023	Turkey	Integration of TPACK in Lesson Planning
Loseñara et al	2023	Phillipines	Integration of TPACK in Lesson Planning
Max, et al	2022	Germany	Role of Reflection on TPACK
Mishra, et al	2019	USA	Integration of TPACK in Lesson Planning
Ocak, et al.	2019	Turki	Integration of TPACK in Lesson Planning
Pondee, et al.	2021	Thailand	Integration of TPACK in Lesson Planning
Purwianingsih et al.	2022	Indonesia	Integration of TPACK in Lesson Planning
Rolando, et al.	2021	Brazil	Cultural Influence on TPACK
Stinken et al.	2023	Germany	Impact of Personal Characteristics on TPACK
Subali, et al.	2021	Indonesia	Effectiveness of TPACK Course
Tafli, et al.	2021	Turkey	Impact of Personal Characteristics on TPACK
Tanak, et al.	2020	Thailand	Integration of TPACK in Lesson Planning
Valtonen, et al.	2020	Finland	Role of Reflection on TPACK
Von Kotzebue, et al.	2023	Austria	Impact of Personal Characteristics on TPACK
Welter, et al.	2022	Germany	Role of Reflection on TPACK
Wollmann et al.	2022	Germany	Effectiveness of TPACK Course

### **Demographic Characteristics of the Research**

Demographic characteristics, such as the countries in which the research has been conducted, need to be examined to understand where studies have been conducted, as well as the impact of cultural or geographical factors on TPACK. It is also important to analyze trends based on years to determine whether the number of studies has increased or decreased, to guide future research. Table 1 shows the demographic characteristics of the 25 articles reviewed in this study. Firstly, regarding the country of origin, the articles cover research from various countries, with a concentration in Asia and Europe. Studies from Asia include countries such as Turkey (Aktaş & Özmen, 2020; Irmak & Yilmaz Tüzün, 2019), Indonesia (Dewi et al., 2022; Purwianingsih et al., 2022), China (Jiang et al., 2024), and Thailand (Pondee et al., 2021). In Europe, most studies are from Germany (Aumann et al., 2024), Austria (von Kotzebue, 2022, 2023), and Finland (Valtonen et al., 2020). A smaller proportion of studies are from Africa (Bwalya et al., 2023), Latin America (Rolando et al., 2021 in Brazil), and the USA (Mishra et al., 2019). This geographical diversity reflects the varied cultural contexts of TPACK research among pre-service Biology teachers.

Secondly, according to publication year, the articles collected from 2019 to 2024, with a significant increase in the number of studies after 2020. The year 2022 shows the highest number of publications, indicating a growing focus on TPACK development post-COVID-19 pandemic, where the integration of technology in education became even more relevant and increased in significance.

### **Trends in TPACK Research of Pre-service Biology Teachers**

The research themes were explored in previous studies to identify which themes have been extensively researched and which have been less explored, in order to recommend areas for future studies. Based on Table 1, five main themes were identified: (1) The Effectiveness of TPACK-Development Courses in Enhancing Technology and Pedagogical Competence (3 studies), (2) The Role of Reflection and Self-Assessment in TPACK Development (5 studies), (3) The Integration of TPACK in Lesson Plans and Challenges in Real-World Implementation (9 studies), (4) The Influence of Culture and Geographical Context on TPACK Development (2 studies), and (5) The Relationship Between Personal Characteristics and Success in TPACK Development (4 studies). These five main themes show that the development of TPACK among pre-service biology teachers is influenced by a combination of well-designed training, objective assessment methods, adjustments to local contexts, and supporting personal characteristics. These findings highlight the importance of a multi-dimensional approach in developing TPACK among pre-service teachers, as well as the need for curriculum and teaching methods to be adapted to local technological and cultural conditions.

The first theme explored in the reviewed research is effectiveness of TPACK-Development Courses in Enhancing Technology and Pedagogical Competence. Most studies indicate that TPACK development courses are effective in improving pre-service biology teachers' technology and pedagogical competencies. Research by Aktaş & Özmen (2022) and Bwalya et al. (2023) found that TPACK-based courses help pre-service teachers master relevant technologies for science teaching, such as digital platforms for simulations and presenting material. However, limited technological resources in some regions, such as Africa and Indonesia, pose challenges in full implementation. This suggests that the effectiveness of TPACK courses is also influenced by the availability of technological infrastructure.

The second theme explored in the reviewed research is the role of reflection and self-assessment in tpack development. Studies by Max et al. (2022) and Stinken-Rösner et al. (2023) show that self-reflection helps pre-service teachers become aware of their strengths and weaknesses in applying TPACK. While this method is effective in building self-awareness, some studies (von Kotzebue, 2023; Welter et al., 2022) reveal that self-assessment is often inaccurate, as pre-service teachers tend to rate their abilities higher than they actually are. Therefore, self-assessment should be complemented with external assessment methods, such as observations or performance analysis. The third theme explored in the reviewed research is the integration of TPACK in lesson plans and challenges in real-world implementation. Studies involving lesson plan analysis, such as by Kapici & Akcay (2023) and Dewi et al. (2022), show that integrating TPACK enables pre-service teachers to develop more interactive, student-centered lesson plans. However, in real-world applications,

pre-service teachers often face challenges such as time constraints and limited access to technological tools.

The fourth theme explored in the reviewed research is the influence of culture and geographical context on TPACK development. Studies by Rolando et al. (2021) in Brazil and Pondee et al. (2021) in Thailand found that collaborative cultures in these countries encouraged pre-service teachers to be more open to using technology as a teaching tool. However, in countries with technological limitations or conservative educational cultures, such as Turkey and some regions of Indonesia (Irdalisa & Djukri, 2020; Purwianingsih et al., 2022), the adoption of TPACK faces significant challenges. This context suggests that TPACK-based teaching approaches need to be adapted to local conditions to enhance their effectiveness.

The last theme explored in the reviewed research is the relationship between personal characteristics and success in TPACK development. Several studies have examined the relationship between personal characteristics of pre-service teachers, such as self-confidence, perseverance, and motivation, and their success in developing TPACK. For example, research by Welter et al. (2022) and von Kotzebue (2022) found that pre-service teachers with higher self-confidence were more successful in applying technology in teaching. However, these studies also noted that personal characteristics alone are not sufficient, but support from the educational environment, such as access to ongoing training, are also crucial.

## **CONCLUSION**

The aim of this research is to analyze the demographic characteristics and research themes in the reviewed studies of TPACK among pre-service biology teachers. Firstly, according to Demographic characteristics, the articles cover research from various countries, with a concentration in Asia and Europe. Then, according to publication year, the articles have a significant increase in the number of studies after 2020. The year 2022 shows the highest number of publications, indicating a growing focus on TPACK development post-COVID-19 pandemic, where the integration of technology in education became even more relevant and increased in significance. Secondly, the research identifies five major themes: (1) The effectiveness of TPACK-development courses in enhancing TPACK competencies (13%), (2) The role of reflection and self-assessment in TPACK development (22%), (3) The integration of TPACK into lesson planning and challenges in real-world application (39%), (4) The influence of cultural and geographical contexts on TPACK development (9%), and (5) The relationship between personal characteristics and successful TPACK development (17%). The theme most frequently studied is the integration of TPACK in lesson plans and challenges in real-world implementation, while the least explored theme is the influence of culture and geographical context on TPACK development. These findings provide insights into gaps for future research.

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