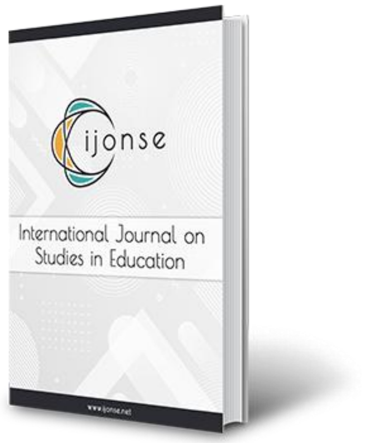

www.ijonse.net

Promoting Technological Pedagogical Content Knowledge (TPACK) in Preservice Science Teacher Education: A Scoping Review of Instructional Strategies, Interventions, and Programs

Ronilo P. Antonio
Bulacan State University, Philippines

To cite this article:

Antonio, R.P. (2025). Promoting technological pedagogical content knowledge (TPACK) in preservice science teacher education: A scoping review of instructional strategies, interventions, and programs. *International Journal on Studies in Education (IJonSE), 7*(1), 157-171. https://doi.org/10.46328/ijonse.302

International Journal on Studies in Education

2025, Vol. 7, No. 1, 157-171 https://doi.org/10.46328/ijonse.302

Promoting Technological Pedagogical Content Knowledge (TPACK) in Preservice Science Teacher Education: A Scoping Review of Instructional Strategies, Interventions, and Programs

Ronilo P. Antonio

Article Info

Article History

Received:
15 September 2024
Accepted:
25 December 2024

Keywords

Preservice science teachers
TPACK
Technology integration
Scoping review

Abstract

Preservice science teacher education is critical for producing competent educators in the 21st century. Consequently, several efforts have been undertaken to enhance preservice science teachers' (PSSTs) technological pedagogical content knowledge (TPACK). In this study, a scoping review, specifically using a meta-synthesis approach aided by the PRISMA and ENTREQ protocol, was employed to critically synthesize previously conducted studies on the effects of various instructional strategies, interventions, or programs (ISIPs) aimed at enhancing PSSTs' TPACK. A systematic literature search of studies published between 2017 and 2022 in four meta-search engines was conducted. Thirteen studies that met the inclusion criteria were analyzed in this study. The results showed that these studies employed diverse ISIPs to facilitate the development of PSSTs' TPACK. These interventions included course-based programs and activities integrated into the PSSTs' curriculum. Among these ISIPs, various activities such as theoretical training, practical training, lesson planning, collaboration, and feedback were employed. The nature of these interventions, which emphasized authentic, experiential learning opportunities and a supportive learning environment, facilitated significant improvements in PSSTs' TPACK. All studies demonstrated favorable outcomes, indicating the effectiveness of the ISIPs in enhancing PSSTs' TPACK across different dimensions of the framework. However, several challenges were encountered by the PSSTs, including issues related to access and availability of technology, digital literacy and experience, time constraints and management, resource scarcity, resistance to change and mindset, interaction and support, self-regulated learning, and subject-specific challenges. The results of the study suggest the importance of providing varied teacher preparation experiential learning experiences and the need to address the aforementioned challenges to better optimize the effectiveness of the ISIPs, sustain PSSTs' engagement, and assist them in their TPACK development.

Introduction

The global pandemic has posed unprecedented challenges to science education, pushing educators to provide high-quality instruction with the primary objective of nurturing students' scientific literacy. This challenge underscores the need for teacher education institutions to produce competent teachers capable of leveraging innovative and adaptive teaching strategies that cater to the dynamic educational landscape. However, research suggests that proficiency in content mastery and pedagogical delivery alone may not suffice. In response, educators have turned to the potential of technology integration to enhance teaching and learning practices.

Technological Pedagogical Content Knowledge (TPACK) has been increasingly recognized as a promising framework that can guide educators towards effective and innovative teaching. This framework emphasizes the integration of technology, pedagogy, and content knowledge (Mishra & Koehler, 2006). Content knowledge focuses on the understanding of the key concepts, principles, and theories of the subject they teach. Meanwhile, pedagogical knowledge pertains to the grasp of teaching processes and practices, including instructional strategies, assessment techniques, and classroom management. Finally, technological knowledge centers on the technologies that teachers use in their teaching practice, such as how to troubleshoot technical issues and how to integrate digital tools and other technologies into their lessons. Effective technology integration occurs when these elements are blended to significantly improve lesson delivery.

In recent years, extensive research has highlighted the significance of TPACK in enhancing the professional development of in-service science teachers. Hsu *et al*., (2015) introduced the TPACK-P framework, specifically designed to guide the practical development of science teachers' TPACK in classroom settings. Syukri *et al.,* (2020) conducted a systematic literature review to create the TPACK-STEM scale, a tool for assessing science teachers' TPACK in STEM-related contexts. Various professional development programs have also been implemented to strengthen teachers' TPACK. For example, Chatmaneerungcharoen (2019) designed an innovative continuing professional development program for Thai science teachers, while Abrencillo (2019) introduced an enhancement training program for science teachers in the Philippines. More recently, Sothayapetch and Lavonen (2022) examined the development of primary science teachers' TPACK during the COVID-19 pandemic in Thailand and Finland. Similarly, Mohamad (2021) investigated factors influencing professional development for science teachers aimed at improving their TPACK. Workshops focusing on TPACK integration in Education for Sustainable Development (ESD) have further demonstrated their potential to advance science teachers' technological and pedagogical skills, aligning with broader educational objectives (Saraswati *et al.*, 2023). Additionally, professional development interventions, particularly TPACK-based argumentation practices, have consistently been shown to increase teachers' TPACK self-efficacy, a critical factor for the effective integration of technology into classroom instruction (Joshi, 2023).

Despite the significant attention given to TPACK in-service science teacher professional development, there has been limited research on TPACK involving preservice science teachers (PSSTs). Aktaş and Özmen (2020, 2022) investigated the impact of TPACK development courses on PSSTs' performance, while Danday (2019) compared the effects of active and passive microteaching lesson study on PSSTs' TPACK development. Studies suggest that TPACK courses have a positive effect on preservice teachers' TPACK development. In spite of these, literature showed that there is a lack of integration of TPACK into preservice teacher education programs, as teacher educators themselves have limited opportunities to develop their integrated TPACK. Many preservice teachers also feel unprepared to use technology in the classroom, indicating a need for investment in developing the TPACK of teacher educators (Tondeur *et al*., 2017). Therefore, a review of existing literature is essential to determine effective strategies, interventions, and programs (ISIPs) that have been successful in developing PSSTs' TPACK, including the activities in which they engage. This study provides substantial information for science teacher education programs that are critical for developing competent science teachers in the future. The major aim of the research was to review existing studies on PSSTs' TPACK. Particularly, the study aimed to seek answers to the following questions:

1. What instructional strategies, interventions, or programs have been utilized to enhance preservice science teachers' technological pedagogical content knowledge?
2. What were the outcomes of the instructional strategies, interventions, or programs implemented to enhance preservice science teachers' technological pedagogical content knowledge?
3. What specific activities have preservice science teachers engaged in to improve their technological pedagogical content knowledge?
4. How can the instructional strategies, interventions, or programs be characterized based on the number of activities employed to enhance preservice science teachers' technological pedagogical content knowledge?

Method

Research Design

This study utilized a scoping review methodology in analyzing scholarly literature that focused on PSSTs' TPACK development. A scoping review methodology was deemed appropriate for this study due to its ability to comprehensively map existing evidence on the development of PSSTs' TPACK. The research aimed to address multiple broad and exploratory questions regarding instructional strategies, interventions, and activities that enhance PSSTs' TPACK, as well as the outcomes of these efforts. Scoping reviews are particularly suited for such inquiries because they allow researchers to examine the extent, nature, and range of available evidence without the strict inclusion and exclusion criteria of systematic reviews (Arksey & O'Malley, 2005; Munn *et al*., 2018).

Literature Search Procedures

The selection of relevant studies was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher *et al*., 2009). To locate research articles, multiple meta-search engines, such as Google Scholar, SCOPUS, CrossRef, and Semantic Scholar were employed. Additionally, a manual search was conducted to exhaust the literature and to reduce bias by manually searching for potential research articles that may have been missed in the initial search (Vassar *et al*., 2016).

Empirical studies published between January 2017 and 2022 were purposively searched by the researcher. Harzing's Publish or Perish (PoP) software was used to aid in the literature search. Furthermore, the keywords *TPACK, preservice science teachers, effects, strategies, interventions, and programs* were strategically entered into the meta-search engines, with some adjustments to account for specific retrieval sources.

As shown in Figure 1, the initial literature search through the various meta-search engines returned 2,326 research articles from 2017 to 2022. A data cleanup tool removed 164 duplicates, but due to differences in formatting, it failed to identify other duplicates, resulting in the need for manual checking and removal (n=118). After screening the abstracts, only 42 articles were deemed eligible for further evaluation based on the inclusion and exclusion criteria.

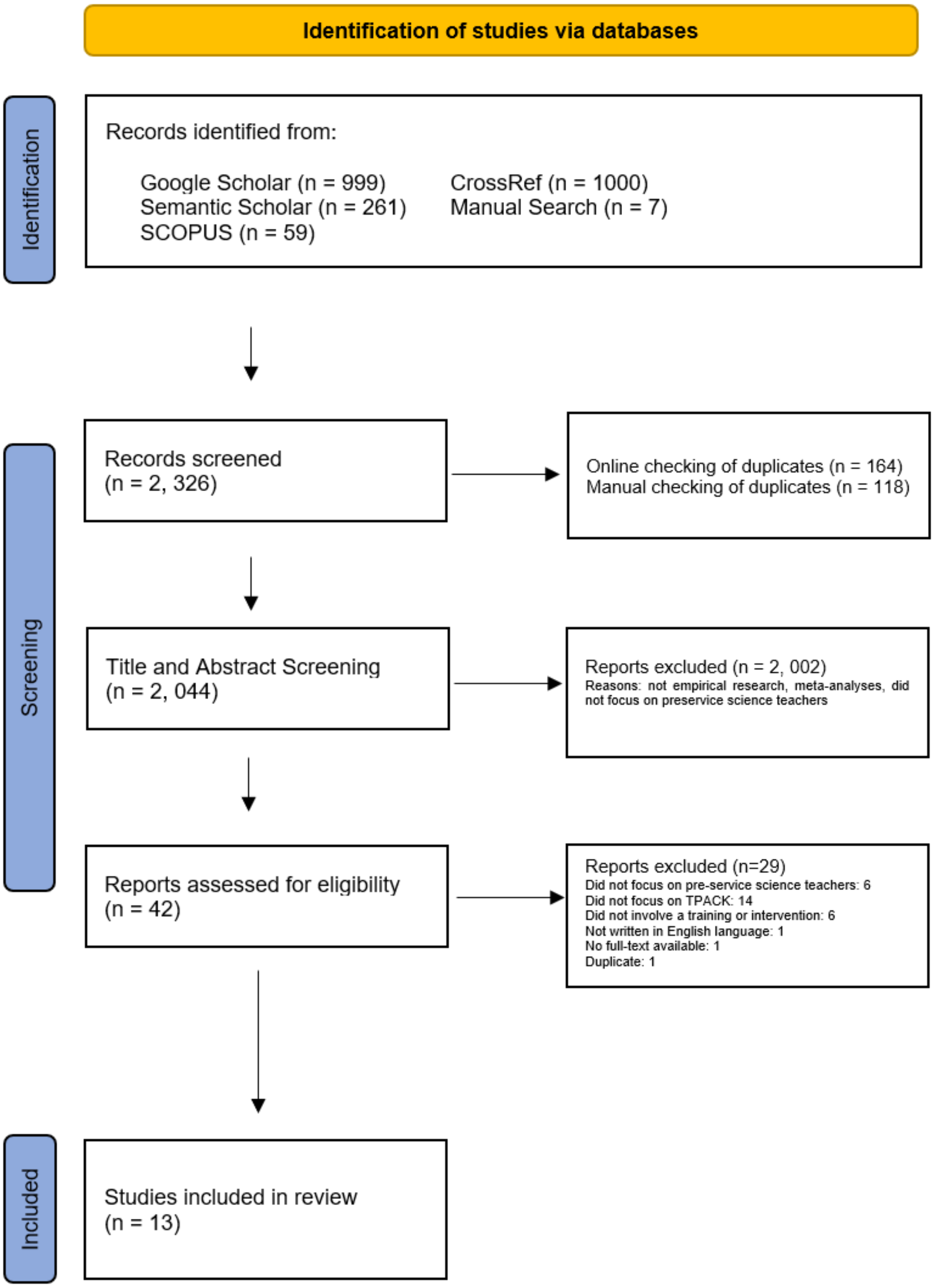

Figure 1. Flow diagram of the literature search using PRISMA protocol

Inclusion and Exclusion Criteria

The analysis of research articles for this study were conducted purposefully, focusing only on articles relevant to the scope. The inclusion criteria for article selection were established by the researcher, and for an article to qualify for inclusion in the scoping review, it had to meet the following criteria:

- published research article within the period of 2017 to 2022;
- involvement of PSSTs' as research participants;
- utilization of an experimental, quasi-experimental, or mixed-method research design;
- implementation of an instructional strategy, intervention, or program that involved PSSTs, and;
- technological pedagogical content knowledge (TPACK) as the dependent (outcome) variable.

Out of the 174 research articles initially screened, 154 studies were excluded for the following reasons: six (6) studies did not involve PSSTs, fourteen (14) studies did not focus on TPACK, six (6) studies did not involve any form of training or intervention, one (1) study was not written in the English language, one (1) study had no full-text available, and one (1) study was found to be a duplicate. Consequently, twelve research articles were included and analyzed in the study.

Coding Procedures

The research articles were analyzed and coded to identify relevant information, including the author/s, publication year, country of implementation, research design, instructional strategies, interventions, and programs employed, duration, and number of participants.

Data Analysis

In reviewing the included studies, descriptive statistics were utilized, with a focus on the features such as the country of implementation, research design, instructional strategies, interventions, and programs employed, as well as the duration and number of participants. Furthermore, the specific activities that PSSTs have participated in to enhance their TPACK and the percentage of such activities across the included studies were also determined and described using frequency and percentage measures.

Results

General Study Characteristics

Table 1 provides an overview of the studies included in this scoping review, detailing the author/s and year of publication, country of implementation, research design, ISIPs employed, as well as the duration and number of participants. The studies collectively involved a total of 427 PSSTs who were exposed to different ISIPs aiming to enhance their TPACK.

To provide an overview of the geographic distribution, these studies were conducted in several countries, including Chile, India, Indonesia, the Philippines, Taiwan, Thailand, and Turkey. Among these countries, Turkey accounted for the largest proportion of studies, representing 38% of the total, while Indonesia accounted for 23%, and the remaining 8% were conducted in Chile, India, the Philippines, Taiwan, and Thailand. The reason for the high number of studies conducted in Turkey may be due to the priority given to TPACK development among preservice teachers in the country. This can be attributed to several policies and regulations implemented that promote the integration of technology in education and the development of TPACK among in-service and preservice teachers (Farhadi, S., & Öztürk, 2023).

In terms of research design, 56% of the included studies in the present review used a mixed-method or quantitative approach, while only 8% utilized a qualitative approach. The prevalence of mixed-method and quantitative studies provided more comprehensive data regarding the development of TPACK among PSSTs. These studies used various research instruments such as self-report measures and lesson plan scoring rubrics to collect quantitative data, while interviews and journal reflections were used to gather qualitative data. The combination of both quantitative and qualitative data allowed for a more thorough examination of the effectiveness of the ISIPs implemented to improve the TPACK of PSSTs.

Table 1. Descriptive Features of the Included Studies

No.	Author/s and Year of Publication	Country	Research Design	Instructional Strategies, Interventions and/or Programs (ISIPs)	Duration	Number of Participants
1	Aktaş & Özmen (2022).	Turkey	quantitative approach	TPACK Practical Course	12 weeks	46 preservice science teachers
2	Aktaş and Özmen (2020)	Turkey	mixed-method approach	TPACK Development Course	24 weeks	6 preservice science teachers
3	Ansari et al., (2019)	India	quantitative approach	5Es Inquiry-based Lesson Plan Activities	3 weeks	26 preservice science teachers
4	Cetin-Dindar et al., (2018)	Turkey	mixed-method approach	Instructional Technology and Material Development Course	14 weeks	17 preservice chemistry teachers
5	Cheng et al., (2022)	Taiwan	quantitative approach	DECODE Model	3 weeks	60 preservice science teachers
6	Danday (2019)	Philippines	mixed-method approach	Microteaching Lesson Study	5 weeks	18 preservice Physics teachers
7	Dewi et al., (2020)	Indonesia	quantitative approach	Project-Based Scaffolding TPACK Model	not specified	4 classes of preservice science teachers

No.	Author/s and Year of Publication	Country	Research Design	Instructional Strategies, Interventions and/or Programs (ISIPs)	Duration	Number of Participants
8	Nugraheni & Srisawasdi (2022)	Indonesia	quantitative approach	Case-based Learning Intervention	not specified	32 preservice science teachers
9	Özdilek & Robeck (2018)	Turkey	mixed-method approach	Case-based Lesson Planning	21 weeks	21 preservice chemistry teachers
10	Rodríguez-Becerra et al., (2020)	Chile	qualitative approach	Educational Computational Chemistry Modules	one academic year (approximately 9 months	22 preservice chemistry teachers
11	Srisawasdi et al., (2018)	Thailand	quantitative approach	Technology-integrated Pedagogy Module - Mobile Laboratory Learning in Science	4 weeks	119 preservice science teachers
12	Widyasari et al., (2022)	Indonesia	mixed-method approach	Subject-specific Pedagogy through Flipped Learning	1 week	34 preservice chemistry teachers

The studies included in this review utilized various ISIPs to enhance PSSTs' TPACK. These interventions include the 5Es Inquiry-based Lesson Plan Activities, Case-based Learning Intervention, Case-based Lesson Planning, DECODE Model, Educational Computational Chemistry Modules, Instructional Technology and Material Development Course, Microteaching Lesson Study, Project-Based Scaffolding TPACK Model, Subject-specific Pedagogy through Flipped Learning, Technology-enhanced Science Teaching Method Course, Technology-integrated Pedagogy Module - Mobile Laboratory Learning in Science, TPACK Development Course, and TPACK Practical Course. These interventions can be classified into two categories: course-based interventions and instructional activities.

The included ISIPs in the review had varying lengths, ranging from one week to 12 weeks, 24 weeks, and even up to one academic year or approximately 9 months. A potential reason of the longer duration of the intervention is that the TPACK development takes time to develop (Özgün-Koca *et al.*, 2011). The number of participants in the included studies varied significantly, with the smallest study involving only six PSSTs (Aktaş & Özmen, 2020) and the largest study involving 119 PSSTs (Srisawasdi *et al.*, 2018). Several studies focused on specific specializations, such as Chemistry, like the ones conducted by Cetin-Dindar *et al.*, (2018), Özdilek & Robeck (2018), Rodríguez-Becerra *et al*,. (2020), Widyasari *et al*., (2022), and Physics, like the study by Danday (2019) in the Philippines. In total, the studies involved a considerable number of PSSTs, although the exact number is not specified for the study conducted by Dewi *et al.*, (2020).

Effects of the Instructional Strategies, Interventions, or Programs Employed by the Included Studies

Table 2 presents the effects of the various instructional strategies, interventions, or programs used to cultivate TPACK among PSSTs. As reflected in the table, all of the studies showed favorable outcomes, indicating the effectiveness of these strategies in fostering the development of TPACK in various dimensions. The interventions aided in enhancing preservice teachers' technological, pedagogical, and content knowledge and their capacity to integrate these three key components while designing technology-enhanced science lessons. Notably, some studies that employed quasi-experimental research designs revealed that PSSTs exposed to the TPACK-based interventions had significantly higher improvements in their TPACK than those in the control group. For example, in the study of Danday (2019), results demonstrated that active microteaching lesson study (MLS) had a more positive influence on the overall TPACK and certain components of PSSTs compared to passive MLS. Similarly, Dewi *et al*., (2020) found that preservice teachers showed significant improvements in both their learning design ability and TPACK after being exposed to the Project-Based Scaffolding TPACK Model when compared to the control group.

Table 2. Effects of the Instructional Strategies, Interventions, or Programs Employed by the Included Studies

No.	**Author/s and Year of Publication**	**Instructional Strategy/ Intervention/Program**	**Effects on Preservice Teachers' TPACK**
1	Aktaş & Özmen (2022)	TPACK Practical Course	• Enhanced the TPACK application skills on PSSTs
2	Aktaş and Özmen (2020)	TPACK Development Course	• Had a positive impact on PSTs' Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK • Facilitated the use of information and communication technology (ICT) tools by PSTs, enabling them to acquire the knowledge necessary to select appropriate teaching methods using technology, teach the subject matter effectively, encourage student engagement, manage the classroom effectively, and provide appropriate guidance when teaching science subjects with ICT tools
3	Ansari et al., (2019)	5Es Inquiry-based Lesson Plan Activities	• Effective in enhancing the TPACK construct of PSSTs
4	Cetin-Dindar et al., (2018)	Instructional Technology and Material Development Course	• Highly effective in enhancing the technological pedagogical content knowledge of PSSTs
5	Cheng et al., (2022)	DECODE Model	• Offers a comprehensive approach to enhance the technological pedagogical and content knowledge of PSSTs • Assists PSSTs in creating courses that incorporate educational technology

No.	Author/s and Year of Publication	Instructional Strategy/ Intervention/Program	Effects on Preservice Teachers' TPACK
6	Danday (2019)	Microteaching Lesson Study	• Active Microteaching Lesson Study (Active MLS) had a greater positive impact on the overall TPCK and certain components of PSSTs compared to the Passive MLS.
7	Dewi et al., (2020)	Project-Based Scaffolding TPACK Model	• Demonstrated a significant improvement in both their learning design ability and TPACK when compared to the control group • Positive correlation between TPACK and learning design ability
8	Nugraheni & Srisawasdi (2022)	Case-based Learning Intervention	• Enhanced the TPACK self-efficacy of chemistry competencies among PSSTs
0	Özdilek & Robeck (2018)	Case-based Lesson Planning	• Assisted PSSTs in enhancing their content knowledge (CK), technological knowledge (TK), pedagogical knowledge (PK), and TPACK knowledge
10	Rodríguez-Becerra et al., (2020)	Educational Computational Chemistry Modules	• Effectively enhance the technological pedagogical science knowledge of PSSTs • Has significant potential to support PSSTs in their instruction of chemistry and pedagogy
11	Srisawasdi et al., (2018)	Technology-integrated Pedagogy Module - Mobile Laboratory Learning in Science	• Exhibited an improved level of all the dimensions of the TPACK focusing on mobile laboratory learning in science after engaging with the MLLS
12	Widyasari et al., (2022)	Subject-specific Pedagogy through Flipped Learning	• Had a significant impact on the PSSTs' TPACK

However, there were challenges encountered by PSSTs in developing their TPACK competencies, which can be categorized into several interconnected themes. In the reviewed studies, access and availability of technology were found to pose significant barriers, with limited internet connectivity, hardware access, and technical difficulties hindering PSSTs' participation (e.g., Rodríguez-Becerra *et al.,* 2020). Coupled with this is the issue of digital literacy, as many preservice teachers lack prior experience with advanced technological tools and software necessary for effective teaching. Time constraints further exacerbate these challenges, as busy schedules and insufficient hands-on practice time limit opportunities for meaningful engagement with technology. Resource-related difficulties, such as inadequate guidance from mentors and the struggle to find appropriate materials, add another layer of complexity (e.g., Cetin-Dindar *et al.,* (2018).

Moreover, resistance to change and reluctance to integrate technology into classroom practice reflect a mindset barrier that impedes progress. The online nature of many programs also creates communication and interaction challenges, leading to difficulties with self-regulated learning and accountability (e.g., Widyasari *et al*., 2022). Finally, subject-specific application remains a persistent issue, as preservice teachers struggle to integrate TPACK into pedagogical strategies for teaching complex scientific concepts (e.g., Widyasari *et al*., 2022). Addressing these challenges holistically is essential for improving the effectiveness of TPACK development programs and ensuring PSSTs are equipped for technology-integrated teaching.

Specific Activities that Preservice Science Teachers Have Participated in to Improve their Technological Pedagogical Content Knowledge

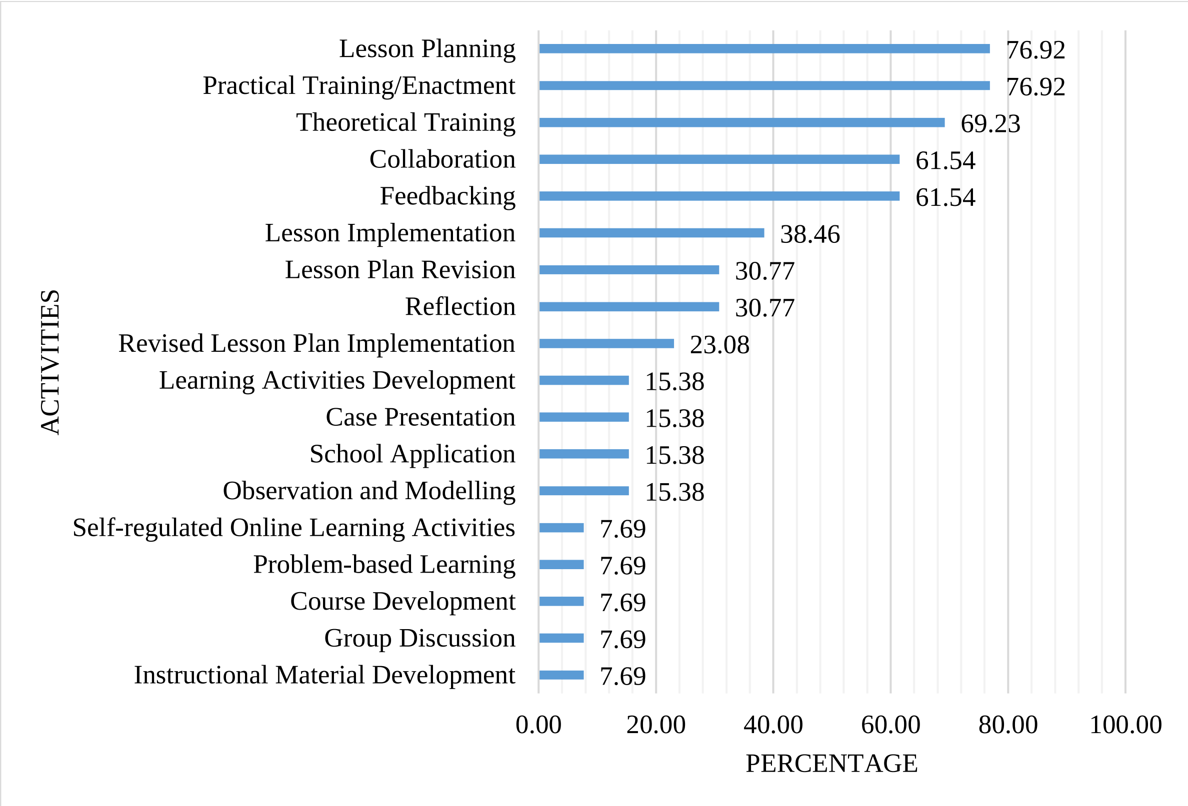

Figure 2. Specific Activities that Preservice Science Teachers Have Participated in to Improve Their Technological Pedagogical Content Knowledge

The specific activities that PSSTs participated in within the various instructional strategies, interventions, or programs employed in the studies were thoroughly examined by the researcher. Figure 2 illustrates the percentage of these activities that were evident across the included studies, providing valuable information on the effective components of the interventions or programs in enhancing TPACK.

Lesson planning and practical training comprised the largest percentage at 76.92%, followed by theoretical training at 69.23% and collaboration and feedback at 61.54%. Garnering the highest percentage, lesson planning and practical training activities provided authentic and experiential learning experiences for preservice teachers. Lesson planning enabled them to make use of their knowledge of technology, pedagogy, and content to design science lessons that actively engage students in meaningful learning. Practical training offered hands-on opportunities for students to utilize various digital tools and technologies to enhance teaching and learning, such as using simulations for scientific inquiry.

Theoretical training was also widely used, providing PSSTs with a theoretical understanding of TPACK and instructional strategies, emphasizing the importance of TPACK in 21st century learning. Collaboration and feedback opportunities were also prominent in the studies, allowing preservice teachers to work collaboratively with peers and receive feedback and suggestions to improve their lesson plans. The authentic, experiential, conceptual, collaborative, and feedback-oriented nature of these interventions seemed to have facilitated significant improvements in PSSTs' TPACK.

A limited number of the interventions incorporated various activities such as lesson implementation (38.46%), lesson plan revision (30.77%), reflection activities (30.77%), and revised lesson plan execution (23.08%). This suggests that a significant proportion of the studies did not only focus on the development of lesson plans for PSSTs but also provided opportunities for them to implement and refine their lessons through microteaching. For instance, Aktaş & Özmen (2022) not only required PSSTs to create TPACK-based lesson plans but also tasked them with presenting their plans to their classmates through video-recorded microteaching. The subsequent group discussion and feedback provided important inputs for the refinement and future execution of the lesson plan.

Moreover, few studies incorporated learning activity development, case presentation, school application, and observation and modeling, accounting for 15.38%. School application allowed preservice teachers to apply their lessons in actual classroom settings, providing a more authentic and practical experience (Aktaş & Özmen, 2020; Özdilek & Robeck, 2018). For example, Özdilek and Robeck (2018) provided opportunities for preservice teachers to plan, revise, and teach chemistry lessons during their field practice in secondary schools. Case presentations were also utilized in some studies. For instance, Dewi *et al.*, (2020) provided theoretical training on the TPACK framework using a case study model. Nugraheni and Srisawasdi (2022) presented research cases addressing the difficulties of chemistry learning in the chemistry laboratory using 360-degree video. In the same study, modeling was also included in the intervention, where PSSTs could observe the best practices from senior teachers in preparing TPACK-based lesson plans and revise the learning tools. Srisawasdi *et al.*, (2018) demonstrated a mini-lesson using mobile-based learning as an inquiry tool and presented pedagogic cases using sensor-based mobile-based learning to PSSTs. Furthermore, other studies incorporated self-regulated online learning activities, problem-based learning, course development, instructional material development, and group discussion. Overall, these activities appeared to further enhance the development of TPACK among PSSTs, providing them with more diverse and practical experiences.

To shed light on the intensity of the interventions or programs, the percentage of activities that PSSTs engaged in for each instructional strategy was identified. As shown in Figure 3, course-based interventions had the highest percentage of activities. Among them, the technology-enhanced science teaching method course and TPACK development course had the highest percentage of activities, accounting for 69.23%. The case-based lesson planning and TPACK practical course had a slightly lower percentage of 61.54%, followed by the microteaching lesson study and instructional technology and material development course with 46.15%.

Percentage of the Activities That the Preservice Science Teachers Engaged in Various Instructional Strategies, Interventions, or Programs

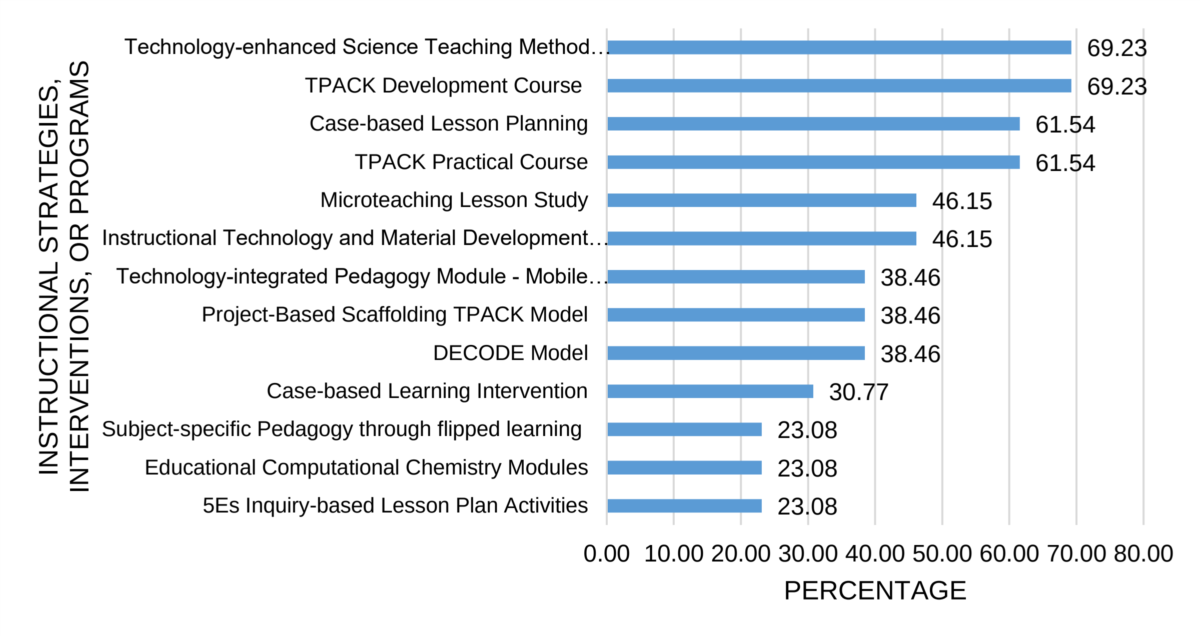

Figure 3. Percentage of the Activities That the Preservice Science Teachers Engaged in Various Instructional Strategies, Interventions, or Programs

Given the longer duration of course-based interventions, it is crucial to provide diverse learning experiences for PSSTs to maintain their engagement and facilitate their TPACK development. Specifically, the science teaching method course was designed to integrate experiences that relate to science teaching and learning with technology.

Conclusion and Recommendations

Upon critical examination of the included studies, it was revealed that various instructional strategies, interventions, and programs were utilized to improve PSSTs' TPACK. These interventions included course-based programs and activities, integrated into the curriculum of PSSTs'. The studies employed activities such as lesson planning, practical and theoretical training, collaboration, and feedback to enhance PSSTs' TPACK. The nature of these interventions, which emphasized authenticity, experiential learning, and a supporting learning environment, facilitated significant improvements in PSSTs' TPACK. All studies yielded favorable outcomes, indicating the effectiveness of these strategies in developing TPACK in different dimensions and enhancing PSSTs' technological, pedagogical, and content knowledge. The study highlights the significance of providing diverse learning experiences to PSSTs to sustain their engagement and facilitate their TPACK development. To sum up, the findings of this review indicate a growing recognition of the crucial role of TPACK in education and preparation of prospective science teachers.

However, the study has some limitations. First, it only included the studies that focused on PSSTs' TPACK. Future studies may explore other instructional strategies, interventions, or programs employed in other disciplines.

Additionally, specific digital tools or technologies that PSSTs were exposed to may also be examined. Further studies may conduct meta-analyses comparing the TPACK development of control and experimental groups. Nevertheless, the study provides valuable information for designing and implementing programs and interventions to capacitate PSSTs with relevant technological and pedagogical content knowledge. TPACK-focused interventions may also be developed and examined in terms of their effectiveness in developing other critical skills among PSSTs, such as self-efficacy in science teaching and reflective thinking skills.

References

**Studies included in the review*

Abrencillo, E. R. (2019). Enriching The Technological Pedagogical Content Knowledge (TPACK) of Science Teachers Through An Enhancement Training Program. *Luzy Saber*, *13*(3), 1-1.

*Aktaş, İ., & Özmen, H. (2022). Assessing the performance of Turkish science pre-service teachers in a TPACK-practical course. *Education and Information Technologies, 27*(3), 3495-3528.

*Aktaş, İ., & Özmen, H. (2020). Investigating the impact of TPACK development course on pre-service science teachers' performances. *Asia Pacific Education Review, 21(*4), 667-682.

*Ansari, I. (2019). The 5Es inquiry-based Lesson plan activities and the Preservice Science Teachers' Technological Pedagogical Content Knowledge (TPACK) Development. J. Res. Method Educ, 9, 58-64

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International journal of social research methodology*, *8*(1), 19-32.

*Cetin-Dindar, A., Boz, Y., Sonmez, D. Y., & Celep, N. D. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. *Chemistry Education Research and Practice*, 19(1), 167-183.

Chatmaneerungcharoen, S. (2019, October). Improving Thai science teachers' TPACK through an innovative continuing professional development program. *Journal of Physics: Conference Series* (Vol. 1340, No. 1, p. 012017). IOP Publishing.

*Cheng, P. H., Molina, J., Lin, M. C., Liu, H. H., & Chang, C. Y. (2022). A new TPACK training model for tackling the ongoing challenges of COVID-19. *Applied System Innovation*, *5*(2), 32.

*Danday, B. A. (2019). Active vs. passive microteaching lesson study: Effects on pre-service teachers' technological pedagogical content knowledge. *International Journal of Learning, Teaching and Educational Research*, 18(6), 181-200.

*Dewi, N. R., Rusilowati, A., Saptono, S., & Haryani, S. (2022). Project-Based Scaffolding TPACK Model to Improve Learning Design Ability and TPACK of Pre-Service Science Teacher. *Jurnal Pendidikan IPA Indonesia*, 11(3).

Farhadi, S., & Öztürk, G. (2023). Technological pedagogical content knowledge (TPACK) level and needs of pre-Service English as a foreign Language (EFL) Teachers: Evidence from Turkey. *Revista Educacion*, *47*(1), 187-203.

Hsu, Y. S., Yeh, Y. F., & Wu, H. K. (2015). The TPACK-P framework for science teachers in a practical teaching context. *Development of science teachers' TPACK: East Asian practices*, 17-32.

Joshi, S. C. (2023). TPACK and teachers' self-efficacy: A systematic review. *Canadian Journal of Learning and*

Technology, *49*(2), 1-23.

Mishra, P., & Koehler, M.J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108, 1017-1054.

Mohamad, F. S. (2021). Technological pedagogical content knowledge (TPACK) and the teaching of science: Determiners for professional development. *Studies of Applied Economics*, *39*(1).

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Journal of Clinical Epidemiology*, 62(10), 1006–1012. https://doi.org/10.1016/j.jclinepi.2009.06.005.

Munn, Z., Peters, M. D., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC medical research methodology*, *18*, 1-7.

*Özdilek, Z., & Robeck, E. C. (2018). Enabling Pre-service Chemistry Teachers' Development of Technological, Pedagogical, and Content Knowledge (TPACK) through Case-Based Lesson Planning. Uludağ Üniversitesi Eğitim Fakültesi Dergisi, 32(1), 207-225.

*Nugraheni, A. R. E., & Srisawasdi, N. (2022). Developing Pre-Service Science Teachers' TPACK Self-Efficacy of Chemistry Competencies through Case-based Learning Intervention.

Ozgün-Koca, S. A., Meagher, M., & Edwards, M. T. (2011). A teacher's journey with a new generation handheld: Decisions, struggles, and accomplishments. School Science and Mathematics, 111(5), 201–224.

*Rodríguez-Becerra, J., Cáceres-Jensen, L., Diaz, T., Druker, S., Padilla, V. B., Pernaa, J., & Aksela, M. (2020). Developing technological pedagogical science knowledge through educational computational chemistry: a case study of pre-service chemistry teachers' perceptions. *Chemistry Education Research and Practice*, 21(2), 638-654

Saraswati, D. L., Riandi, R., Kadarohman, A., Suhandi, A., Samsudin, A., Zulva, R., ... & Supriatna, A. Workshop on Strengthening TPACK in ESD-Based Science Learning in Implementing the Merdeka Curriculum [Workshop Penguatan TPACK pada Pembelajaran IPA Berbasis ESD dalam Implementasi Kurikulum Merdeka]. *Jurnal Pengabdian Isola*, *2*(2), 126-134.

*Srisawasdi, N., Pondee, P., & Bunterm, T. (2018). Preparing pre-service teachers to integrate mobile technology into science laboratory learning: an evaluation of technology-integrated pedagogy module. *International Journal of Mobile Learning and Organisation*, 12(1), 1-17.

Sothayapetch, P., & Lavonen, J. (2022). Technological pedagogical content knowledge of primary school science teachers during the COVID-19 in Thailand and Finland. *Eurasia journal of mathematics science and technology education*.

Syukri, M., Yulisman, H., & Nurina, C. I. E. (2020, February). A systematic literature review of science teachers' TPACK related to STEM in developing a TPACK-STEM scale. *Journal of Physics: Conference Series* (Vol. 1460, No. 1, p. 012105). IOP Publishing.

Tondeur, J., Aesaert, K., Pynoo, B., van Braak, J., Fraeyman, N., & Erstad, O. (2017). Developing a validated instrument to measure preservice teachers' ICT competencies: Meeting the demands of the 21st century. *British Journal of Educational Technology*, 48(2). https://doi.org/10.1111/bjet.12380

*Widyasari, F., Masykuri, M., Mahardiani, L., Saputro, S., & Yamtinah, S. (2022). Measuring the Effect of

Subject-Specific Pedagogy on TPACK through Flipped Learning in E-Learning Classroom. *International Journal of Instruction*, 15(3), 1007-1030.

Author Information

Ronilo P. Antonio

https://orcid.org/0000-0002-2832-7203

College of Education, Bulacan State University

City of Malolos, Bulacan

Philippines

Contact e-mail: *ronilo.antonio@bulsu.edu.ph*