

# Technological Pedagogical Content Knowledge (TPACK) Competence of Science Teachers in the Philippines: A Systematic Review

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## ABSTRACT

This systematic review examines the Technological Pedagogical Content Knowledge (TPACK) competence of Science teachers in the Philippines by synthesizing studies published from 2015-2025. Guided by the PRISMA framework, relevant studies were identified, screened, and analyzed to determine the level of TPACK competence, influencing factors, challenges, and recommended interventions to further improve their competence. The findings reveal that Science teachers generally demonstrate moderate to high levels of TPACK, particularly in pedagogical and content knowledge domains. However, technology-related components, especially

technological content and technological pedagogical knowledge, still remain as areas of concern. Professional development, self-efficacy, teaching experience, and institutional support significantly influence the ability of teachers to integrate technology effectively in their science instruction. Given the persistent challenges in terms of infrastructure, training quality, and contextual limitations, holistic approaches are required such as continuous and context-responsive professional development programs, policy-aligned initiatives, and strengthened institutional support. Hence, this review highlights the importance of a comprehensive and holistic approach towards strengthening TPACK competence among Science teachers to further continue in promoting high-quality, inclusive, and technology-enabled Science education.

**Keywords:** *Technological Pedagogical Content Knowledge, TPACK competence, Science Teachers, Technology Integration, Professional Development, Science Education*

## INTRODUCTION

The field of education is constantly transforming as a result of the changing demands of our society, whether on the student or teacher's perspective. With the advent of the 21st century, it highly encourages the teachers to not only possess extensive knowledge on content and pedagogy, but also an in-depth ability to incorporate technology in the teaching and learning process. Every teacher is expected to embody these three domains to foster in learners the skills of creativity, communication, collaboration, and critical thinking, commonly known as the 4Cs. Somphol et al. (2020) highlighted that these competencies are significant in preparing the learners for a technologically advanced and evolving society. Hence, as the world works to provide students with 21st century abilities, the integration of technology into education emerges as a key subject (Castillo et al., 2024).

In Science Education wherein it places a strong emphasis on abstract concepts, inquiry-based learning, and visualization; technology integration is essential to improve both the conceptual comprehension and engagement of the learners. However, utilizing technology in science classrooms effectively demands more than just technical proficiency; it also calls for the purposeful integration of pedagogical approaches, technological tools, and subject matter expertise. In this manner, when these three domains are linked, teachers will be able to create lessons that support data-driven research, encourage active student participation, and make abstract and difficult scientific concepts understandable.

In the Philippines, the K to 12 Program which is the flagship educational reform of the Department of Education (DepEd) seeks to develop a 21st century-ready curriculum. It aims to give all Filipino learners a comprehensive education wherein they can acquire the necessary knowledge and skills for employability and life-long learning. This change in the educational system also made it possible for the science curriculum to use innovative teaching strategies to improve students' scientific and critical thinking abilities. These changes placed a great expectation too on science teachers to successfully incorporate the three domains into their classroom instruction.

The Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler in 2006 provides a theoretical foundation for understanding how teachers synthesize technology, pedagogy, and content knowledge to facilitate meaningful learning experiences. According to Bakar et al. (2020), before integrating technology into instruction, teachers must understand the relationships between technology, pedagogy, and content knowledge. Since TPACK describes the ability of educators on how to develop, deliver, and assess instructional materials and utilization of technology effectively, it is a significant framework to be considered in the field of education (Putri et al., 2024). As Cordova and Linaugo (2022) stated, teacher's pedagogical techniques, content knowledge of the subject, and proficiency with technology are all directly related to the quality of science education which means that the development of teachers' TPACK is essential to meet the goals of the curriculum.

Over the past years, studies on TPACK in the Philippines have expanded significantly that explored teachers' competence, technology integration practices, and instructional effectiveness particularly in Science teaching. Science teachers often exhibit moderate to high levels of overall TPACK competence, especially in the pedagogical and content knowledge domains (Alegre & Galado, 2025; Castillo et al.,

2024). However, technology-related domains like technological pedagogical knowledge and technological content knowledge have been found to be relatively weaker in the studies of Gacayan (2025) as well as Gorospe and Ocdenaria (2025), indicating continuing challenges in aligning digital tools with science content and pedagogy. These results imply that although science teachers possess instructional skills, effective technology integration still remains an area of concern.

Given these gaps, it is important to provide a thorough understanding of the level of TPACK competence among Science teachers in the country, the factors affecting their competence, the challenges they encounter in integrating TPACK in Science education, and interventions to further improve their TPACK competence. Hence, this systematic review consolidated existing studies from 2015-2025 to provide a comprehensive synthesis of current evidence regarding the TPACK competence of Science teachers in the Philippines. By analyzing the existing trends, strengths, gaps, and influencing factors, this review aims to inform educational policy, guide professional development initiatives, and contribute to the advancement of technology-integrated Science education, thereby supporting the pursuit of Sustainable Development Goal 4 which is Quality Education.

## **METHODS**

This chapter outlined the research methodology that was utilized in analyzing the TPACK competence of Science teachers in the Philippines through the synthesis of different studies. It described the research design, study selection procedure, inclusion and exclusion criteria, data extraction, and data synthesis and analysis.

### **Research Design**

This study employed a systematic review research design guided by the Preferred Reporting Items for Systematic and Meta-Analyses (PRISMA) framework to synthesize empirical evidence on the TPACK competence of Science teachers in the Philippines. This approach was selected to ensure transparency and accuracy of method in identifying, evaluating, and synthesizing relevant studies. In this manner, the principles of systematic inquiry in educational research such as comprehensive literature retrieval, clearly defined inclusion criteria, and structured thematic analysis was established.

### **Study Selection Procedure**

To ensure the relevance and quality of the included literature, the study selection process was conducted in multiple stages. An initial search was performed across multiple international and local databases, including ERIC, Google Scholar, Philippine E-Journals, ResearchGate, and institutional repositories of the Department of Education (DepEd) and the Department of Science and Technology–Science Education Institute (DOST-SEI). In addition, in order to find papers not included in major databases, peer-reviewed education and science education journals were also manually searched. The search employed combinations of keywords and Boolean operators such as “TPACK”, “Filipino science teachers”, “TPACK competence among Science teachers in Philippines”, and “technology, pedagogy, and content knowledge” to identify relevant articles.

After the initial search, duplicate records were removed. Afterwards, titles and abstracts were examined to determine their relevance to the objectives of the study. Studies that did not focus on TPACK, Science teachers, or the Philippine educational context were excluded. To determine the final eligibility based on specified inclusion and exclusion criteria, full-text screening was then carried out. The final synthesis only included research that met all of the criteria.

### **Inclusion and Exclusion Criteria**

To ensure the relevance of the studies included in the review, inclusion and exclusion criteria were applied. Studies were included if they (a) were published between 2015 and 2025 in peer-reviewed journals, institutional repositories, or official government reports; (b) were conducted within the Philippine educational context; (3) involved Science teachers teaching within the basic education context (Grades 4–12); and (4) investigated TPACK competence, factors influencing TPACK, challenges in TPACK integration, and possible interventions to be implemented in improving TPACK competence. Furthermore, quantitative, qualitative, and mixed-methods research designs were also considered to allow for a comprehensive understanding of the phenomenon. Meanwhile, studies which focused on pre-service teachers and teachers teaching in tertiary education as respondents were excluded from the analysis to ensure that the data directly addressed the objectives of the review.

### **Data Extraction**

The data extraction was carried out on the studies that were kept for analysis after identification and eligibility screening. In order to ensure consistency among the studies, relevant information was carefully obtained from the texts such as author(s), year of publication, research design, sample characteristics, educational level, instruments used to measure TPACK, and major findings related to TPACK competence, influencing factors, challenges, and recommendations. These findings were coded, categorized, and compared across multiple sources.

### **Data Synthesis and Analysis**

The included studies were analyzed using thematic synthesis approach, a method appropriate for integrating findings across diverse research designs. The findings were coded and organized into four major themes: (1) TPACK competence of Science teachers, (2) factors influencing TPACK competence, (3) challenges in integrating TPACK in Science education, and (4) interventions to improve TPACK competence. To guarantee the validity and consistency of the interpretations, cross-referencing and triangulation using at least two independent sources were conducted. This approach retained the integrity of each research findings while investigating recurring trends and contextual insights.

## **RESULTS AND DISCUSSION**

This section summarizes and explains the main findings of the systematic review on the TPACK competence of science teachers in the Philippines. It discusses the level of teachers' TPACK competence,

the factors that influence TPACK, the challenges in integrating TPACK in Science education, and the recommended initiatives to improve it.

### **TPACK Competence of Science Teachers in the Philippines**

The level of TPACK competence that each educator possess plays an important role in navigating the educational process since it can influence students' scientific competencies and advance thinking skills (Yanti et al., 2024). From the reviewed studies, it was revealed that Science teachers in the Philippines demonstrated moderate to high levels of TPACK competence, indicating that they have a satisfactory capability to integrate technology in the Science instruction.

In the study of Castillo et al. (2024), Senior High School Science teachers in Biñan City demonstrated a high level of proficiency in all the aspects of TPACK particularly in integrating technology with content and pedagogy. Similar findings were also noted from the study of Alegre and Galado (2025) which was conducted among the Junior High School Science teachers from Southeast Butuan District 1 wherein the teachers demonstrated high levels of technological competence in using ICT in teaching and high levels of Pedagogical and Content Knowledge practices. Furthermore, a very high level of TPACK and a very satisfactory teaching performance were also noted from the teachers of the public secondary school of Loon, Bohol (Relator, 2022). The results suggest that Science teachers exhibit high to very high TPACK competence which indicates that they have strong ability to integrate technology, pedagogy, and content effectively in their teaching.

However, despite that teachers reported high in their overall TPACK competence, Gawang and Soriano (2024) emphasizes that Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) remained as areas of difficulty. Although Science teachers were capable of using technology for lesson delivery, assessment, and classroom management, their competence in aligning specific digital tools with Science concepts and pedagogical approaches was comparatively limited and needs to be improved (Gorospe & Ocdenaria 2025).

In the study of Mugot and Fajardo (2021), it was revealed that there is perceived low competence in employing simulations and other technological applications in teaching science concepts. These findings suggest that TPACK competence among Science teachers is uneven, with technology-related intersections requiring further development. As Gacayan (2025) stated, Science teachers are confident in their ability to use technology in teaching however, their actual ability to combine technology with appropriate teaching strategies and science content is still limited and needs to be strengthened through proper training and professional development.

### **Factors Influencing TPACK Competence**

Science teachers' TPACK competence was found to be significantly influenced by professional development. According to Gacayan (2025) and Abrencillo (2025), teachers who took part in technology-related seminars, training programs, and enhancement workshops showed higher levels of TPACK and greater confidence in technology integration. Apart from that, Castillo et al. (2024) also noted that training

programs that focused on pedagogical integration and practical application rather than just technical skills were particularly effective in enhancing teacher's holistic knowledge in these three particular domains.

Furthermore, TPACK competence was also influenced by demographic factors and teaching experience. Younger teachers often demonstrated higher technological skills and adaptability to digital tools, while experienced teachers exhibited strong pedagogical and content knowledge (Gacayan, 2025). Meanwhile, self-efficacy in terms of technology integration was found by Anud and Caro (2022) to be strongly associated with higher TPACK competence, indicating that teachers' beliefs in their own abilities greatly influence their teaching practices.

The institutional factors were also considered as factors that influence teacher's TPACK competence. The availability of digital infrastructure, access to ICT resources, and administrative encouragement were found to facilitate teachers' opportunities to practice and improve technology-integrated instruction (Castillo et., 2024). These results highlight how systemic support and individual competence interact to shape successful implementation of TPACK.

### **Challenges in Integrating TPACK to Science Education**

Despite having positive levels of TPACK competence, Science teachers still struggle to utilize this framework in the classroom setting due to certain circumstances. Based on the reviewed studies, three categories of challenges were identified namely technological, pedagogical, and content-related challenges.

The technological challenges were the most commonly identified issues. Teachers' ability to implement technology-driven science instruction was severely affected by limited access to functional ICT equipment, inconsistent internet connectivity, and a lack of digital resources, especially in public schools and rural contexts (Castillo et al., 2024). Meanwhile, for pedagogical challenges, teachers reported that they are being reluctant to employ technology because of previous technical difficulties and lack of confidence caused by inadequate pedagogical training (Gawang & Soriano, 2024). In the studies of Abrencillo (2020) and Gacayan (2025), they noted that professional development programs have a limited long-term impact on TPACK development because they are usually focused on tools and short-term skills, with limited emphasis on the alignment of technology use on the science-related pedagogical approaches.

In terms of content-related challenges, Gawang and Soriano (2025) said that they were commonly linked with time constraints, administrative duties, and heavy teaching workloads. These demands reduced opportunities for considerable technological integration with science curriculum, reflective practice, and course modification. Furthermore, due to strict curriculum standards and evaluation requirements, teachers were often pushed to prioritize content coverage over innovative and technology-supported teaching approaches (Gorospe & Ocdenaria, 2025).

These challenges reveal that effective integration of TPACK in science education depends not just on the competence of each teacher but also on adequate infrastructure, continuous professional development, and supportive institutional and governmental frameworks.

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## **Interventions to Improve TPACK Competence of Science Teachers**

Amidst the identified factors and challenges on the TPACK competence of science teachers, it was also noted from the reviewed studies different interventions that can be done to improve this matter.

The schools and educational institutions should prioritize sustained, TPACK-based professional development programs that are extended over time and grounded in authentic classroom practice. Such programs have been shown to enhance teachers' technological, pedagogical, and integrative skills, enabling them to design, implement, and reflect on technology-integrated science lessons more effectively (Abrencillo, 2020). Hence, Palmares and Batisla-ong (2023) emphasized that in order to ensure alignment with teachers' current demands and classroom needs, school administrators are encouraged to institutionalize TPACK-centered training as part of faculty development and in-service education programs.

Furthermore, professional development programs should focus on advanced technological applications, technical troubleshooting, and pedagogically significant technology use, extending beyond basic technology training (Castillo, et al., 2024). By concentrating on these areas, teachers can become more competent and confident in their ability to use digital tools in science instruction.

Gacayan (2025) also recommended that collaborative professional learning frameworks like communities of practice and mentoring programs need to be reinforced. These programs encourage group learning, collaborative problem-solving, and contextualized technology use, each of which have been established to support science teachers' long-term TPACK development.

Moreover, administrators and policymakers should also prioritize the balanced development of teachers' technological knowledge (TK), pedagogical knowledge (PK), and metacognitive processing skills, since these elements are needed to support effective delivery of instruction and TPACK implementation (Abuan et al., 2023). This was supported by Alegre and Galado (2023) together with Gorospe and Ocdenaria (2025) who suggested looking into other aspects of teaching effectiveness, such as how technology integration affects pedagogical content knowledge and how socio-cultural and contextual factors affect science instruction. These studies can offer a more comprehensive understanding of effective TPACK implementation and contribute to the continuous improvement of teacher development programs.

These recommended initiatives indicate that enhancing TPACK competence requires continuous, collaborative, and policy-aligned professional development that targets both technological proficiency and broader pedagogical and contextual aspects of science instruction.

## **CONCLUSION**

This systematic review synthesizes studies on the TPACK competence of Science teachers in the Philippines. The findings reveal that although most teachers have moderate to high levels of TPACK competence, especially in the pedagogical and content domains, technology-related components still remain as areas of concern. Professional development, self-efficacy, teaching experience, and institutional support significantly influence the ability of teachers to integrate technology effectively in their science instruction.

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Given the persistent challenges in terms of infrastructure, training quality, and contextual limitations, holistic approaches are required such as continuous and context-responsive professional development programs, policy-aligned initiatives, and strengthened institutional support. In this manner, TPACK competence of Science teachers in the Philippines will be further improved and the education system will continue to promote high-quality, inclusive, and technology-enabled Science education, which directly contributes to the Sustainable Development Goal (SDG) 4; the Quality Education.

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