

## **The Integration of Digital Interactive Whiteboards in Elementary School Education: A Literature Review Based on the TPACK Framework**

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### **Abstract**

This study seeks to analyze and synthesize the outcomes of previous studies about the implementation of PID in elementary education using the TPACK framework as a framework for analysis. This study is a review of scientific literature that analyzes ten scientific articles found in national and international scientific journals accessed via the Google Scholar, ERIC, and ScienceDirect databases. The technique utilized in analyzing the data involves collecting, coding, organizing, and synthesizing the information derived from the research. Based on the findings of this study, PK and TPK are identified as the most dominant dimensions of TPACK in the process of implementing PID in the classroom setting. On the other hand, TK and TCK were recognized as the weakest elements among the ten articles examined. It can be inferred from these findings that teachers are more at ease discussing instructional matters and integrating technology in their teaching methods, but still have issues in terms of technical proficiency in using devices and integrating technology in the curriculum content. In addition, it was also noted that teachers who used student-centered pedagogy effectively developed transformative TPACK, while teachers who utilized teacher-centered pedagogy failed to do so. Contextual knowledge (CK) has similarly been found to be an essential variable in moderating the effectiveness of PID implementation in various school contexts. In summary, the results obtained in this study prove that the effectiveness of PID implementation in elementary schools is not only contingent upon the presence of technology tools and their use in training sessions, but more importantly, the effective implementation of PID relies on the appropriate combination of all the seven TPACK components, especially TK and TCK, a student-centered instructional model, and careful considerations of the teaching and learning context. Finally, it is recommended that there should be more holistic, collaborative, and sustainable professional development programs for teachers, as well as future studies involving experimental and longitudinal research designs to investigate the effects of different TPACK training approaches in elementary schools.

Keywords: Digital Interactive Whiteboard, Elementary School Learning, TPACK

### **INTRODUCTION**

However, the evolution of digital technology in the 21st century has revolutionized different spheres of life, with education being one of them. Technology cannot be overlooked when discussing learning methods in elementary schools. There is an urgent need to integrate technology into learning processes due to the requirements of 21st-century skills such as digital literacy, critical thinking, collaboration, and creativity (Lumbu et al., 2025). Since elementary school is the introductory level for children within the formal education system, it becomes a pivotal point for equipping them with the right knowledge of how to apply technology productively. This is where different technologies are integrated to create a conducive learning environment for children in the 21st century (Silvester et al., 2024).

The government of Indonesia has been reacting to the learning digitization challenge by formulating specific measures that will help enhance the quality of education offered in the country. The presidential instruction number seven of 2025 on accelerating the implementation of programs for the development and revitalization of educational institutions

and learning digitization provides a solid legal base for digital transformation in educational institutions in the Republic of Indonesia (Republic of Indonesia, 2025). A practical example of the application of such a policy measure includes the supply of Digital Interactive Boards (PID) commonly referred to as interactive flat panels (IFP) in elementary schools throughout Indonesia. In his speech on the occasion of National Education Day on 2nd May 2025, the president of the Republic of Indonesia reiterated the government's commitment to supplying interactive boards in all schools in Indonesia to ensure that students obtain the best education possible (Syauky & Silahuddin, 2026).

Despite the availability of IWB and its gradual distribution to different learning institutions, its utilization by teachers on site seems to exhibit considerable disparity. Many preliminary studies suggest that several teachers utilize PIDs simply as digital whiteboards or advanced projectors, failing to maximize the interactivity of such technology (Marlis et al., 2025). However, this scenario is not necessarily an indicator of teachers' inability to be creative. It may be attributed to the difficulty of shifting from conventional classroom instruction (chalk and talk) to digital touch-based learning. To this end, appropriate direction, continuous training, and perhaps most important, teachers' confidence in the utilization of the technology are crucial (Inayati et al., 2025). On the contrary, when harnessed with specific pedagogical goals, PID is highly potent to revolutionize the learning process and create an engaging and student-oriented learning environment for elementary learners.

The Technological Pedagogical Content Knowledge framework, formulated by Koehler & Mishra (2009), provides a complete framework through which the integration of technological tools like PID can be comprehensively analyzed. The TPACK framework indicates that for the successful implementation of any technology in teaching, the mere presence of technological knowledge is not adequate; instead, there should be a well-balanced combination of technological knowledge, pedagogical knowledge, and content knowledge. These areas of knowledge are not separate from one another but inter-relate to produce different types of knowledge such as PCK (Pedagogical content knowledge), TCK (Technological Content Knowledge), TPK (Technological Pedagogical knowledge), eventually resulting in TPACK. This framework is of great relevance while evaluating the degree to which ICT has been integrated not just as a tool but as an element that promotes a learning experience consistent with the characteristics of elementary school children (Rintayati et al., 2025).

There have been many previous studies conducted on the use of interactive whiteboards in education both internationally and nationally. In their study of 30 Canadian teachers,

Lefebvre et al. found that the practice of interactive whiteboard use involved mostly technological knowledge and technological-pedagogical knowledge irrespective of teachers' educational qualifications, gender, and teaching experience (Lefebvre et al., 2016). Similarly, in their study of teachers from Australia, Kearney et al. found that while elementary school teachers made multiple uses of technology, secondary school teachers used interactive whiteboards exclusively for instructional purposes (Kearney et al., 2018). On the other hand, in their application of the TPACK framework to investigate the use of IWBs in early childhood mathematics classrooms, Muir et al. confirm the significance of balancing all three forms of knowledge in technology integration (Muir et al., 2016). At the national level, a thematic review conducted by Setiawan based on 21 empirical studies shows that simply providing devices to schools is not enough to enhance learning outcomes because the effectiveness of technology largely relies on teachers' ability to effectively utilize digital technologies with adequate content and pedagogic knowledge (Setiawan, 2025).

Even though numerous studies have already achieved some valuable insights into the use of interactive whiteboards, these achievements are dispersed and have not yet been systematized, especially considering the TPACK framework for elementary schools. The majority of previous research studies focus on quantitative methods and surveys. As a result, the available empirical data fails to deliver a thorough overview of the practical application of TPACK by teachers when using interactive whiteboards. What is more, there is an evident lack of research devoted to the application of TPACK in the use of interactive whiteboards in elementary schools that could be considered a gap in current academic research. In other words, it is important to conduct a thorough literature synthesis to systematize existing findings and identify factors contributing to the successful implementation of PID into the learning process. In this way, a literature review will serve as a guideline for further research and will help educators make the best use of interactive whiteboards.

Based on this background, this article aims to review and synthesize the findings of previous studies on the integration of PID in elementary school education, using the TPACK framework as an analytical lens. It is hoped that this study will contribute to the advancement of educational technology research and provide practical recommendations for teachers, schools, and policymakers on how to optimize the integration of PID as a means of transforming learning in the digital age.

## **DISCUSSION**

Table 1 presents the results of an analysis of 10 relevant articles, from both national and international journals, which were collected from various database sources. The findings are

presented in a table containing the following components: author name and year, study title, research objectives, research methods, and research findings.

Table 1. Article Analysis

No	Researcher	Title	Objective	Methods	Findings
1	Su & Zou (2026)	Pre-service Teachers' TPACK Application in the Context of Interactive Whiteboard-Supported Collaborative Microteaching	Investigating how prospective teachers apply TPACK in collaborative microteaching sessions using Seewo (an interactive whiteboard).	Qualitative (thematic analysis of 70 prospective teachers, microteaching videos, and reflection journals).	The most frequently applied framework was PCK (307 times), followed by CK (190), TCK (50), PK (27), TK (23), TPCK (9), and TPK (2). Prospective teachers also took contextual knowledge (CK) into account in technology integration.
2	Rukmana & Handayani (2022)	Improving the Skills of Prospective Elementary Teachers in Designing Earth and Space Science Digital Teaching Materials: TPACK Framework	Enhancing the skills of prospective elementary school teachers in designing TPACK-based digital teaching materials for Earth and space science.	An experiment involving 75 students. A pretest-posttest design.	There was a moderate increase in TPACK perceptions (N-gain 0.46). The greatest increase was observed in CK, while the smallest increase was observed in TK. There was a positive correlation ( $r = 0.71$ ) between TPACK perceptions and the ability to create digital instructional materials.
3	Gonzales & Gonzales (2021)	Introducing IWB to Preservice Mathematics	Evaluating the impact of the introduction of interactive	A mixed-methods (intervention) study with a	TPACK enhances teaching planning and demonstration skills. TK

No	Researcher	Title	Objective	Methods	Findings
		Teachers: An Evaluation Using the TPACK Framework	whiteboards on prospective mathematics teachers' TPACK in instructional planning and practice.	single-subject experimental design. Thirty-five pre-service teachers participated in an 80-hour seminar.	components have improved significantly. However, pedagogical skills such as the formulation of learning objectives still lag behind.
4	Meileni et al. (2021)	The Implementation of TPACK Framework Based Interactive Digital Learning for Cruise Vocational School (SMKP) Sinar Bahari Palembang	Implementing TPACK-based interactive digital learning in maritime vocational schools.	Research & Development (4-D model: Define, Design, Develop, Disseminate).	The use of apps like Netboard, Quizwhizzer, and Qodlu effectively implements TPACK. Learning becomes more enjoyable for students thanks to a more personalized approach.
5	Paneru (2020)	Information Communication Technologies in Teaching English as a Foreign Language: Analysing EFL Teachers' TPACK in Czech Elementary Schools	Investigating how EFL teachers at Czech elementary schools develop ICT competencies and integrate them into their teaching.	Aphenomenological qualitative study (interviews and observations) of 12 EFL teachers.	Two approaches were identified: formal practice (mechanistic, teacher-centered) and functional practice (constructivist, student-centered). Functional practice fosters transformative TPACK, which enhances students' creative potential.
6	Malik & Lambert	Exploring 1:1 iPad	Investigating 1:1 iPad integration	Qualitative multi-case	Teachers who successfully

No	Researcher	Title	Objective	Methods	Findings
	(2020)	Integration Practices through a TPACK-in-Practice Lens	practices in the classroom through the TPACK lens.	study (4 high school teachers).	integrate iPads adopt a student-centered approach and use iPads as cognitive tools, not just for productivity. Successful experiences boost motivation and self-confidence.
7	Lefebvre et al. (2016)	TPACK in Elementary and High School Teachers' Self-Reported Classroom Practices with the Interactive Whiteboard (IWB)	Identifying the types of knowledge used by elementary and high school teachers in their use of interactive whiteboards based on self-reports.	Qualitative (focused group discussions) with 30 teachers in Quebec, Canada. Content analysis based on the 7 dimensions of TPACK.	Teachers most frequently use TPK and TK. CK and PK are rarely mentioned. Female teachers tend to use TCK more often than male teachers.
8	García-Valcárcel & Martín del Pozo (2016)	Analysis of the Digital Competences of Graduates of University Degrees to be a Teacher	Analyzing the digital competencies of graduates from teacher education programs in Spain using the TPACK model.	A quantitative survey (questionnaire) of 362 students from 14 universities.	Students feel most competent in PK and TPK, but less competent in TK and TCK. Specific skills that are lacking include: designing materials for PDI (31.8%), using tablets for teaching (39%), and creating video games (12.4%).
9	Sarac & Özarlan (2016)	The Investigation of Relation Between the Attitude of	To determine the relationship between teachers' TPACK levels	A correlational (quantitative) study involving 45 teachers and	Students' attitudes toward interactive whiteboards are high, and female students' attitudes

No	Researcher	Title	Objective	Methods	Findings
		Students Towards Interactive Board in Education Process and Technologi- cal, Pedagogical and Content Knowledge of Teachers	and students' attitudes toward interactive whiteboards.	632 elementary and middle school students in Turkey.	are more positive. Teachers' TPACK levels are also high. However, no significant relationship was found between teachers' TPACK and students' attitudes toward interactive whiteboards ( $r = -$ 0.071).
10	Souza & Guidoni (2015)	Utilização didático- pedagógica da lousa digital interativa: capacitando professores do ensino fundamental	Training elementary school teachers in Brazil in the pedagogical and didactic use of the Interactive Digital Whiteboard (IDW).	Action research/devel opment using the workshop model (Oficina I and II).	Following the training, 35 teachers were successfully trained in the use of LDI. The teachers demonstrated improved skills in planning and implementing pedagogical activities using LDI. Teacher interest and participation were very high.

### **The Dominance of Pedagogical Knowledge (PK) and Technological Pedagogical Knowledge (TPK) in the Use of Digital Interactive Whiteboards**

An analysis of the ten articles reviewed indicates that PK and TPK are the most dominant dimensions in both teachers' perceptions and practices when using digital interactive whiteboards. Findings by Lefebvre et al. (2016) reveal that elementary and high school teachers in Quebec most frequently use TPK and PK in their practice of using interactive whiteboards, with each accounting for 36 percent of the total units of meaning analyzed. This dominance indicates that teachers tend to be more comfortable discussing how technology can support their teaching strategies rather than discussing subject content

separately. A similar phenomenon was reported by García-Valcárcel & Martín del Pozo (2016), who found that pre-service teachers in Spain felt most competent in PK and TPK, suggesting that teacher education programs tend to emphasize pedagogical aspects and technology-pedagogical integration over purely technical or content-based aspects. These findings align with the TPACK framework proposed by Mishra & Koehler (2006), in which pedagogical and technological knowledge are essential foundations that teachers must master before they can fully integrate all three domains.

In addition, the study conducted by Su & Zou (2026) gives a completely different view on actual classroom instruction practice. Although the teachers-to-be expressed confidence about their high level of TPACK in self-assessment, in collaborative microteaching lessons that made use of the Seewo interactive whiteboard, PCK emerged as the most prevalent form with 307 occurrences, TK with only 23 times, and TPK only twice. This evidence corroborates the statement already made by Koehler & Mishra (2009) that there exists a difference between the knowledge that the teacher claims to know and his or her competence to actually apply such knowledge in real-life instructional situations. Teachers usually fall back on conventional pedagogic skills acquired through experience whenever confronted with the pressure of instructing the class, despite being adequately trained with regard to technology.

### **The Gap Between Technological Knowledge (TK) and Technological Content Knowledge (TCK)**

A recurring observation in the reviewed literature is that TK and TCK are the least developed elements in teachers' TPACK framework. In this regard, Gonzales & Gonzales (2021) noted that even though prospective mathematics teachers were willing to adopt technology into their lessons, they still lack proficiency when it comes to handling the interactive whiteboard. In addition, Rukmana & Handayani (2022) indicated that out of all the TPACK elements, TK saw the smallest increment following a TPACK-based instruction, with a gain of only 0.39 compared to CK's 0.54. The underdeveloped level of TK poses a great challenge for the development of TPK and TCK since TK acts as a prerequisite for exploring the point of convergence between technology and other types of knowledge. As Mishra (2019) pointed out, teachers cannot incorporate technology into the lesson if they are not proficient with it.

Paneru (2020) found to reinforce this argument by showing that teachers trapped in formal practice tend to use technology only to a limited extent, merely to mechanically transfer knowledge from English texts, while teachers in functional practice, who possess

better technological competence, are able to utilize technology to create collaborative and constructivist learning experiences. This difference has a direct impact on the quality of student learning, as functional practice has been shown to enhance students' creative potential. This aligns with Warschauer (2000) view that teachers with adequate technological competence do not merely use technology as a tool but as a medium to fundamentally transform their teaching practices. Therefore, strengthening technological competence must be a priority in every teacher professional development program related to the use of digital interactive whiteboards.

### **The Student-Centered Approach as the Key to Transformative Technological Pedagogical Content Knowledge (TPACK)**

Findings across various articles consistently show that teachers who adopt student-centered and constructivist approaches tend to develop transformative TPACK, while teachers with teacher-centered approaches tend to remain stuck in a mechanical and limited use of technology. Malik & Lambert (2020) found in their multi-case study that three out of four teachers who successfully integrated iPads shifted from traditional approaches toward student-centered learning, using iPads as cognitive tools rather than merely productivity tools. These teachers were more willing to take risks, more confident, and more experimental in using various applications. Successful experiences in technology integration then create a positive cycle: success boosts motivation, which in turn encourages further experimentation. These findings confirm the theory proposed by Rogers (2003) regarding the diffusion of innovations, in which successful early adopters tend to become agents of change who influence other adopters.

Paneru (2020) expands on these findings by identifying two fundamentally different approaches in the context of teaching English as a foreign language in the Czech Republic. Constructivist, student-centered functional practice has been shown to foster transformative TPACK capable of enhancing students' creative potential, whereas mechanical formal practice leads teachers to feel that technology limits the transmission of knowledge. This difference lies not only in the level of technical proficiency but more in teachers' pedagogical beliefs about how students learn effectively. As stated by Ertmer & Ottenbreit-Leftwich (2010), teachers' beliefs about teaching and learning are stronger predictors of effective technology integration than technical skills alone. Teachers who believe that students learn actively through the construction of knowledge will tend to utilize technology to facilitate collaboration, exploration, and creation, rather than merely the transmission of information.

## **The Role of Contextual Knowledge in the Successful Integration of Digital Interactive Whiteboards (DIW)**

One of the important conclusions drawn from the analysis of the recent studies is that contextual knowledge (CK) is essential for the effective implementation of digital interactive whiteboards in education based on the updated TPACK model by Mishra (2019). Su & Zou (2026) found that the teachers involved in the current research purposefully evaluated several contextual parameters prior to using particular functions of the Seewo interactive whiteboard, such as the mental state and cognitive skills of the learners, the complexity of the course content, technical preparedness of the educational environment, and administrative backing. Instead of applying technology just because it was accessible, the educators performed a thorough needs assessment to guarantee the suitability of the chosen technology for the particular educational setting. These results confirm the views expressed by Rosenberg & Koehler (2015), who stated that context should be regarded not as a peripheral parameter in the TPACK diagram but as one of the active components responsible for implementing other types of knowledge.

This point is illustrated by Sarac and Özarlan (2016) who provide a thought-provoking approach in understanding how situational elements can influence the link between the level of TPACK competencies in teachers and attitudes held by students. Despite the high TPACK skills among teachers and the favorable attitude towards interactive whiteboards held by students, there was no statistically significant correlation between the two variables ( $r = -0.071$ ). In other words, students' positive attitude towards using technologies can depend on different aspects not related to teachers' TPACK competencies such as their experience of working with technologies in their spare time, family support for learning, socio-economic status of families, and policies in particular schools. In the given case, where research took place within the walls of a private institution equipped with necessary technologies, the participants could already hold positive attitudes due to their previous experience.

## **The Effectiveness of Technological Pedagogical Content Knowledge (TPACK)-Based Training and the Challenges of Its Implementation**

The effectiveness of the TPACK-based training in developing teachers' competencies is consistent among all analyzed studies; however, there is some difference in the level of success based on the time spent, method used, and support received during the training. According to Rukmana & Handayani (2022), one semester-long TPACK-based training program for pre-service elementary teachers was successful in developing their competencies in the moderate category (N-gain 0.46). The greatest improvements were observed in the CK

domain, while the lowest gains were observed in the TK domain. In addition, Souza & Guidoni (2015) found the success of the workshop method in training teachers in Brazil to use interactive digital whiteboards. Specifically, 35 elementary school teachers were trained on using the technology successfully with very high levels of engagement and interest. The reason for the success was attributed to the implementation of the "learning by doing" model, where the teachers could practice their skills in using the technology while developing lessons. This finding supports the TPACK-in-Action principle proposed by Tai (2015).

As Meileni et al. (2021) highlight, the main thing that will help ensure success in the implementation of TPACK is choosing the correct applications that will enable one to make the learning process fun and personal. For example, such apps as Netboard, Quizwhizzer, and Qodlu can be used by teachers to develop activities where all three components of TPACK are merged without being limited by numerous technical limitations. At the same time, according to Gonzales & Gonzales (2021), pre-service teachers rapidly adopt the digitization of their learning activities and pedagogical skills, such as writing learning goals related to technology, lag significantly behind. Thus, when teaching future teachers TPACK, it should be noted that the development of skills for writing learning goals in the context of using certain technologies cannot be omitted. According to Harris & Hofer (2011), teachers should learn to think inversely – start with writing goals and working with content, and then choose technology.

### **Implications of the Research for the Development of Teachers' Technological Pedagogical Content Knowledge (TPACK) in Elementary Schools**

From the discussions above, a number of implications arise concerning the development of TPACK among elementary school teachers who utilize interactive digital whiteboards. Firstly, it is imperative to train teachers in a manner that would emphasize the enhancement of TK and TCK, since they are traditionally the weakest components. The training of teachers should not only include the technical abilities of an interactive whiteboard, but it should also incorporate the application of the technology in order to convey particular subject concepts like mathematics, science, or language. According to Rukmana & Handayani (2022), the "learning by design approach," where teachers get to design their digital learning tools, has shown much more efficiency than any other training approaches.

Secondly, the development of TPACK for elementary school teachers should be done in conjunction with the use of a student-centered approach to education as the pedagogical theory guiding technology integration. Elementary school teachers should be motivated to take on new roles from being information providers to facilitators of learning, whereby

students are able to construct their own knowledge by engaging in interactive learning through the use of digital interactive whiteboards. Malik & Lambert (2020) have shown that teachers who effectively integrate iPads into the teaching process use them as tools for critical thinking and problem-solving, not for mere presentation purposes.

Thirdly, contextual knowledge should be explicitly included within the framework of TPACK to ensure that teachers are ready to deal with the diverse nature of the learning contexts. Elementary school teachers should be taught how to assess student demographics, school environment, infrastructure provision, and supportive policies before opting for the proper way to employ an interactive whiteboard. According to Su & Zou (2026), a teacher will only be considered good when they are able to tailor their use of technology according to student needs.

Finally, cooperation and reflection should be included in all efforts aimed at developing TPACK among educators. According to the findings of Paneru (2020) and Su & Zou (2026), practices such as peer microteaching, peer observation, and reflection are very efficient in aiding educators in mastering TPACK. The school administration should facilitate the establishment of professional learning communities where educators could continuously exchange experiences, give each other feedback, and solve issues associated with utilizing digital interactive whiteboards.

Lastly, it should be remembered that the success of technology integration does not only have to do with increased TPACK scores and positive student attitude toward technology integration. As mentioned by Sarac & Özarlan (2016), there might not necessarily be a correlation between teachers' TPACK level and students' attitude; thus, more comprehensive tools for assessing the effectiveness of technology integration should take into account students' engagement, understanding of concepts, high-level thinking, as well as creativity and cooperation. More research needs to be conducted in terms of the effect of interactive digital boards on the development of science literacy, numeracy, and 21st-century skills among Indonesian elementary school students.

## **CONCLUSION**

Taking into account the research aim of investigating the previously published research on integrating PID in elementary school learning with the TPACK framework being utilized as the research instrument, it is possible to make the following conclusions: the effectiveness of implementing PIDs in elementary school learning does not depend only on the presence of the needed technology or the length of the technical training that the teacher had prior to implementing the PIDs into their lessons. The success depends to a large extent on the

balance of all the TPACK factors, in particular, TK and TCK, which have been underestimated for quite a long time already, student-centered approach, and consideration of the specific context of learning. Therefore, training programs should be developed taking all those aspects into account and applying such approaches as collaboration and reflective practices. In other words, PIDs should not be viewed as simple alternatives to whiteboards, but as real learning transformation tools.

## **SUGGESTIONS**

Based on the synthesis of the ten articles analyzed and the limitations identified in previous studies, it is recommended that further research be conducted on the integration of PID in elementary school education. This is because most of the studies analyzed, such as those conducted by Gonzales & Gonzales (2021) on mathematics, Paneru (2020) on English, and Rukmana & Handayani (2022) on Earth and Space Science, focused on specific subjects in isolation. In fact, the primary characteristic of the elementary school curriculum in Indonesia (and in many other countries) is thematic learning that integrates various subjects (in Indonesia, this includes Natural and Social Sciences, or IPAS). It is recommended that research be conducted specifically examining how the TPACK framework can be applied in the context of elementary school learning, where classroom teachers must simultaneously integrate technology, pedagogy, and content from various disciplines. This research could employ a case study design to deeply observe how classroom teachers design and implement PID-assisted learning, as well as how they balance the TPACK demands of several subjects with differing characteristics.

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