TPCK (*Technological Pedagogical and Content Knowledge*) Competence for Educator: A Literature Review

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ABSTRACT

This study aimed to analyze the competence of TPCK (Technological Pedagogical and Content Knowledge) in teachers through a literature review. The research conducted literature searches through academic databases, journals, books, and other sources of information using relevant keywords related to TPCK and the role of teachers in the context of technology use in teaching and learning. Subsequently, relevant literature was selected and evaluated for its quality, validity, and relevance to the research objectives. The analysis results indicated that teachers with high levels of TPCK tended to create more meaningful and profound learning experiences for their students. This suggested that TPCK development was a continuous process and required long-term commitment. Therefore, the role of TPACK in learning was crucial in supporting the sustainability of education.

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1. INTRODUCTION

The 21st century, with its advancements in knowledge and technology, has had a significant impact on various aspects of life, including education (Fayanto et al., 2023). The initial role of technology as merely a tool has evolved, involving substantial changes in how learners understand and engage in learning processes (Yusuf et al., 2015) . Conversely, the presence of technology in the present era plays a crucial role in all aspects of education, particularly in the dynamics of the learning process (Mairisiska et al., 2014). The challenges of learning in the 21st century, coupled with the changes in the 2013 curriculum, emphasize the importance of teachers' pedagogical skills as educators to be more adept at designing learning experiences that are not only effective but also innovative. The development of various information technology media serves as the primary basis for the evolution of 21st-century learning (Sointu et al., 2019; Sole & Anggraeni, 2018; Wayan Maba et al., 2023). In this context, teachers are expected to be human resources capable of responding to the developments in science and technology, especially in applying technology in the learning process (Ramli et al., 2018). Not only that, but teachers are also faced with demands to enhance their skills in mastering Information and Communication Technology

(ICT), with the aim of facilitating learning and improving learning outcomes (Rahmadi, 2019). The challenge of developing this task is becoming increasingly complex, involving not only intellectual abilities but also skills in using and utilizing technology in the learning process (Baslanti, 2006).

After the implementation of the independent curriculum in schools, students and teachers have the opportunity to explore and develop their potential according to their respective fields and apply it to students in the school. New innovations in education provide additional motivation to implement the independent curriculum, including the ongoing development of technology. TPCK involves a complex integration of technology, content, and pedagogy. Engaging teachers in collaboration allows them to share, learn from, and integrate available knowledge distributed among colleagues with different expertise (Yeh et al., 2021). The use of the TPCK approach (Technological Pedagogical Content Knowledge) in learning creates different dynamics in a teacher's self-development (Palopo, 2023). These differences are significantly felt compared to learning in previous curricula. By leveraging technology and content in learning media at school, the learning atmosphere becomes more enjoyable and less boring for students (Manfra & Hammond, 2008). This approach helps teachers facilitate students to develop material actively and creatively (Wood & Ashfield, 2008). Teachers also have the flexibility to develop models and learning media used for teaching(Sheffield et al., 2015). The freedom to choose and determine teaching materials poses its own challenges in exploring learning in schools.

In the implementation of the independent curriculum by applying the TPCK approach, teachers need to have the skills to determine the appropriate material and timing in utilizing technology(Putriani, 2023). In delivering learning materials, teachers can choose to use various supporting media, including displays through accessible or downloadable links from the internet. Similarly, in the process of collecting student assignments, technology can be used to fulfil tasks given by the teacher, either through provided addresses or pre-existing websites. The TPCK approach, which integrates technology, pedagogy, and content knowledge, has been shown to have several advantages in education. Lavrysh (2019) and Setyosari et al. (2018) both highlight its potential to enhance students' understanding and improve teachers' collaborative skills. Lavrysh (2019) specifically demonstrates its effectiveness in redesigning learning activities to enhance language skills, while Setyosari (2018) emphasizes its role in improving higher-order thinking skills. Owings & Hofer (2007) further support the application of TPCK in teacher education, with Owings (2007) showing its benefits in increasing pre-service teachers' knowledge and confidence. These studies collectively underscore the potential of the TPCK approach to support competency development and simplify complex learning content with technological support.

The TPCK approach, which integrates content, pedagogy, and technology knowledge, is crucial for effective teaching (Kadijevich, 2012). To successfully implement this approach, teachers should be well-prepared in instructional approaches and educational technologies (Martin, 2015). The Handbook of TPCK for Educators provides a comprehensive guide for teachers to develop this knowledge(Oliver, 2011). Additionally, Kramarski & Michalsky (2009) suggests that fostering self-regulated learning in the evaluation phase is particularly effective in enhancing TPCK. Therefore, teachers can follow these steps to implement the TPCK approach: explain learning objectives, deliver core materials through PowerPoint, facilitate interaction through messaging apps, and conduct learning evaluations.

The professional competence of teachers, as mandated by Law No. 14 of 2005, is a critical aspect of their role. However, there are significant challenges in this regard, including a lack of skills in applying the curriculum, understanding student characteristics, and utilizing ICT in learning (Fredy & Hamsinah Day, 2021). These challenges are further compounded by the need for high-quality teacher recruits and effective professional preparation (Newkirk, 2007). Anif (2012) suggests that the formation of professional competence, along with the other required competencies, can be achieved through structured and ongoing education and professional development training. Therefore, the 21st-century teacher skills, as outlined by ISTE, encompass a range of competencies, including the ability to inspire creativity, design digital learning experiences, model digital era work, promote digital citizenship, and engage in professional development (ISTE, 2017). These skills are further developed through the concept of teacher technological leadership, which emphasizes the importance of school culture, self-leadership, and

innovative practices in teaching and learning (Samsudin & Ghani, 2020). These skills reflect the complexity of teachers' tasks in facing technological advancements and globalization in the 21st century. The skills expected from 21st-century teachers are more international, multicultural, and interconnected, reflecting the challenges and demands of an era increasingly linked to technological advancements and globalization.

Teachers play a primary role in integrating technology into learning to ensure sustainable development in line with the changing times. They not only act as facilitators of learning but also guide the direction to ensure that learning aligns with the context of the material being taught. However, initial studies by Putrawangsa & Hasanah (2018) indicate teachers' concerns regarding the integration of technology in learning. Some of them are worried that the use of digital technology may have negative impacts, such as students' reliance on calculators, which could affect their calculation abilities. Additionally, there are concerns about the potential misuse of digital technology by students, leading to distraction from the material that should be learned. Therefore, the role of teachers in supporting the integration of technology into learning becomes crucial. There needs to be clarity regarding the role of teachers in integrating technology, including understanding what teachers should do and how to do it.

Research conducted the integration of technology in education faces several obstacles, including a lack of personnel with IT competencies, inadequate infrastructure, and high costs for original software (ATABEK, 2019; Bingimlas, 2009; Ryan & Bagley, 2015). These barriers can lead to a lack of confidence and competence among teachers, as well as a lack of access to resources (Bingimlas, 2009). The ever-changing nature of technology and personal beliefs and perceptions about its use also pose internal obstacles (Bagley, 2015). To address these challenges, effective professional development, sufficient time, and technical support are crucial (Bingimlas, 2009). Field problems indicate that the importance of knowledge about technology, pedagogy, and content in teacher education has been recognized as an integral part of the education program. This program aims to prepare teachers to adopt technology in the learning process (Feladi & Puspitasari, 2019) . The TPCK (Technological Pedagogical Content Knowledge) model is considered a promising framework for understanding how teachers can integrate technology into the classroom (Wong et al., 2015). The research findings that the TPCK model has been shown to be a valuable tool in improving teaching and learning conditions. Setyosari (2018) and Lavrysh (2019) both highlight its role in enhancing teachers' professional development and in bridging the gap between educational technology and pedagogical strategies. Omoso & Odindo (2020) further demonstrate its potential in improving classroom practice, with a focus on the development of technological knowledge and the use of project-based learning to enhance TPCK. Integrating knowledge of technology, pedagogy, and content can determine effective learning models capable of achieving learning goals. One positive outcome is the enhancement of students' creative thinking abilities through creative learning activities that utilize technology (Nugroho et al., 2019).

TPCK, in addition to being a new form of knowledge, also serves as a framework that can be applied to evaluate teachers' knowledge related to the integration of technology in learning. Within this framework, there are seven variables that influence TPCK, as proposed by Koh (2020) , Jiménez Sierra et al. (2023), Mishra & Koehler (2006), and Shulman (2019). These variables include: (1) Technological Knowledge (TK), which involves knowledge of how to operate computers and relevant software, (2) Pedagogical Knowledge (PK), referring to the ability to manage student learning, (3) Content Knowledge (CK), which is knowledge of subject matter, (4) Technological Content Knowledge (TCK), which includes knowledge of how content can be explained or represented by technology, (5) Pedagogical Content Knowledge (PCK), involving knowledge of how to represent and formulate subjects so they can be understood by others (Shulman, 2013), (6) Technological Pedagogical Knowledge (TPK), which is knowledge of how technology can facilitate pedagogical approaches, and (7) TPCK, which encompasses knowledge of how to facilitate student learning related to specific content through the integration of pedagogical and technological approaches. The Koehler framework (2006), known as TPCK (Technological Pedagogical Content Knowledge), provides a solution for teachers to develop pedagogical and technological abilities in classroom teaching practice. This framework creates an integrative

understanding among the three key knowledge domains required by teachers. TPCK provides a foundation for teachers to integrate technology into their teaching practices in meaningful and effective ways. With this holistic understanding, teachers can design more relevant, engaging learning experiences that align with technological advancements and student needs. It also helps teachers address challenges in facing curriculum changes, demands of 21st-century learning, and optimize the potential of technology to enhance student learning outcomes. The purpose of this study is to analysis TPCK (Technological Pedagogical and Content Knowledge) Competence for Educator

2.   METHODS

The literature review method was a systematic approach to synthesizing, analyzing, and evaluating relevant literature on a specific topic. The systematic literature review method, as proposed by ((Ferreras-Fernández et al., 2016), (Williams et al., 2021) and (Lowe, 2009), offered several benefits. It provided a comprehensive overview of relevant literature, allowing for the synthesis, analysis, and evaluation of existing knowledge on a specific topic. This approach was particularly valuable in fields like Library and Information Science (LIS) and management research, where it could enhance the foundation of knowledge and address research shortcomings. The systematic review method was also crucial in evidence-based practice, as it helped to identify the most reliable evidence and made it accessible to researchers, clinicians, and healthcare consumers. The stages of the literature review built by the authors were presented in Figure 1.

Figure 1. Literature review stages

The literature review method allowed researchers to obtain a comprehensive understanding of a particular topic by combining existing research findings. This study analyzed various literature reviews related to TPCK (Technological Pedagogical and Content Knowledge) abilities in teachers. The research method used was a systematic and detailed literature review to collect, review, and analyze studies related to the topic. In this study, researchers conducted literature searches using academic databases, journals, books, and other sources of information using relevant keywords related to TPCK and the role of teachers in the context of using technology in learning. Then, relevant literature was selected and evaluated for quality, validity, and relevance to the research objectives. Data extracted from the literature was then analyzed to identify patterns, themes, and trends related to TPCK abilities in teachers. Findings from the literature were synthesized to draw conclusions summarizing the main findings, identifying knowledge gaps, and providing implications for practice and research in this field. Through this systematic literature review analysis, this study provided an in-depth understanding of TPCK abilities in teachers, identified factors influencing TPCK development, and offered insights into practical implications and further research in this area.

3.   FINDINGS AND DISCUSSION

2.1. Technological Pedagogical Knowledge (TPK) for educator

Technological Pedagogical Knowledge (TPK) referred to teachers' understanding of how teaching and learning could change when technology was used in the educational context. This knowledge is particularly important in the context of the "new millennium learners" who have grown up in a digital age (Yusof et al., 2019). The TPCK framework, which combines pedagogical, content, and technological knowledge, can help bridge the gap between educational technology and the teaching process (Lavrysh, 2019). It involved knowledge of how technology could be effectively used to support pedagogical approaches and appropriate learning strategies. Research has shown that teachers with Technological Pedagogical Content Knowledge (TPCK) are able to enhance the learning process, facilitate teaching, and create a more dynamic learning environment (Yusof, 2019; Lavrysh, 2019; Atashgahi, 2016). This knowledge is developed through project-based learning (Hosseini, 2011) and is crucial for educators in the 21st century (Yusof, 2019). The effective integration of educational technologies, as guided by the TPCK framework, can lead to improved language skills and academic achievements (Lavrysh, 2019). They had knowledge of various technological tools and resources that could be integrated into learning activities to enhance student understanding. TPK involved understanding how to select, develop, and use technology according to learning needs. Teachers with TPK could identify ways in which technology could enhance content delivery, interact with students, and support learning evaluation. This created a close relationship between technological knowledge and pedagogical knowledge, ensuring that the use of technology effectively supported learning goals.

Technological Pedagogical Knowledge (TPK) was a component of the TPCK framework described by (Graham et al., 2009). It encompassed teachers' understanding of how technology could be integrated with pedagogical approaches to achieve effective learning. Here were some key aspects of Technological Pedagogical Knowledge: (1). Understanding of Teaching and Learning: particularly in the context of secondary social studies, has shown that it can enhance teachers' instructional planning, leading to more conscious, strategic, and varied use of learning activities and technologies (Harris & Hofer, 2011); (2). Use of Technology in Teaching: This requires a deep understanding of when, where, and how to use domain-specific knowledge and strategies for guiding students' learning with appropriate digital technologies (Niess, 2012); (3). Integration of Technology into the Curriculum: Tunjera & Chigona (2020) both highlight the importance of constructivist teaching theory in this process, with the former finding that it significantly increases TPACK in student-teachers, and the latter emphasizing the need to assist teacher educators in integrating technology in a constructive manner; (4). Adaptation to Student Needs: Understanding how technology could be adapted to meet the needs and characteristics of students. Teachers used technology to create learning experiences that were suitable and relevant. Tanak (2018) found that student teachers often used technology as a motivational tool, but struggled to integrate it into inquiry-based learning experiences.; (5). Development of Learning Strategies with Technology: Teachers could design learning strategies that effectively utilized technology. They knew how to make learning more engaging and relevant through technology integration. The TPACK framework, which emphasizes the integration of technology, pedagogy, and content knowledge, has been found to be effective in helping teachers develop their TPACK. Liu (2013) and Wong et al. (2015) both highlight the importance of professional development programs and collaborative design processes in this development
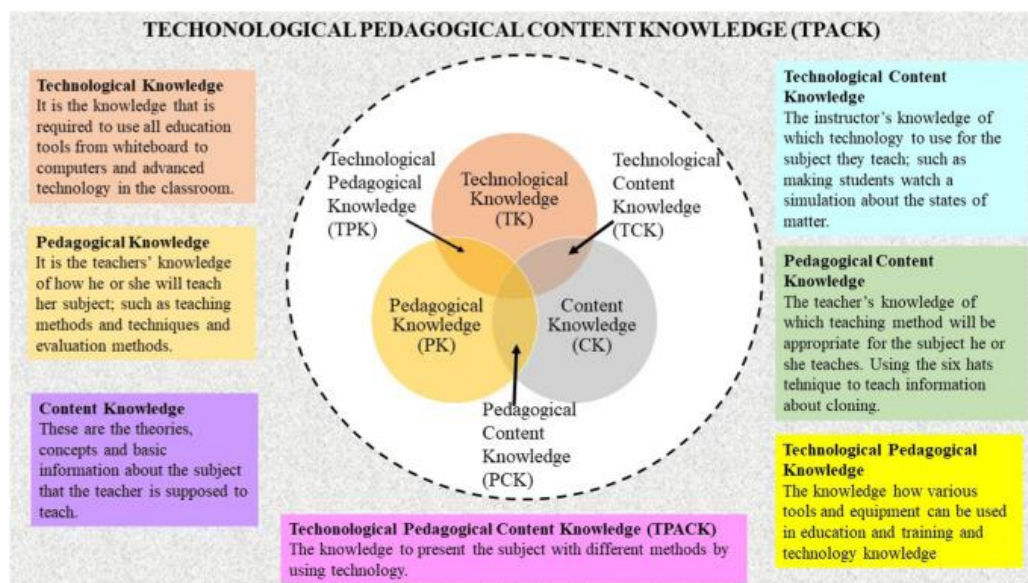
Figure 2. The TPACK Framework in Learning (Çam & Erdamar Koç, 2021)

Having a good understanding of Pedagogical and Technological Knowledge allows teachers to become more competent in addressing the challenges of learning in the digital era and utilizing technology as an effective tool to support student development. Developing Technological Pedagogical Knowledge (TPK) indeed requires a deep understanding of the benefits, potential, and limitations of specific technologies. Here are some things to consider in developing TPK: (1). Knowledge of Tools and Applications: Teachers need to have a good understanding of various technological tools and applications available. They should understand how each tool works, its functions, and how the tool can support the learning process. (2). Evaluation of Technology Effectiveness: Teachers need to be able to evaluate the effectiveness of technology in the context of learning. This includes the ability to identify how technology can enhance student understanding and to what extent technology can achieve learning goals. (3). Understanding Technology Limitations: Teachers should be aware of the limitations of technology. While technology offers many advantages, it also has certain limitations. Teachers need to consider factors such as access availability, technology reliability, and student training needs. (4). Relevance to Learning Content: Developing TPK also requires an understanding of how technology can be integrated with learning content. Teachers need to think about how to use technology to support student understanding of specific concepts in subjects. As a form of effort in training and developing oneself, teachers need to continuously engage in training and self-development related to technology. Technological development is ongoing, and teachers need to constantly update their knowledge and skills to remain relevant.

1. By understanding technology's benefits, potential, and limitations, teachers can develop strong TPK, improving their ability to integrate technology into the learning process effectively. Effective development of Technological Pedagogical Knowledge (TPK) requires a forward-looking, creative and open-minded approach to technology applications. Here are some important points to pay attention. Understanding the benefits, potential, and limitations of technology is crucial for teachers to develop strong Technological Pedagogical Knowledge (TPK) and effectively integrate technology into the learning process (Setyosari, 2018). The TPCK framework can help bridge the gap between educational technology and the teaching process, promoting the combination of pedagogical strategies and technologies (Lavrysh, 2019). Teachers' TPK, along with their self-efficacy, outcome expectations, and interest, influences their technology integration behaviors (Dikmen & Demirer, 2022). The integration of techno-pedagogical approach, which includes TPK, is essential for educators to cater to the needs of 21st-century learners (Yusof et al., 2019).

2. Forward-looking: Quality TPK must involve developing foresight, namely the teacher's ability to predict trends and technological developments that may affect the world of education. This allows teachers to design relevant learning strategies and adapt to changes. The development of Technological Pedagogical Content Knowledge (TPCK) is crucial for teachers to effectively integrate technology into their teaching practices (Kadijevich, 2012). This knowledge enables teachers to predict trends and technological developments that may affect education, allowing them to design relevant learning strategies and adapt to changes (Trevisan & De Rossi, 2020).

3. Creativity in Using Technology: Teachers need to develop creativity in designing and implementing learning strategies using technology. The use of technology is not only limited to using tools but also to how technology can inspire and increase students' creativity in understanding the material. Qizi (2020) further underscores the importance of creative activities in elementary technology classes, suggesting the use of various methods and tools to enhance students' creativity

4. Oriented towards improving learning: Using technology in the TPK context must always be centred on improving student learning. Teachers must be able to consider how technology can support students' understanding, provide better learning experiences, and stimulate their interests. The use of technology in the TPK context should be focused on improving student learning, as emphasized (Angeli & Veletsianos, 2010)

5. Clear Learning Goals: Technology must be directed toward achieving specific learning goals. Teachers must be able to plan the use of technology with clear objectives related to the subject matter being taught. The importance of clear learning goals in the use of technology in education is emphasized in several studies. Adler & Wilcox (1985) say stress the need for careful planning and the accurate grasp of curriculum standards, respectively.

6. Openness to Innovation: Teachers need to be open to innovation and changes in the use of technology. The ability to adopt and adapt to new technology can improve the quality of learning. Teachers play a key role in this process, as they need to be open to innovation and changes in technology (Barkoczi, 2022). This requires them to be creative and innovative in their instructional strategies, and to integrate technology into their teaching.

Implementing technology in an educational context can influence pedagogical decisions or decisions related to the teaching and learning process. The relationship between technology implementation and pedagogical decisions can be described as follows: (1) Determination of Teaching Methods: Technology implementation can influence the teaching methods used by teachers. Technology often enables more interactive, collaborative, and adaptive approaches to learning. The implementation of technology in education has a significant impact on teaching methods, as it enables more interactive, collaborative, and adaptive approaches to learning (Altınay-Gazi & Altınay-Aksal, 2017); (2) Selection of Learning Content: Teachers can select or arrange learning content based on available technological capabilities. Technology enables wider access to various learning materials, including digital resources and multimedia content'. Grasha & Yangarber-Hicks (2000) underscores the importance of integrating teaching and learning styles with instructional technology, which can be achieved through the use of various digital resources; (3) Support of Learning Differentiation: Technology can support pedagogical decisions in implementing learning differentiation. Teachers can use technology tools and applications to provide material tailored to each student's level of understanding and learning speed. Research has shown that technology can support pedagogical decisions in implementing learning differentiation (Beasley & Imbeau, 2015; Kendal & Stacey, 2001). For example, the use of a hand computer algebra system can lead to different differentiation competencies in students, depending on the teacher's approach; (4) Evaluation and Monitoring Progress: Technology allows teachers to evaluate and monitor student progress more efficiently. Digital learning management systems, measurement applications, and online evaluation tools can help teachers make pedagogical decisions based on student progress data. Theall & Franklin (2001) both emphasize the potential of technology to streamline these processes, with Sandnes specifically

highlighting the use of open tools to track and manage student progress. 5) Classroom Management: Technology can also influence how teachers manage the classroom. Digital learning management tools can help with administrative tasks, communication with students and parents, and preparation of activity schedules. Ayyildiz (2020) both emphasize the role of digital technologies in classroom management. Ayyildiz (2020) further underscores the positive impact of technology on classroom management, particularly in terms of monitoring student behavior and performance

Technology integration can support pedagogical decisions aimed at developing 21st-century skills. Teachers can design learning that emphasizes problem-solving, collaboration, communication, and digital literacy skills. Technology implementation allows teachers to be more creative in designing learning experiences. The selection and use of various digital tools can stimulate the creativity of teachers and students. Therefore, wise implementation of technology can be a significant factor in shaping pedagogical decisions and increasing the effectiveness of teaching and learning. Technological Pedagogical Knowledge (TPK) is part of the TPCK (Technological Pedagogical Content Knowledge) framework developed by Mishra & Koehler (2006). TPK involves teachers understanding how technology can be used effectively in educational contexts. TPK consists of two main dimensions: (1). Knowledge of Technology (Technological Knowledge): This includes understanding the tools, applications, and technological solutions that can be used in learning. Teachers must know how to effectively use various hardware, software, and digital resources; (2). Pedagogical Knowledge (PK): This includes understanding the principles of teaching and learning. Teachers with good TPK know how to operate technology and have a deep understanding of effective teaching strategies, design engaging lessons, and support students' learning needs. Jones & Moreland (2004) and Heitink et al., (2017) both emphasize the need for teachers to develop a strong knowledge base for teaching technology, with Heitink et al., (2017) specifically focusing on the importance of teachers' reasoning about how technology can support specific pedagogical strategies. TPK integration requires teachers to combine knowledge of technology and pedagogical knowledge well. This includes designing and implementing teaching strategies that utilize technology to support learning goals and student needs. With TPK, teachers can identify how technology can effectively enhance learning, facilitate student engagement, and create innovative learning environments. In this context, teachers must continuously update their knowledge about technological developments and engage them productively in learning experiences.

2.2. Implications of TPK for Educators

The implications of TPK (Technological Pedagogical knowledge) for educators are very important in an era where technology plays a central role in education. Technology has fundamentally changed the educational landscape, opening up new opportunities, challenges, and responsibilities for educators. Therefore, a deep understanding of using technology effectively in a learning context is the key to educating the younger generation. First of all, we need to understand what TPK means. TPK is one of three knowledge domains in the TPACK (Technological Pedagogical Content Knowledge) model, developed by Mishra & Koehler in 2006. TPK refers to knowledge about how to use technology in an effective learning context. This involves an understanding of available technology tools and resources and the ability to integrate these technologies into learning designs that suit student needs and learning goals.

In modern education, where technology has become an integral part of everyday life, having a strong TPK has become increasingly important for educators. A strong implication of TPK for educators is that they must continually update their knowledge and skills in using technology and understand how technology can enhance students' learning experiences. The integration of Techno-Pedagogical Content Knowledge (TPK) is crucial for educators, as it requires them to continually update their knowledge and skills in using technology to enhance students' learning experiences (Yusof, 2019; Lavrysh, 2019; Matherson et al., 2014). This is particularly important in the current educational landscape, where technology is pervasive and students are increasingly engaged with it (Matherson,

2014). However, there is a recognized gap in teachers' knowledge and practice with TPK, which can be addressed through sustained professional development (Matherson et al., 2014). The use of adaptive electronic learning environments can also play a role in developing teachers' expertise in TPK(Angeli & Veletsianos, 2010). This involves understanding the various technology tools and platforms available and how technology can be integrated into the curriculum to enhance conceptual understanding, facilitate collaboration, and promote student-centred learning. One of the concrete implications of TPK for educators is the need to continue learning and developing skills in using technology. This includes understanding how to use different software and hardware and how technology can be used to design engaging and meaningful learning experiences. Educators need to continually update their knowledge of the latest developments in educational technology and collaborate with their colleagues to share best practices in the use of technology in the classroom.
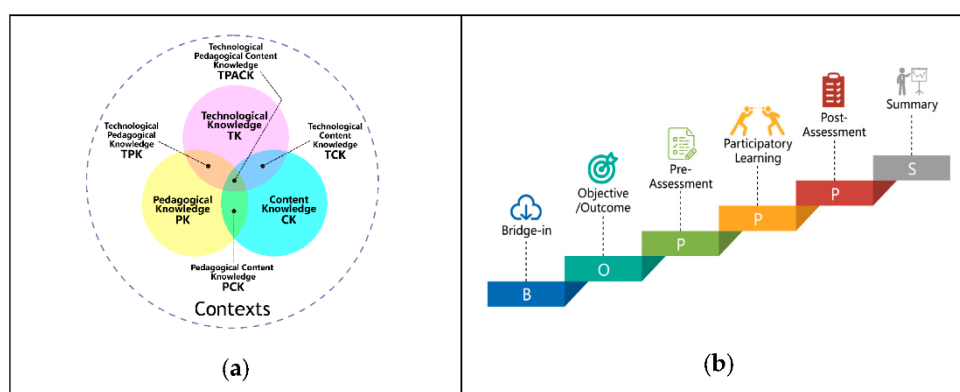

Figure 2. TPK for educator (S. Zhang & Zhou, 2023)

Additionally, educators need to understand how technology can be used to meet the needs of diverse students. With various technological tools and resources, educators can customize the learning experience to suit individual student needs. For example, for students with learning difficulties, technology can provide additional accessibility through voice captioning or live translation. On the other hand, for students who learn through practical experience, technology can be used to create simulations or interactive learning games. In addition to understanding how to use technology to enhance students' learning experiences, educators must also understand the ethical and social implications of technology use. In an era where information can be easily accessed via the internet and social media, educators must teach students the importance of critical thinking, evaluating information, and participating positively in the digital world. This involves providing knowledge about using technology wisely and guiding students to develop critical thinking skills and ethics in using technology.

Additionally, educators need to understand how technology can facilitate collaboration and communication between students and between students and educators. In an increasingly connected educational environment, technology can enable students to work together on group projects, share ideas, and provide feedback to each other online. Research indicates that technology can significantly impact interactions between educators and students, both in traditional and virtual classrooms (Harper, 2018). Electronic collaboration, facilitated by technology, can be a powerful tool for educators to work together on teaching and learning issues (Caskey, 2000). The use of new technologies, such as Google Docs and Prezi Meeting, can enhance student skills in communication, critical thinking, and collaboration (Clapp & Swenson, 2013). Furthermore, classroom conversation and dialogue, particularly in technology education, can greatly enhance learning (Fox-turnbull, 2010). This requires an understanding how to select and manage appropriate collaboration tools and effectively facilitate discussion and collaboration in a virtual environment. Apart from the practical implications of TPK for educators, there are also broader conceptual implications. Technology in education is not only about replacing traditional learning methods with digital tools but also about changing the way we

understand the learning process itself. With technology, learning is no longer limited to physical classrooms but can occur anywhere and anytime. This challenges traditional paradigms of what constitutes an effective learning environment and requires educators to rethink their role in supporting ongoing learning outside the classroom.

Additionally, the use of technology in education also raises questions about equality of access. While technology can be a powerful tool for increasing educational accessibility for many students, there is also a risk that technology can strengthen the digital divide between students with adequate access to technology and those without. Therefore, educators must pay attention to how they use technology in the classroom to ensure that all students have equal opportunities to learn and develop. By developing TPK, educators can become better prepared and effective in facing educational demands increasingly driven by technology (Koehler et al., 2013a). The TPCK (Technological Pedagogical Content Knowledge) framework assists teacher professional development by integrating knowledge about technology, pedagogy, and content. With a holistic understanding of these three dimensions of knowledge, teachers can create better learning experiences that suit students' needs. Several important points related to the TPCK framework involve knowledge integration, understanding context, the ability to design learning, focusing on student learning experiences, technological developments, interdisciplinary collaboration, creative thinking, and innovative solutions. By internalizing the TPCK concept, teachers can be better prepared to face the challenges and opportunities of using technology as an integral part of the learning process. The TPCK framework, which encompasses knowledge integration, understanding context, the ability to design learning, focusing on student learning experiences, technological developments, interdisciplinary collaboration, creative thinking, and innovative solutions, is a crucial tool for teachers in integrating technology into the learning process (Guerra et al., 2018; Lavrysh, 2019; Niess, 2017). It is particularly important for science teachers, as it can help them develop innovative lessons (Guerra et al., 2018). The framework is dynamic and requires continued practice in integrating technologies (Niess, 2016). When effectively implemented, the TPCK framework can bridge the gap between educational technology and the situational educational process, leading to improved student outcomes (Lavrysh, 2019).TPCK practice in learning involves the integrated use of knowledge about Technology (TK), Pedagogy (PK), and Content (CK). The application of TPCK is not a rigid formula but a dynamic approach that requires creativity, reflection, and the teacher's active involvement in the learning process. To integrate TPCK into learning, teachers must manifest several interrelated knowledge types. The following are the types of knowledge that teachers need to demonstrate.

2.2. TPK (Technological Pedagogical Knowledge) in learning models

Technology has become an integral part of the learning process in the modern era. In this context, understanding the concept of TPK (Technological Pedagogical Knowledge) is very important. TPK is one of the key elements in a learning model that combines technology, pedagogy, and subject knowledge to create an effective and meaningful learning environment for students. PK refers to teachers' understanding of how to use technology to support student learning in educational contexts. It involves the teacher's ability to select, use, and integrate various technological tools and resources relevant to specific learning objectives. In addition, TPK also includes an understanding of how technology can be used to facilitate active, collaborative, and interesting learning processes for students. The TPACK framework, which combines technology, pedagogy, and content knowledge, has been shown to be effective in various educational settings. Meileni et al. (2022) and Lavrysh (2019) both highlight the importance of this framework in enhancing student learning, with Meileni et al. (2012) specifically emphasizing the need for interactive digital learning. Dee-Chan (2020) further underscore the significance of TPACK in creating effective learning environments, particularly in medical education and initial teacher training.

In an effective learning model, TPK works with two other elements: pedagogical knowledge (PK) and content knowledge (CK). PK refers to a teacher's understanding of learning principles and effective

teaching strategies. This includes understanding how to present learning materials, designing appropriate learning activities, and evaluating student understanding. Meanwhile, CK refers to the teacher's knowledge about the content or subject matter. When TPK, PK, and CK work together, they form what is known as TPACK (Technological Pedagogical Content Knowledge). TPACK describes the complex interactions between technology, pedagogy, and content in a learning context. The concept of Technological Pedagogical Content Knowledge (TPACK) is a critical framework for effective teaching with technology, as it involves the complex interaction of content, pedagogy, and technology (Koehler et al., 2013b). This interaction is essential for successful technology integration in teaching, and the development of TPACK by teachers is crucial in this process. TPACK can be visualized as a two-dimensional space, with educators placing their teaching episodes within this space to determine the best approach (Farah et al., 2016). Teachers with a strong understanding of TPACK can design and implement meaningful and in-depth learning experiences for their students. One important aspect of TPK is the ability of teachers to select and evaluate appropriate technological tools and resources for use in their learning. This involves a deep understanding of the different types of technology available and the ability to assess the suitability of that technology for students' learning goals and needs. Teachers need to consider factors such as the accessibility, reliability, and relevance of technology in their learning context.

Effective TPK, PK, and CK integration to form TPACK requires a holistic understanding of how technology can substantially support the learning process. Teachers with a strong understanding of TPACK can recognize the various technology tools and resources available and evaluate the advantages and disadvantages of each in their specific learning context. In selecting technology tools and resources, teachers need to consider their students' individual characteristics, learning styles, and specific learning needs. For example, in a classroom with students with special needs, teachers may need to select technology tools and resources that can be adapted or adapted to suit the needs of those students.
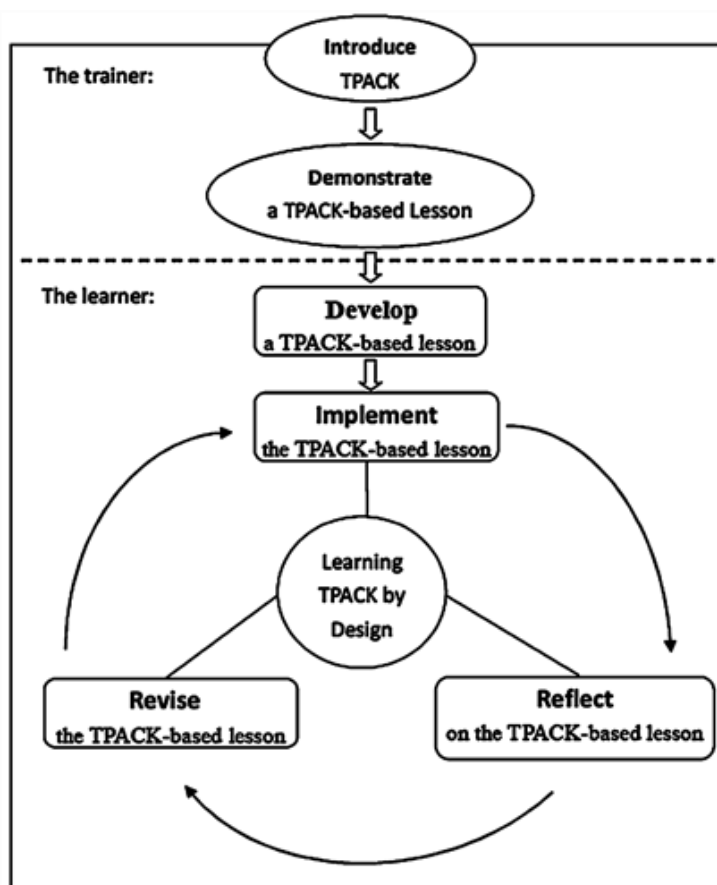

Figure 3. TPACK by learning design (W. Zhang & Tang, 2021)

Apart from that, teachers must also pay attention to the availability of technological infrastructure in their schools. Even though there are various sophisticated technological tools and resources, not all schools have equal access to this technology. Therefore, teachers must be creative in utilizing available resources and finding solutions that suit their situation. Furthermore, teachers must consider several factors in evaluating technology's suitability for learning goals and student needs. First, they must ensure that the technology chosen supports specific learning objectives and can integrate course content well. For example, if the learning objective is to teach mathematical concepts, teachers must choose tools or applications that can facilitate understanding of these concepts through interaction and creativity. Second, teachers must consider the security and privacy aspects of using technology. This is especially important when engaging students in online activities or using platforms requiring registration and personal data collection. Teachers must ensure their technology is safe and complies with applicable privacy policies. In addition, teachers must also consider practical factors such as cost and technical support when selecting and evaluating technology. Some technologies may require expensive subscription or licensing fees, while others may require additional training or technical support to implement successfully. Therefore, teachers need to thoroughly consider all these factors before making decisions about the use of technology in their learning.

By considering all of these considerations, teachers can select and evaluate technology tools and resources wisely, thereby supporting the achievement of learning goals and effectively meeting students' needs. In doing so, they can create meaningful and immersive learning experiences for their students, harnessing the potential of technology to improve the quality of education and prepare future generations to face the challenges of an increasingly connected and changing world.

4. CONCLUSION

The conclusion of this study highlights the importance of TPCK (Technological Pedagogical and Content Knowledge) competency for teachers. Teachers with high levels of TPCK are able to create more meaningful and in-depth learning experiences for students by effectively integrating technology into their teaching. The school context and professional culture also significantly influence the development of TPCK; teachers working in environments that support innovation and collaboration tend to have higher TPCK levels. Developing TPCK is an ongoing process that requires a long-term commitment from both teachers and educational institutions, with continuous training, teacher collaboration, and access to technological resources being key strategies. This study implies that the development of TPCK should be strengthened through a supportive and innovative school culture, with school leaders fostering an environment that encourages technological experimentation in teaching.

REFERENCES

Adler, K., & Wilcox, G. B. (1985). Educators Using high Technology must set Objectives. *The Journalism Educator*, *40*(2), 21–24. https://doi.org/10.1177/107769588504000207

Altınay-Gazi, Z., & Altınay-Aksal, F. (2017). Technology as Mediation Tool for Improving Teaching Profession in Higher Education Practices. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(3). https://doi.org/10.12973/eurasia.2017.00644a

Angeli, C., & Veletsianos, G. (2010). An Adaptive Electronic Learning Environment to Develop Teacher Expertise and ICT-Related Technological Pedagogical Content Knowledge (ICT-TPCK). In *Affective, Interactive and Cognitive Methods for E-Learning Design* (pp. 173–186). IGI Global. https://doi.org/10.4018/978-1-60566-940-3.ch009

Anif, S. (2012). Implementasi Fungsi Manajemen Pendidikan terhadap Profesionalitas Guru (Sebuah Kajian Implementasi Sertifikasi Guru dalam Jabatan). *Varia Pendidikan*, *24*(1).

Atabek, O. (2019). Challenges In Integrating Technology Into Education. *Turkish Studies - Information Technologies and Applied Sciences*, *14*(ITAS Volume 14 Issue 1), 1–19. https://doi.org/10.7827/TurkishStudies.14810

Ayyildiz, P. (2020). *Technology for Classroom Management*. https://doi.org/10.4018/978-1-7998-1408-5.ch003

Barkoczi, N. (2022). *The Impact Of New Technologies Diffusion On Open Educational Practices*. 412–422. https://doi.org/10.15405/epes.22032.41

Baslanti, U. (2006). Challenges in Preparing Tomorrows Teachers To Use Technology: Lessons To Be Learned From Research. *The Turkish Online Journal of Educational Technology*, *5*(1).

Beasley, J. G., & Imbeau, M. B. (2015). *Differentiation 2.0: Using the Tools of Technology to Meet the Needs of All Learners* (pp. 287–310). https://doi.org/10.4018/978-1-4666-6489-0.ch014

Bingimlas, K. A. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. In *Eurasia Journal of Mathematics, Science and Technology Education* (Vol. 5, Issue 3). https://doi.org/10.12973/ejmste/75275

Çam, Ş. S., & Erdamar Koç, G. (2021). Technological Pedagogical Content Knowledge Practices in Higher Education: First Impressions of Preservice Teachers. *Technology, Knowledge and Learning*, *26*(1), 123–153. https://doi.org/10.1007/s10758-019-09430-9

Caskey, W. H. (2000). Electronic Collaboration: A Practical Guide for Educators. *Journal of Research Administration*, *1*.

Clapp, B., & Swenson, J. (2013). The Collaborative Classroom: New Technology Brings New Paradigm. *Atlantic Marketing Journal Atlantic Marketing Journal Atlantic Marketing Journal Atlantic Marketing Journal Special*, *2*(1).

Dee-Chan, R. (2020). Introducing the Technological Pedagogical Content Knowledge (TPACK) Framework to the University of Santo Tomas Faculty of Medicine and Surgery. *Journal of Medicine, University of Santo Tomas*, *4*(1), 474–476. https://doi.org/10.35460/2546-1621.2019-0054

Dikmen, C. H., & Demirer, V. (2022). The role of technological pedagogical content knowledge and social cognitive variables in teachers' technology integration behaviors. *Participatory Educational Research*, *9*(2), 398–415. https://doi.org/10.17275/per.22.46.9.2

Farah, M., Ireson, G., & Richards, R. (2016). A Content, Pedagogy and Technology [CPT] Approach to TPACK. *Imperial Journal of Interdisciplinary Research (IJIR*, *2*(12).

Fayanto, S., Erniwati, E., & Sabilu, M. (2023). Analysis of the Inquiry Learning Model with ICT Support for Science Learning: A Literature Review. *Proceedings Series of Educational Studies*, 153-169.

Feladi, V., & Puspitasari, H. (2019). Analisis Profil Tpack Guru TIK SMA di Kecamatan Pontianak Kota. *Jurnal Edukasi Dan Penelitian Informatika (JEPIN)*, *4*(2). https://doi.org/10.26418/jp.v4i2.29616

Ferreras-Fernández, T., Martín-Rodero, H., García-Peñalvo, F. J., & Merlo-Vega, J. A. (2016). The systematic review of literature in LIS. *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality*, 291–296. https://doi.org/10.1145/3012430.3012531

Fox-turnbull, W. (2010). The Role of Conversation in Technology Education. *Design and Technology Education*, *15*(1).

Fredy, F., & Hamsinah Day, W. O. S. (2021). Strategi Pengembangan Kompetensi Guru Sekolah Dasar. *Prima Magistra: Jurnal Ilmiah Kependidikan*, *3*(1), 30–40. https://doi.org/10.37478/jpm.v3i1.1312

Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., Clair St., L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of inservice science teachers. *TechTrends*, *53*(5). https://doi.org/10.1007/s11528-009-0328-0

Grasha, A. F., & Yangarber-Hicks, N. (2000). Integrating Teaching Styles and Learning Styles with Instructional Technology. *College Teaching*, *48*(1), 2–10. https://doi.org/10.1080/87567550009596080

Guerra, C., Moreira, A., & Vieira, R. M. (2018). *A Design Framework for Science Teachers' Technological Pedagogical Content Knowledge Development*. https://doi.org/10.1007/978-3-319-61121-1_17

Harper, B. (2018). Technology and Teacher–Student Interactions: A Review of Empirical Research. *Journal of Research on Technology in Education*, *50*(3), 214–225. https://doi.org/10.1080/15391523.2018.1450690

Harris, J. B., & Hofer, M. J. (2011). Technological Pedagogical Content Knowledge (TPACK) in Action.

Journal of Research on Technology in Education, *43*(3), 211–229. https://doi.org/10.1080/15391523.2011.10782570

Heitink, M., Voogt, J., Fisser, P., Verplanken, L., & Van Braak, J. (2017). Eliciting teachers' technological pedagogical knowledge. *Australasian Journal of Educational Technology*, *33*(3). https://doi.org/10.14742/ajet.3505

Jiménez Sierra, Á. A., Ortega Iglesias, J. M., Cabero-Almenara, J., & Palacios-Rodríguez, A. (2023). Development of the teacher's technological pedagogical content knowledge (TPACK) from the Lesson Study: A systematic review. In *Frontiers in Education* (Vol. 8). https://doi.org/10.3389/feduc.2023.1078913

Jones, A., & Moreland, J. (2004). Enhancing Practicing Primary School Teachers' Pedagogical Content Knowledge in Technology. *International Journal of Technology and Design Education*, *14*(2), 121–140. https://doi.org/10.1023/B:ITDE.0000026513.48316.39

Kadijevich, D. M. (2012). TPCK framework: assessing teachers' knowledge and designing courses for their professional development. *British Journal of Educational Technology*, *43*(1). https://doi.org/10.1111/j.1467-8535.2011.01246.x

Kendal, M., & Stacey, K. (2001). The impact of teacher privileging on learning differentiation with technology. *International Journal of Computers for Mathematical Learning*, *6*(2). https://doi.org/10.1023/A:1017986520658

Koehler, M. J., Mishra, P., & Cain, W. (2013a). What is Technological Pedagogical Content Knowledge (TPACK)? *Journal of Education*, *193*(3). https://doi.org/10.1177/002205741319300303

Koehler, M. J., Mishra, P., & Cain, W. (2013b). What is Technological Pedagogical Content Knowledge (TPACK)? *Journal of Education*, *193*(3), 13–19. https://doi.org/10.1177/002205741319300303

Koh, J. H. L. (2020). Three approaches for supporting faculty technological pedagogical content knowledge (TPACK) creation through instructional consultation. *British Journal of Educational Technology*, *51*(6). https://doi.org/10.1111/bjet.12930

Kramarski, B., & Michalsky, T. (2009). Three metacognitive approaches to training pre-service teachers in different learning phases of technological pedagogical content knowledge. *Educational Research and Evaluation*, *15*(5), 465–485. https://doi.org/10.1080/13803610903444550

Lavrysh, Y. (2019). Effective integration of educational technologies in terms of TPCK framework at technical university. *International Journal of Pedagogy, Innovation and New Technologies*, *6*(2), 33–39. https://doi.org/10.5604/01.3001.0013.6824

Liu, S.-H. (2013). Exploring the Instructional Strategies of Elementary School Teachers When Developing Technological, Pedagogical, and Content Knowledge via a Collaborative Professional Development Program. *International Education Studies*, *6*(11). https://doi.org/10.5539/ies.v6n11p58

Lowe, N. K. (2009). Systematic Literature Reviews. *Journal of Obstetric, Gynecologic & Neonatal Nursing*, *38*(4), 375–376. https://doi.org/10.1111/j.1552-6909.2009.01033.x

Mairisiska, T., Sutrisno, S., & Asrial, A. (2014). Pengembangan Perangkat Pembelajaran Berbasis TPACK pada Materi Sifat Koligatif Larutan untuk Meningkatkan Keterampilan Berpikir Kritis Siswa. *Edu-Sains: Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam*, *3*(1). https://doi.org/10.22437/jmpmipa.v3i1.1764

Manfra, M. M., & Hammond, T. C. (2008). Teachers' instructional choices with student-created digital documentaries: Case studies. *Journal of Research on Technology in Education*, *41*(2). https://doi.org/10.1080/15391523.2008.10782530

Martin, B. (2015). Successful Implementation of TPACK in Teacher Preparation Programs. *International Journal on Integrating Technology in Education*, *4*(1), 17–26. https://doi.org/10.5121/ijite.2015.4102

Matherson, L. H., Wilson, E. K., & Wright, V. H. (2014). Need TPACK? Embrace Sustained Professional Development.: EBSCOhost. *Delta Kappa Gamma Bulletin*, *81*(1).

Meileni, H., Satriadi, I., Oktapriandi, S., Apriyanty, D., Prasetya, D. H., Prasetyo, A., & Faraby, M. (2022). *The Implementation of Tpack Framework Based Interactive Digital Learning for Cruise Vocational School (SMKP) Sinar Bahari Palembang*. https://doi.org/10.2991/ahe.k.220205.049

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. In *Teachers College Record* (Vol. 108, Issue 6). https://doi.org/10.1111/j.1467-9620.2006.00684.x

Newkirk, T. (2007). Differential Analysis Of Problems Faced By Elementary School Teachers. *Review of Research*, *84*(6), 539–548. https://doi.org/10.58680/la20075670

Niess, M. L. (2012). Teacher Knowledge for Teaching with Technology. In *Educational Technology, Teacher Knowledge, and Classroom Impact* (pp. 1–15). IGI Global. https://doi.org/10.4018/978-1-60960-750-0.ch001

Niess, M. L. (2017). *Technological Pedagogical Content Knowledge (TPACK) Framework for K-12 Teacher Preparation*. IGI Global. https://doi.org/10.4018/978-1-5225-1621-7

Nugroho, A. M., Wardono, Waluyo, S. B., & Cahyono, A. N. (2019). Kemampuan Berpikir Kreatif ditinjau dari Adversity Quotient pada Pembelajaran TPACK. *In PRISMA, Prosiding Seminar Nasional Matematika*, 2.

Oliver, M. (2011). Handbook of technological pedagogical content knowledge (TPCK) for educators. *Learning, Media and Technology*, *36*(1), 91–93. https://doi.org/10.1080/17439884.2011.549829

Omoso, E., & Odindo, F. (2020). TPACK in Teacher Education: Using Pre-Service Teachers' Self-Reported TPACK To Improve Pedagogic Practice. *International Journal of Education and Research*, *8*(5).

Owings, K., & Hofer, M. (2007). Content-Specific Technology Infusion Program in Pre-Service Teacher Education: The Technology Leadership Cadre (TLC). *Social Studies Research and Practice*, 2(1), 117–127. https://doi.org/10.1108/SSRP-01-2007-B0012

Palopo, I. (2023). Analysis of Pedagogic Content Knowledge Technology (TPCK) Capabilities of Teachers in Senior High School. *Jurnal Kependidikan*, *12*(4).

Putrawangsa, S., & Hasanah, U. (2018). Integrasi Teknologi Digital Dalam Pembelajaran Di Era Industri 4.0 Kajian dari Perspektif Pembelajaran Matematika. *Jurnal Tatsqif*, *16*(1).

Putriani, I. (2023). Analysis Of Technological Pedagogical Content Knowledge (TPACK) of Elementary School Teacher Education Students In Developing Merdeka Curriculum Lesson Plans. *JOSAR (Journal of Students Academic Research), 8*(1), 171–179. https://doi.org/10.35457/josar.v9i1.2782

Rahmadi, I. F. (2019). Technological Pedagogical Content Knowledge (TPACK): Kerangka Pengetahuan Guru Abad 21. *Jurnal Pendidikan Kewarganegaraan*, *6*(1). https://doi.org/10.32493/jpkn.v6i1.y2019.p65-74

Ramli, A., Rahmatullah, R., Inanna, I., & Dangnga, T. (2018). Peran media dalam meningkatkan efektivitas belajar. *Prosiding Seminar Nasional Lembaga Pengabdian Kepada Masyarakat UNM*.

Ryan, T., & Bagley, G. (2015). Nurturing the integration of technology in education. *Journal of Theory & Practice in Education*, *11*(1).

Samsudin, N., & Ghani, M. F. A. (2020). Teacher Technological Leadership: Realising Potentials and Practices. *Proceedings of the 3rd International Conference on Research of Educational Administration and Management (ICREAM 2019)*. https://doi.org/10.2991/assehr.k.200130.138

Sanjar Qizi, U. M. (2020). Methods And Tools For Making Student `S Creative Activity In Elementary Technology Classes. *The American Journal of Social Science and Education Innovations*, *02*(11), 575–578. https://doi.org/10.37547/tajssei/Volume02Issue11-99

Setyosari, P., Slamet, T. I., Ulfa, S., & Oktaviani, H. I. (2018). Technology-Supported Learning Environment to Improve Higher-Order Thinking Experience of Social Science Teachers TPCK for the 21st Century Learning. *Proceedings of the 2nd International Conference on Learning Innovation*, 41–46. https://doi.org/10.5220/0008407500410046

Sheffield, R., Dobozy, E., Gibson, D., Mullaney, J., & Campbell, C. (2015). Teacher education students using TPACK in science: a case study. *Educational Media International*, *52*(3). https://doi.org/10.1080/09523987.2015.1075104

Shulman, L. S. (2019). Those who understand: Knowledge growth in teaching. *Profesorado*, *23*(3). https://doi.org/10.30827/profesorado.v23i3.11230

Sointu, E., Hirsto, L., & Murtonen, M. (2019). Editorial Transforming Higher Education Teaching and Learning Environments – Introduction to the Special Issue. *International Journal of Learning, Teaching and Educational Research*, *18*(13), 1–6. https://doi.org/10.26803/ijlter.18.13.1

Sole, F. B., & Anggraeni, D. M. (2018). Inovasi Pembelajaran Elektronik dan Tantangan Guru Abad 21. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *2*(1), 10. https://doi.org/10.36312/e-saintika.v2i1.79

Tanak, A. (2018). Designing TPACK-based course for preparing student teachers to teach science with technological pedagogical content knowledge. *Kasetsart Journal of Social Sciences*. https://doi.org/10.1016/j.kjss.2018.07.012

Theall, M., & Franklin, J. (2001). Using Technology to Facilitate Evaluation. *New Directions for Teaching and Learning*, *2001*(88), 41–50. https://doi.org/10.1002/tl.36

Trevisan, O., & De Rossi, M. (2020). Student teachers' pedagogical reasoning in TPCK-based design tasks. A multiple case study. *Qwerty. Open and Interdisciplinary Journal of Technology, Culture and Education*, *15*(2), 1–10. https://doi.org/10.30557/QW000031

Tunjera, N., & Chigona, A. (2020). Assisting teacher educators with constructive technology integration into curriculum delivery in the 21st Century. *Conference of the South African Institute of Computer Scientists and Information Technologists 2020*, 12–18. https://doi.org/10.1145/3410886.3410900

Wayan Maba, Ida Bagus Nyoman Mantra, & Ida Ayu Made Sri Widiastuti. (2023). Teachers Of 21st Century: Teachers' Roles, Strategies Innovation And Challenges. *International Journal of Social Science*, *2*(6), 2405–2412. https://doi.org/10.53625/ijss.v2i6.5473

Williams, R. I., Clark, L. A., Clark, W. R., & Raffo, D. M. (2021). Re-examining systematic literature review in management research: Additional benefits and execution protocols. *European Management Journal*, *39*(4), 521–533. https://doi.org/10.1016/j.emj.2020.09.007

Wong, L. H., Chai, C. S., Zhang, X., & King, R. B. (2015). Employing the TPACK framework for researcher-teacher co-design of a mobile-assisted seamless language learning environment. *IEEE Transactions on Learning Technologies*, *8*(1). https://doi.org/10.1109/TLT.2014.2354038

Wood, R., & Ashfield, J. (2008). The use of the interactive whiteboard for creative teaching and learning in literacy and mathematics: A case study. *British Journal of Educational Technology*, *39*(1). https://doi.org/10.1111/j.1467-8535.2007.00703.x

Yeh, Y. F., Chan, K. K. H., & Hsu, Y. S. (2021). Toward a framework that connects individual TPACK and collective TPACK: A systematic review of TPACK studies investigating teacher collaborative discourse in the learning by design process. *Computers and Education*, *171*. https://doi.org/10.1016/j.compedu.2021.104238

Yusof, M. M. M., Alias, N. A., Luaran, J. @ E., & Jain, J. (2019). The Integration of Techno-Pedagogical Approach in Teaching and Learning among Lecturers in Public Universities in Malaysia. *International Journal of Academic Research in Business and Social Sciences*, *9*(13). https://doi.org/10.6007/IJARBSS/v9-i13/6258

Yusuf, I., Widyaningsih, S. W., & Purwati, D. (2015). Pengembangan perangkat pembelajaran Fisika Modern berbasis media laboratorium virtual berdasarkan paradigma pembelajaran abad 21 dan Kurikulum 2013. *Pancaran Pendidikan*, *4*(2).

Zhang, S., & Zhou, A. (2023). The Construction and Practice of a TPACK Development Training Model for Novice University Teachers. *Sustainability*, *15*(15), 11816. https://doi.org/10.3390/su151511816

Zhang, W., & Tang, J. (2021). Teachers' TPACK Development: A Review of Literature. *Open Journal of Social Sciences*, *09*(07), 367–380. https://doi.org/10.4236/jss.2021.97027