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Evaluating AI-TPACK in Education: A Qualitative SWOC Analysis of Artificial Intelligence Integration in Teaching and Learning

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Abstract

Recently, artificial intelligence technologies that emulate human capabilities or occupations have emerged as a prominent concern. Research on AI-Technological Pedagogical Content Knowledge (AI-TPACK) has significantly increased. Several educational technology review studies have identified issues and patterns in AI-TPACK research conducted over the past few years. The integration of artificial intelligence technologies globally and their application in educational settings necessitates an evaluation of the existing strengths and weaknesses, as well as the opportunities and challenges they present. Education has partially utilised the potential of artificial intelligence (AI). Teachers must possess specialised technological and pedagogical knowledge regarding AI to successfully incorporate it in education. Nevertheless, this research aims to analyse AI-TPACK in education through SWOC analysis. A qualitative research methodology was employed to elucidate. The current study aims to analyse the strengths, weaknesses, opportunities, and challenges of AI-TPACK. The results indicated that increased knowledge of the strengths, weaknesses, opportunities, and challenges of AI-TPACK improves learners' understanding of the pedagogical benefits of AI. Furthermore, it highlights the necessity for ongoing professional development for educators, ensuring they are well-equipped to navigate the evolving landscape of technology in teaching. By fostering a deeper comprehension of these elements, educational institutions can better prepare both teachers and students for a future increasingly influenced by artificial intelligence.

Keywords: Artificial Intelligence; PCK; TPACK; AI-TPACK; SWOC Analysis

Introduction

The scientific study of artificial intelligence is commonly referred to as AI. It trains computers to learn human behaviours like learning, judgement, and decision-making, and it uses computers to mimic intelligent human behaviours (Da et al., 2021; Zhang & Lu, 2021). Artificial intelligence (AI) is seen as a significant technological revolution capable of transforming all facets of human existence. It encompasses machine learning, natural language processing, computer vision, and robotics, enabling computers to do activities often necessitating human intellect, including learning, reasoning, problem-solving, and decision-making (Chen, 2018: Chatterjee, 2020). Machine-learning systems and AI are revolutionizing technology, addressing legal, ethical, and sociological concerns related to the potential for

machines to mimic human minds, prompting increased attention from researchers and policymakers (Girasa, 2020). In 1950, Alan Turing articulated the concept of "thinking machines", which has since propelled advancements in artificial intelligence (AI) research across various fields, resulting in a growing body of literature (Zhang & Aslan, 2021). AI tools streamline administrative tasks for teachers, allowing them to focus on teaching and student support, offering virtual tutors and chatbots for accessibility and engagement (Zhang & Lu, 2021). Leveraging technologies like AI can transform education, but ethical concerns must be addressed to ensure efficient use. India's national AI strategy aims to harness AI for economic growth and social inclusion (Ning et. al., 2024).

NITI Aayog, India's government think tank, introduced the AI for All strategy in its artificial intelligence document released on June 4, 2018. Recognizing AI as a transformative technology, this initiative aims to promote AI throughout the country (Roy & Kant, 2018). The National Education Policy 2020 emphasizes the role of AI in education, advocating for its ethical use to personalize learning, automate assessments, and assist educators, thereby enhancing language comprehension and ensuring equitable access to technology (NEP, 2020).

This study, "Evaluating AI-TPACK in Education: A Qualitative SWOC Analysis," identifies a significant gap in integrating artificial intelligence (AI) in education. It critiques existing research for overlooking teachers' knowledge, emphasising the importance of AI-TPACK, which combines technological skills, pedagogical methods, and content knowledge that is essential for educators. The study shifts the focus from whether to use AI to how teachers can effectively incorporate it to enhance student learning. Through a qualitative SWOC (Strengths, Weaknesses, Opportunities, Challenges) analysis, the research maps out teacher preparedness concerning AI, detailing internal strengths and weaknesses, as well as external opportunities and challenges in adopting AI in classrooms. This analysis provides educators, policymakers, and institutions with a structured, evidence-based roadmap for successful and sustainable AI integration, ensuring that innovations are also pedagogically effective.

SWOT analysis has historically been pivotal in strategic planning, evaluating internal strengths and weaknesses against external opportunities and threats. Due to its limitations, organizations are now shifting towards SWOC analysis, which adds challenges to the assessment framework (Aithal & Kumar, 2015). Explores how integrating strategic planning theories and financial strategies can promote sustainability, emphasizing the transition from SWOT to SWOC analysis (N & T, 2020; Singh et al., 2021). SWOT analysis assesses an organization's internal strengths and weaknesses alongside external opportunities and threats but is critiqued for its static nature and lack of focus on the interactions between these factors (Dinkel & Sánchez-Lizaso, 2020). As a response to these limitations, organizations are adopting SWOC analysis, which includes challenges that emerge from internal contexts such as culture and processes, thus providing a more dynamic evaluation.

Background of the Study

Lee Shulman introduced Pedagogical Content Knowledge (PCK) in the mid-1980s, which has evolved over time. The Technological, Pedagogical, and Content Knowledge (TPACK) model adds complexity to teaching by incorporating technology and emphasizing interactions among

key areas. The AI-TPACK framework describes how teachers integrate technology using AI tools in teaching content. Researchers need to focus on creating an AI-enhanced TPACK model (Celik, 2023; Lodge et al., 2023). Shulman's Pedagogical Content Knowledge (PCK) is a concept that integrates subject content and teaching methods to understand how specific topics are organized, adapted, and presented for instruction. It emphasizes the importance of addressing both content and teaching methods to enhance teaching effectiveness, requiring educators to consider their interrelationships. Figure 1 illustrates this relationship.

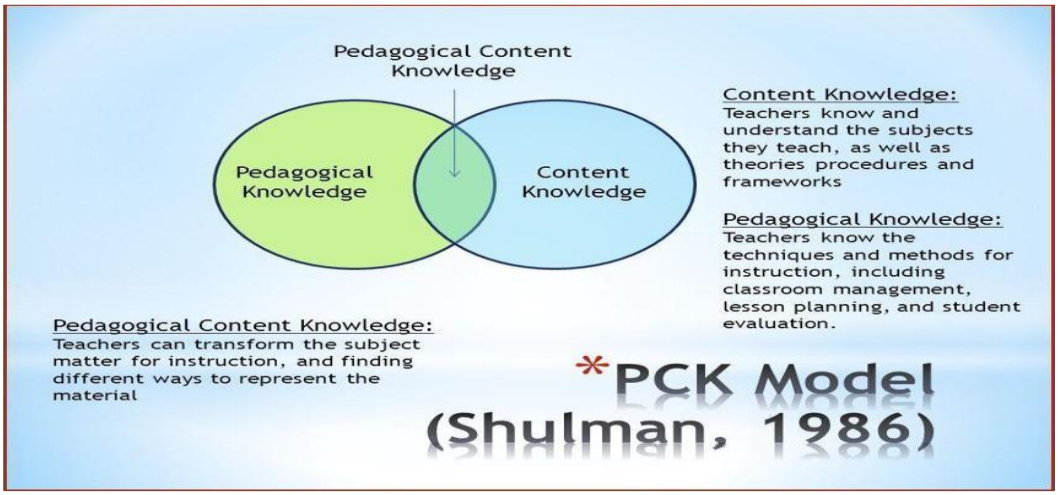

Figure. 1: Illustrates the relationship of Pedagogical Content Knowledge

***Shulman's Pedagogical Content Knowledge Model**

Shulman's PCK framework, a subject-specific approach, guides teachers' actions in classrooms. Extensively researched, it connects students' creative ideas to various fields and daily life. The TPACK model complicates teaching by introducing new knowledge areas and emphasizing interactions between core areas.

The TPACK framework expands upon Shulman's (1987, 1986) explanations of PCK to illustrate how teachers' knowledge of educational technologies and PCK interact to create successful technology-assisted instruction. Various publications have evolved the TPACK framework, with Mishra and Koehler (2006) and Koehler and Mishra (2008) providing comprehensive descriptions. This model (see Figure 2) comprises three primary components of teachers' knowledge: content, pedagogy, and technology. The interactions between these bodies of knowledge are equally significant to the model, encompassing PCK (pedagogical content knowledge), TCK (technological content knowledge), TPK (technological pedagogical knowledge), and TPACK. TPACK integrates content, pedagogy, and technology in education, addressing contemporary demands, understanding subject intricacies, and utilizing technology to enhance students' prior knowledge and learning methodologies.

TPACK improved teacher education, professional development, and technology research. Understanding the complex relationship between technology, teaching methods, and content is crucial. Collaboration between these areas is essential for effective teaching, with lesson needs determining tech use. Positive tech attitudes aid in integration (Kumar, 2021). Rapid technological advancements pose a significant challenge to education technology, necessitating

the integration of content, pedagogy, and technology through TPACK, addressing learning complexity, and helping students organize and build knowledge (Koehler & Mishra, 2009).

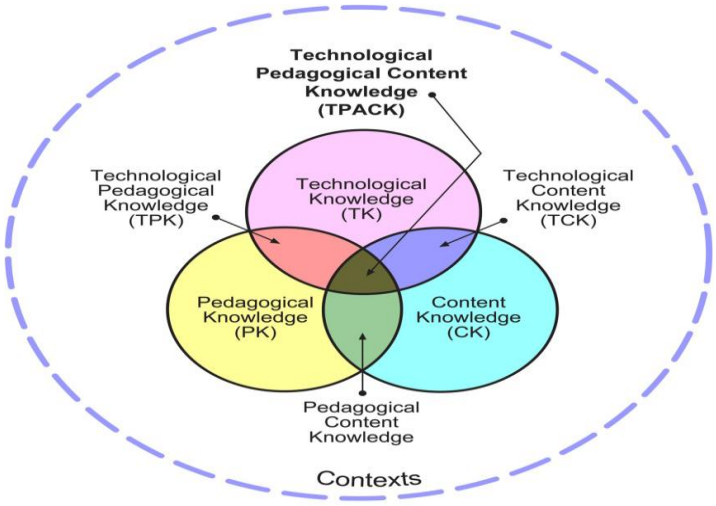

Figure. 2: The TPACK framework and its knowledge components. Source: (http://tpack.org)

TPACK is a framework that outlines the necessary teacher knowledge for effective technology integration in educational contexts. It focuses on the connections between technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) to facilitate teachers' integration of technology into teaching and learning, enhancing the essential qualities of an effective educator.

AI-TPACK represents a specialized amalgamation of pedagogical, disciplinary, and technological knowledge centered on artificial intelligence, distinguishing it from both subject-matter experts and AI specialists. This approach emphasizes the necessity for educators to reassess the interplay between technology, pedagogy, and content, especially given the profound influence of AI on education (Ning et al., 2024). AI-TPACK equips educators with capabilities akin to those of human educators, allowing for autonomous teaching or collaboration with human educators (Adipat, 2021). The integration of AI technology within the TPACK framework has gained traction in teacher education, particularly in enhancing technological integration skills in AI-focused educational contexts (Celik, 2023).

Researchers developed the AI-TPACK framework to assist teachers in integrating AI-based applications into lesson plans, providing educators with equivalent knowledge to human educators, enabling them to perform teaching duties independently or in collaboration (Celik, 2023; Lodge et al., 2023). The AI-TPACK model integrates AI technologies into traditional TPACK components, aiming to develop innovative teaching strategies for AI advancements. It examines the dynamic relationship between technology, pedagogy, and subject matter. Based on this assumption, the new theoretical framework of AI-TPACK is presented in Figure 3, along with a table outlining its constituent parts. This approach helps teachers better adapt to the rapidly changing technological landscape.

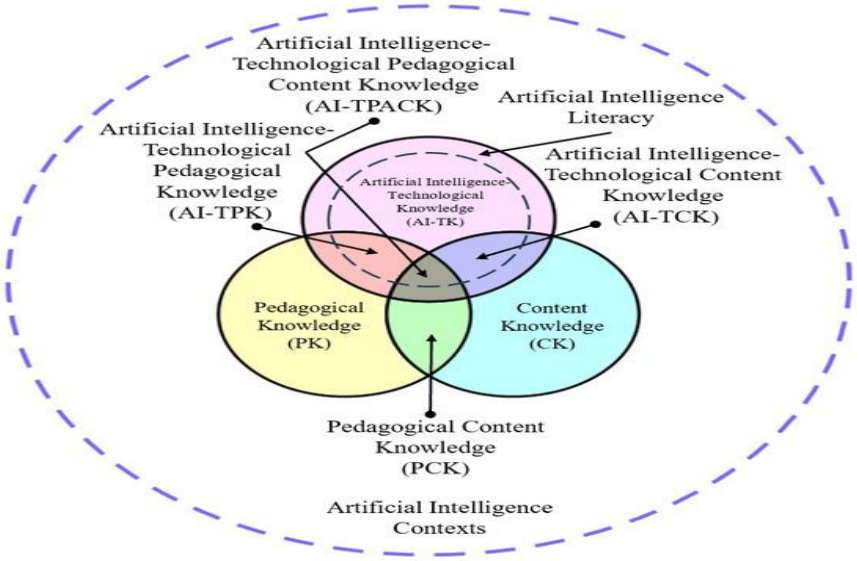

Figure. 3: AI-TPACK structural diagram. (Ning et al., 2024)

The five fundamental elements that make up the AI-TPACK framework are AI Technological Knowledge (AI-TK), AI-Technological Pedagogical Content Knowledge (AI-TCK), AI-Technological Pedagogical Knowledge (AI-TPK), and Ethics. Celik (2023). Figure 4 offers a thorough summary of these components.

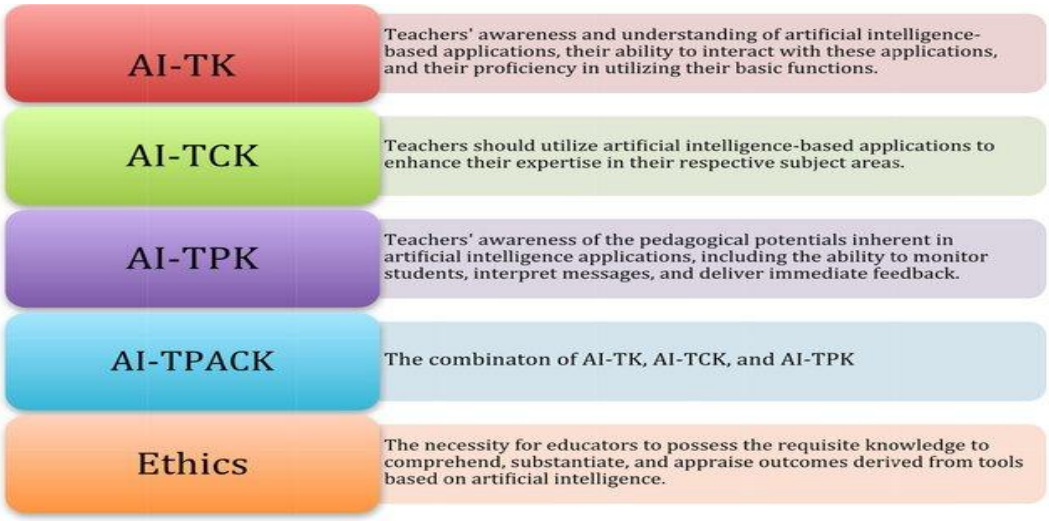

Figure. 4: The components of AI-TPACK (Celik, 2023)

The AI-TPACK model, a significant research field, combines AI technology with traditional TPACK components, potentially leading to more creative teaching strategies. This approach is crucial for understanding how AI can enhance education and help teachers adapt to the rapidly evolving technological environment, as AI technologies become more widespread (Celik, 2023; Ning, 2024). The integration of AI with TPACK highlights the dynamic relationship between pedagogy and technology, requiring a reassessment of traditional teaching paradigms while simultaneously offering new opportunities for personalised learning (Angeli & Valanides, 2009; Karataş & Yuce, 2024). Teachers must acquire competencies that integrate

their understanding of AI with pedagogical techniques and subject-matter expertise, according to AI-TPACK (Karataş, & Ataç, 2024).

Mishra and Koehler (2006) created TPACK to address the lack of technology integration theory in education. Since then, technology education and teacher professional development research have focused on TPACK (Chai et al., 2013). The "Intelligent-TPACK" scale, developed by Celik in 2023, assesses teachers' ethical use of AI-based tools in the classroom. The study involved 219 teachers in Turkey and 428 teachers in the development phase. Results showed that technological knowledge positively impacts pedagogical, content, and ethical knowledge, emphasizing the importance of ethics in technology integration (Smakman et al., 2021; Yurdakul et al., 2012; Yurdakul & Coklar, 2014). The use of technology in TPACK has not addressed ethical issues, especially those pertaining to AI. The study introduces the Intelligent-TPACK scale, a data-gathering tool utilizing structural equation modelling, to evaluate teacher professional knowledge and explore the ethical implications of AI-based tools in education.

Methodology

The Strengths, Weaknesses, Opportunities, and Challenges (SWOC) Analysis

The SWOT framework is a strategic tool that identifies strengths, weaknesses, opportunities, and threats in an environment to aid decision-making (Ghazinoory et al., 2011). It is one of the oldest and most popular strategies, but its origins are unclear (Puyt et al., 2023). The term "SWOT" is unsourced and has no documented history (Indrasari, 2023). However, in recent years, the limitations of SWOT have become apparent, leading to a shift towards a more comprehensive approach, namely SWOC analysis, which also considers the challenges and opportunities arising from the external environment and the internal context of the organization (Aithal & Kumar, 2015). SWOC analysis is used to evaluate the integration of AI-TPACK into teacher educators' pedagogical practices, identifying opportunities, challenges, weaknesses, and strengths. This helps guide future educational strategies, identify potential risks, and provide a comprehensive understanding of the organization's strengths, weaknesses, opportunities, and challenges.

Objectives

- To conduct a comprehensive SWOC analysis of AI-TPACK integration in educational settings to understand the current state and future potential of artificial intelligence technologies in teaching and learning.

Strengths of AI-TPACK

Mofakham, Nassiri, Kanejiya, and McFarland have all contributed to the advancement of AI technology in various fields, including education. AI has been used since the 1980s for intelligent tutoring systems, and its impact on education is expected to be significant. Applications include responding to student queries, providing comments, and evaluating narrative responses. Technological advancements, including AI, are transforming education by allowing a wider audience to access content, improving learning outcomes through learning management systems, and gaining popularity in Massive Open Online Courses (MOOCs). In an experiment, a Georgia Tech professor developed an AI-powered system to support him in a

course and engage with students (Nassiri & Mofakham, 2017; Kanejiya, 2017; McFarland, 2018; Karataş & Ataç, 2024)

The AI-TPACK framework emphasizes accountability, transparency, inclusivity, and fairness in evaluating AI tools in education. It provides a fresh perspective for assessing AI tools and incorporating ethical knowledge to inform decisions about AI-based technologies (Celik, 2023; Ning, 2024). Advocates for the Ethical Utilisation of Artificial Intelligence: AI TPACK emphasises the importance of understanding the ethical implications of AI in education, ensuring the responsible and equitable use of AI tools (Celik, et al., 2025). Teachers must possess pedagogical and technological expertise specific to AI to successfully incorporate it into the classroom. Additionally, teachers need to have the knowledge to evaluate AI-based decisions due to emerging ethical issues associated with artificial intelligence. Prior research hasn't looked at teachers' understanding of the ethical and pedagogical applications of AI-based tools (Celik, 2023). High proficiency in Intelligent Technology Knowledge (AI-TK), Intelligent Technological Content Knowledge (AI-TCK), and Intelligent Technological Pedagogical Knowledge (AI-TPK) was found in the AI-TPACK components (Karataş & Ataç, 2024).

AI TPACK, or Artificial Intelligence Technological Pedagogical Content Knowledge, enhances instruction, customizes learning, and broadens our understanding of AI in education. It helps teachers incorporate AI technologies into lessons, increasing student engagement and personalization. By analysing student data, AI can enhance learning efficiency and enjoyment. This knowledge allows teachers to decide whether to implement AI in their classrooms (Celik et al., 2025). Future-Readiness, AI is rapidly revolutionising education, and AI TPACK ensures teachers stay at the forefront (Xie & Luo, 2025; Runge et al., 2025).

The effectiveness of AI-driven systems in education relies heavily on educators' understanding, but traditional teaching methods alone are insufficient. It is crucial for educators to comprehend the educational benefits of AI and have an ethical perspective when utilizing it, as AI-driven instruction emphasizes teachers as orchestrators (Dillenbourg, 2013; Holstein et al., 2019; Celik, 2023)

The Indian National Education Policy emphasizes the use of AI in teaching and learning to enhance access, personalize learning, and improve teacher effectiveness. AI-driven tools like adaptive learning platforms and intelligent tutoring systems support competency-based education and individual student needs. The policy also emphasizes digital infrastructure for blended and flipped classrooms, automated assessments, predictive analytics, and multilingual content delivery (NEP. 2020).

Weaknesses of AI-TPACK

The trend of younger instructors becoming more proficient in digital abilities is seen in their excellent fundamental knowledge of technology (Hava & Babayiğit, 2024). There is, however, room for improvement in their ability to incorporate ethical considerations, as evidenced by the lower scores in the AI-Ethics dimension. These difficulties in incorporating these skills into comprehensive pedagogical frameworks suggest that current teacher education curricula may

not be sufficiently preparing teachers for the challenging aspects of integrating technologies like AI into education (Karataş et al., 2024; Velander et al., 2023; Karataş, & Ataç, 2024).

The TPACK framework, while neutral in its overarching objectives, does not address specific content or instructional methods, a trend that scholars argue is necessary for the new millennium, as it emphasizes higher-order thinking skills, collaboration, and creativity (Mishra & Kereluik, 2011). An initial step has been taken to argue for the significance of TPACK in fostering transdisciplinary skills relevant to the twenty-first century (Mishra et al., 2011).

Mishra and Koehler (2006) highlighted the complexity of TPACK, a model that has been dubbed a "wicked" problem by Borko et al. (2008). The balance between complexity and parsimony in TPACK remains unclear, but it should aid researchers and practitioners in understanding structures without becoming too sophisticated for only a select few academics. Critics argue that TPACK is excessively complicated with too many subcomponents, and that researchers have presented modifications to reduce conceptual clarity. Additionally, some researchers feel that too much research focuses on TPACK exploration and validation, neglecting teaching knowledge (Deng & Zhang, 2023).

The AI-TPACK framework for teaching and learning, while identifying key components, lacks comprehensive understanding of their interactions, necessitating further empirical research to validate its effectiveness and improve teaching outcomes (Ning et al, 2024: Archambault & Barnett, 2010). Highlight the need for educators to understand AI technology and address challenges in incorporating new technologies into lessons. They emphasize the need for AI-TPACK to address ethical ramifications like data privacy and algorithmic biases, and for educators to receive training to recognize and address these issues (Koudhury et al., 2024; Karataş & Ataç, 2024).

Opportunities of AI-TPACK

Celik, Mishra & Islam, and Rahimi & Rezvani have highlighted the potential of AI-TPACK technology in enhancing teaching and learning by increasing student participation, automating administrative tasks, providing personalized instruction, and promoting equity (Celik, 2023; Mishra & Islam, 2023; Rahimi & Rezvani, 2024).

Increased Teacher Efficiency and Effectiveness: AI can automate time-consuming chores like lesson planning and grading, giving teachers more time to engage with students in deeper ways (Mishra & Islam, 2023). Teachers can make data-driven decisions about instruction by using AI to give them insights into the performance and progress of their students (Celik, 2023). Additionally, AI can help educators create dynamic and captivating educational resources, like games and simulations (Rahimi & Rezvani, 2024). Advancement of Equity and Accessibility: AI can help students with disabilities by providing features like personalised accommodations, translation, and text-to-speech (Manna & Sett, 2025). By offering English language learners' real-time translation and support, artificial intelligence (AI) can assist in overcoming language barriers (Rahimi & Rezvani, 2024). Additionally, AI can assist in detecting and resolving possible biases in instructional strategies and materials, fostering a more equal learning environment (Celik, 2023; Marino, et al., 2023).

Promoting More profound Student Engagement: AI-driven technologies can produce dynamic and captivating educational materials, including virtual field trips, simulations, and customised learning games (Celik, 2023). AI can help students stay motivated and involved in their learning by giving them immediate feedback and support. By putting students in touch with peers and experts worldwide, AI can also promote collaborative learning (Nguyen et al., 2024).

The NEP 2020 aims to address the digital divide by promoting technology use, removing language barriers, expanding access, and improving educational planning and administration (NEP, 2020). Teachers are integrating AI into classrooms, involving educators in creating AI-integrated curricula for children with learning disabilities, involving discussions on data, ethics, student participation, teamwork, and introspection (Lin & Brummelen, 2021; Alhiane & Nafidi, 2025).

Strengths	Weaknesses
• Enhances personalized and adaptive learning experiences (Luo et al., 2023) • Automates administrative tasks, freeing up teacher time (Zhang & Lu, 2021) • Supports ethical use of AI through frameworks like AI-TPACK (Celik, 2023) • Improves student engagement and instructional effectiveness (Celik et al., 2025) • Aligns with national policies like India's NEP 2020 • Encourages data-driven decision-making in education (Celik, 2023) • Provides a fresh perspective for assessing AI tools with ethical considerations (Ning, 2024)	• Limited teacher preparedness in integrating AI ethically (Karataş et al., 2024) • TPACK framework is often seen as overly complex (Borko et al., 2008; Deng & Zhang, 2023) • Lack of comprehensive understanding of AI-TPACK component interactions (Ning et al., 2024) • Teacher education curricula may not adequately address AI integration (Velander et al., 2023) • Ethical dimensions (e.g., data privacy, bias) are often overlooked (Koudhury et al., 2024) • Lower scores in the AI-Ethics dimension among younger instructors (Hava & Babayiğit, 2024) • Excessive focus on TPACK exploration rather than teaching knowledge (Saubern et al., 2020)

Opportunities	Challenges
• AI can automate grading and lesson planning, improving teacher efficiency (Mishra & Islam, 2023) • Supports inclusive education through tools like translation and accessibility features (Manna & Sett, 2025) • Enables creation of engaging educational content (simulations, virtual labs) (Rahimi & Rezvani, 2024) • Promotes collaborative and global learning experiences (Nguyen et al., 2024) • Potential to bridge educational gaps and support students with disabilities (Marino et al., 2023) • Can help overcome language barriers for English language learners (Rahimi & Rezvani, 2024) • Potential to detect and resolve biases in instructional materials (Celik, 2023)	• Rapid evolution of AI requires continuous teacher professional development (Mishra et al., 2023) • Digital divide and lack of infrastructure (e.g., internet access, devices) (Oxfam India Inequality Report, 2022) • Ethical concerns such as algorithmic bias and lack of transparency (Webb et al., 2021) • Resistance from teachers due to lack of time, training, or confidence (Torregosa and Boloron, 2024) • Need for a flexible and evolving AI-TPACK framework (Ning et al., 2024) • Connectivity issues and limited technological knowledge among stakeholders (Torregosa and Boloron, 2024) • Only 31% of rural India uses the internet (Oxfam India Inequality Report, 2022)

Challenges of AI-TPACK

AI technology is constantly evolving, necessitating ongoing professional development for teachers. A flexible framework is needed to accommodate this growth. The research pace in AI has also increased, with 2,941 publications as of June 2023, demonstrating the importance of TPACK as a fundamental foundation for research in this rapidly changing field (Mishra et al. 2023).

The Pedagogical Content Knowledge (PCK) framework, developed by Shulman (1986), The framework emphasizes the practical application of knowledge in practice, adapted for specific

purposes. It is crucial in teacher education and professional development programs, but its widespread use may render it obsolete. Its practical application allows practitioners to effectively utilize it.

GenAI's rise raises questions about its relevance and value. GenAI-era TPACK apps use machine learning algorithms to generate new content, such as text, photos, video, music, artwork, and synthetic data, analyzing rules and patterns in large datasets (Ray, 2023; Mishra et al., 2023). TPACK is well-known in teacher education. Several studies have defined teachers' technological integration expertise as the incorporation of AI technology into technological pedagogical content knowledge, known as AI-TPACK (Celik, 2023).

According to Williamson, Molnar, and Boninger (2024), the AI system's decision to classify these people as "at risk" and limit their access to certain information or resources might potentially exacerbate the issue by restricting or eliminating their access to information and resources. Additionally, the lack of transparency in the reasoning processes of AI algorithms can lead to opaque decisions that are challenging to verify (Webb et al., 2021).

Torregosa and Boloron (2024) identifies four major obstacles to the effective implementation of the Technology-Based Approach to Teaching and Learning (TPACK) model: connectivity issues, limited knowledge of technology among students, teachers, and teachers' interests, time, and age.

The India Inequality Report 2022: Digital Divide by Oxfam highlights the digital divide in India, with 70% of the population lacking access to ICTs. Government schemes like BharatNet have failed to improve connectivity, with only 2.7% of poor households having access to computers and 8.9% to internet facilities. Social, political, and environmental factors determine who goes online and for how long. Only 38% of households are digitally literate, and only 31% of rural India uses the internet. In 2023, 44% of urban Indians had access to the internet, compared to 17% in rural areas (Oxfam India Inequality Report, 2022).

Conclusion

This study analysed academic literature to create a SWOC analysis of the Artificial Intelligence–Technological Pedagogical Content Knowledge (AI-TPACK) framework. The analysis provides a comprehensive understanding of its successful application in educational settings, offering a strong theoretical foundation for curriculum developers, educators, and policymakers. The study highlights the advantages and drawbacks of AI-TPACK, offering a comprehensive understanding of its potential in enhancing technology integration research (Xie & Luo, 2025; Runge et al., 2025). Highlights the effectiveness of AI-TPACK in enhancing academic performance by promoting the deliberate use of technology in various educational contexts. The framework combines technology with effective teaching techniques and subject-matter expertise, enhancing engagement, personalized learning opportunities, and better memory retention. It also serves as a valuable tool for teacher education programs, providing instructors with necessary knowledge to successfully integrate technology into lesson plans Celik (2023). However, the study highlights challenges in implementing AI-TPACK in education, such as connectivity issues, inadequate facilities, and limited device access. Teachers and students face technological proficiency, low engagement, time constraints, and

age-related issues. Addressing these requires targeted interventions, professional development programs, and strategic resource allocations. The research emphasizes the importance of understanding the advantages, disadvantages, opportunities, and difficulties of AI-TPACK to enable more strategic, inclusive, and sustainable technology integration in education.

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