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Perspective

Intersecting Technological Pedagogical Content Knowledge and Artificial Intelligence in Medical and Health Sciences Education: A Perspective

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ABSTRACT

Medical education requires systematic strategies to optimize the incorporation of technology into educational strategies. A prominent framework for achieving this integration is the Technological Pedagogical Content Knowledge (TPACK) model. The advent of Artificial Intelligence (AI) has significantly influenced all aspects of education, impacting both teachers and students in their academic endeavors. Integrating AI with TPACK has created a new approach, the AI-TPACK framework, which is explored in this study. By incorporating AI-specific knowledge and skills, this framework enables educators to effectively utilize AI technologies in their teaching, adapting to their students' diverse contexts and needs. The significance of this integrated model is underscored by various studies that highlight AI's transformative effects on teaching and learning methods. A strong TPACK, combined with AI tools, appears to enhance teaching outcomes and enrich learning experiences. Furthermore, research demonstrates the crucial role of AI-driven intelligent tutoring systems in improving student performance in medical education by providing tailored feedback and dynamically adjusting educational content to individual learning needs. This article further investigates the transformative influence of AI in medical and health sciences education through the lens of the AI-TPACK framework. It explores how educators can align technological innovation with pedagogical effectiveness and content mastery to create meaningful learning experiences. Additionally, it emphasizes the necessity of AI-TPACK while addressing its advantages, considerations, and implications.

Keywords: Education; Teaching; Technological Pedagogical Content Knowledge; TPACK; Artificial Intelligence; Learning

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Introduction

Accelerated Artificial Intelligence (AI) progress has revolutionized numerous disciplines, most notably the education field (1). In medical and health sciences education, AI has emerged as a transformative tool that offers personalized learning experiences, administrative efficiency, and data-driven insights, among others. (2-4). As educational institutions strive to prepare graduates for the demands of modern medical education environments, adopting frameworks that facilitate the seamless integration of technology into instructional methodologies is imperative. One such framework is Technological Pedagogical Content Knowledge (TPACK) (5).

While the TPACK framework has proven effective for integrating technology into education, the rise of AI requires an evolution of this model to tackle emerging challenges and seize new opportunities. This perspective article introduces the AI-TPACK framework (2, 4), an extension of TPACK that includes AI-specific competencies designed to help educators leverage AI technologies for adaptive and personalized learning environments. By merging AI capabilities with pedagogical strategies and content expertise, the AI-TPACK framework aims to enhance teaching and learning outcomes while addressing critical challenges such as resistance to change, ethical considerations, and equitable access to AI resources.

This article examines the transformative role of AI in medical and health sciences education through the perspective of the AI-TPACK framework. It discusses how educators can balance technological innovation with pedagogical effectiveness and content mastery to create meaningful learning experiences.

The intersection of TPACK and AI

Advancements in AI technology have prompted educators to rethink and improve instructional methods in medical and health sciences training programs. There is a new requirement for systems to be employed to meet students' and employers' expectations within a technology-enhanced environment. Medical and health programs must be able to embrace change and implement technologies that provide a personalized approach to education in a way that can help prepare graduates for work in a modern clinical and health environment. One way to promote career readiness is for medical and health programs to adopt a cohesive approach using the TPACK framework, which integrates Pedagogical Knowledge (PK), Technological Knowledge (TK), and Content Knowledge (CK) (5). This framework is adopted from Shulman's Pedagogical Content Knowledge (PCK) model, which highlights integrating domain-specific knowledge alongside appropriate pedagogical strategies while implementing technological approaches to empower students through their learning process and outcomes (5, 6). TPACK mainly emphasizes incorporating technological knowledge as a vital component of facilitating teaching, particularly in personalization and enhancing the practicality of teaching and learning (7).

The TPACK framework provides a foundational model for understanding how technology and AI can enhance teaching practices by identifying three core components (5, 7):

- **Content Knowledge (CK):** Mastering the subject matter and adjusting the content based on the context and students' needs to be more engaging, evidence-based, and practical.
- **Pedagogical Knowledge (PK):** Implementing practical approaches to transform teaching methods via multimodal approaches for enhancing personalization, flexibility, and engagement.
- **Technological Knowledge (TK):** Understanding and implementing the right technologies based on the context and their educational applications for creating an adaptive learning environment.

The interplay between CK, PK, and TK is essential for providing cohesive learning and teaching approaches in medical and health sciences education. For instance, educators

with strong content knowledge (a high CK) may struggle to convey this effectively without suitable pedagogical strategies. On the other hand, a technologically savvy educator (a high TK) may not incorporate technology effectively without a deep understanding of the subject matter. The TPACK framework encourages educators to balance these components holistically and integrate them, ensuring that technology is used to enhance the overall learning experience rather than detract from it (5). With advancing technology, including AI applications, the traditional TPACK framework requires adopters to address emerging educational demands to ensure an up-to-date and integrated interaction between CK, PK, and TK.

The Transformative Role of AI in Medical and Health Sciences Education

Technology has dramatically impacted education in the past decade, and this has been accelerating with the widespread adoption of AI. This phenomenon can be seen as a historical milestone in medical and health sciences education, effectively dividing it into pre- and post-AI eras (8). As AI is evolving, it is essential to have a structured plan in place for its integration into medical and health sciences education and to enhance the readiness of educators and students. Incorporating AI into educational frameworks is a transformative shift rather than merely a trend, with great potential for teaching and learning paradigms. As educators navigate this new landscape, understanding TPACK becomes essential in successfully implementing content knowledge, pedagogical strategies, and technology. However, this approach must evolve to accommodate AI's unique challenges and opportunities. This evolution is encapsulated in the emerging framework of AI-TPACK, which aims to integrate AI technologies into the educational process for an effective, personalized, and adaptive approach.

AI is profoundly redesigning the educational landscape by empowering both educators and learners. AI facilitates personalized learning experiences and provides data-driven insights into student performance (9). It allows analyzing a large amount of information about learning processes to examine students' learning patterns, preferences, and performance data. This will assist in tailoring educational content and approaches based on the specific context of students and their needs, enabling each learner to progress at their own pace and create a meaningful direction in their personal and professional development. For instance, implementing intelligent tutoring systems can offer real-time feedback and modify instructional strategies based on students' learning paths (10).

Beyond its role in enhancing learning experiences, AI also provides substantial assistance from the administrative workload educators face. By leveraging AI to automate tasks, including marking/grading, scheduling, and attendance tracking, educators can focus on other priorities, such as providing high-quality and engaging delivery and investing in more innovative approaches to teaching (11). In addition, AI's capacity to analyze extensive datasets provides educators with valuable data-driven insights regarding students' learning journey and performance. These data-driven approaches assist with identifying at-risk students early on and implementing timely interventions to make informed decisions and create a more proactive and responsive educational environment (12).

Integrating AI into educational practices highlights the need to develop an AI-TPACK framework. This framework extends the traditional TPACK model by incorporating AI-specific knowledge and competencies, enabling educators to strategically incorporate AI tools into their instructional methods while addressing their students' unique contexts and learning requirements. Multiple studies confirm the importance of the integrated model of artificial intelligence and TPACK. A survey conducted by Ning and colleagues (2024) underscores the significant impact of AI on teaching and learning

methods, necessitating a reexamination of the relationships among technology, pedagogy, and content knowledge. (2). Additionally, research conducted by Oved and colleagues underscores the importance of professional development programs to enhance teachers' TPACK, which, in turn, facilitates the adoption of AI in educational environments. Their findings indicate that integrating AI tools, supported by strong TPACK, can lead to better teaching outcomes and enriched student learning experiences (3). The study conducted by Mir and colleagues showed how AI-driven intelligent tutoring systems improved student performance in medical education by providing personalized feedback and adaptive learning paths (8). Similarly, Naseer and colleagues (2024) highlighted the use of deep learning techniques to create personalized learning pathways, significantly enhancing engagement and learning outcomes for students in higher education (9).

AI literacy and Educators' Readiness

To maximize AI's potential benefits, educators must adopt a comprehensive approach that includes systematic planning and infrastructure development. This involves modernizing teacher training programs to emphasize AI literacy and combining technical proficiency with pedagogical knowledge to ensure the effective integration of AI tools into classroom instruction (13).

Educators must acquire a thorough understanding of AI technologies, including both their capabilities and limitations. AI knowledge is the foundation for making informed decisions about integrating AI tools as a complementary approach to teaching practices (14). In addition, the AI-TPACK framework highlights the potential for a sustainable collaborative educator-AI synergy in education, redefining the roles in education (15). This mutual collaboration between educators and AI capitalizes on the strengths of both human and machine intelligence to optimize personalized learning experiences and educational outcomes and long-term impact (9).

As AI advances accelerate, significant attention is required to consider ethical matters. A systematic approach must be established to enhance educators' awareness of various ethical issues related to AI, including data privacy, algorithmic biases, students' use of AI platforms, and the impact of AI-driven decisions on student outcomes (4). Educators should be empowered through systematic training to promote responsible and equitable use of AI in educational settings by addressing ethical concerns proactively. This includes ensuring transparency in AI-driven decision-making and protecting the data privacy of both educators and students.

Challenges in Implementing AI-TPACK

Despite the potential benefits of AI-TPACK, various challenges still hinder the full implementation of this framework to achieve optimal impact. Many of the educators may face difficulties integrating AI into their teaching practices. A significant hurdle to adopting AI-TPACK is *resistance to change*. Educators often rely on traditional teaching methods, which can hinder the adoption of new technologies. This resistance is usually due to a lack of understanding and awareness of AI's benefits or simply a fear of the unknown. Two complementary interventions can be used to improve this resistance. Firstly, gaining early buy-in from educators significantly facilitates the implementation of AI-TPACK. Secondly, providing ongoing professional development programs is paramount to enhance the necessary support, training, and resources to build their confidence in understanding and applying AI tools (16).

The second issue is the *ambiguity and unpredictability* surrounding AI-TPACK. Unlike the well-defined components of TPACK, this framework is still evolving, making it difficult for partners, including educators, to identify the knowledge and skills required for optimal integration. More empirical research is necessary to clarify the relationships between AI and TPACK and develop valid and reliable measures for

their applications and effectiveness based on the context (2). The engaged partners, particularly students and educators, often do not have sufficient knowledge and equal access to AI-supporting services to fully use its applications (16). To address these challenges, ongoing empirical research is crucial to examine the practical applications of AI-TPACK in various educational contexts. This can provide valuable insights into its effectiveness and identify best practices for implementing AI technologies for an optimal outcome (16).

While AI-TPACK's potential in education is promising, significant challenges must be addressed to fully leverage its advantages. Implementing AI-TPACK raises critical ethical issues, particularly regarding data privacy and security. Using sensitive information from teachers and students to train AI models presents risks of data breaches and misuse (17). Another major concern is the risk of over-reliance on AI-TPACK, which could diminish essential traditional skills among teachers and students, such as critical thinking and problem-solving (18).

Conclusion

Integrating AI into TPACK frameworks signifies a transformative change in teaching and learning. The AI-TPACK framework, which extends the conventional TPACK model by including AI-specific knowledge and competencies, is essential for educators to leverage AI technologies effectively. Although AI offers abundant benefits, including personalized learning and administrative efficiency, systematic challenges still need to be overcome, including resistance to change, ambiguity surrounding AI-TPACK components, and unequal access to AI resources.

For a smooth implementation of the AI-TPACK framework, systematic planning is required, from gaining partners' buy-in at the early stages of the change to training and a supportive system for all the partners, ensuring equal access to AI facilities. By tackling these challenges, all partners involved can leverage AI's full potential to create a more responsive and effective learning environment. Educators play a crucial role in successfully integrating AI, adapting and innovating to ensure that technology complements rather than replaces them.

Considering that AI is here to stay and is continuing to evolve, an adaptable approach is essential to maintaining pace with advancements in educational technology. Moreover, collaboration among educators, researchers, and technology developers is vital to shaping the future of AI in education. The journey toward integrating AI in education is just beginning, and with continued research and collaboration, the possibilities are endless.

Although AI provides many advantages, excessive dependence on these technologies might impede students' growth in critical thinking and interpersonal skills. Additionally, paying attention to user data protection, data security, and preventing machine bias in data retrieval and analysis are essential issues in the application of AI. Therefore, addressing ethical concerns, ensuring data privacy, and avoiding overreliance on AI are crucial steps to maximize its potential without compromising traditional educational values.

Abbreviations

AI: Artificial Intelligence
CK: Content Knowledge
PK: Pedagogical Knowledge
TK: Technological Knowledge
TPACK: Technological Pedagogical Content Knowledge

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Not applicable.

Authors' Contribution

ZK wrote the initial draft of the article. NS and CM enhanced the critical argument and contributed to editing and revising it. All the authors reviewed and approved the final version.

Conflict of Interest

The authors declare no competing

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