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The Requirements and Impacts of Teachers' TPACK Competency for AI Application in Education During the Digital Era

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Abstract: Teachers' competence in effectively integrating technology, pedagogy, and subject content (TPACK) has long been a critical area of research. However, despite its importance, educators continue to face emerging challenges in adapting to the rapidly changing educational landscape driven by digitalization and globalization. This paper identifies three major challenges faced by educators in the integration of educational technology: insufficient adaptation to new technologies, difficulties in applying technology-enhanced instructional strategies, and the overwhelming abundance of teaching resources. The lack of strong informational literacy among teachers exacerbates these challenges. This study argues that the development of the TPACK competency can address these issues by equipping educators with the necessary skills to comprehend, manipulate, and integrate new technological tools into their teaching. Based on this, the paper proposes the following recommendations: the introduction of specialized technological training programs, ongoing pedagogical development and reflective activities, and academic sharing and self-oriented learning. These strategies are vital for refining educators' adaptability in the digital age and contribute to their professional growth.

Keywords: TPACK, AI, Teacher Professional Development, Technology Integration

1. Introduction

Technology is unprecedentedly rising, and the wide application of artificial intelligence (AI) technology is profoundly reforming the way of modern teaching since it was first proposed in 1956. In 2019, scholars described AI on a broader level as computers that can perform cognitive tasks, particularly in learning and problem-solving [1].

Online learning platforms like Duolingo demonstrate AI's potential to support teachers by tailoring linguistic content to the unique needs of each student and allowing them to monitor in-time learning progress. In classroom management, platforms with automated grading systems, Turnitin and Grammarly, effectively reduce teachers' burden on routine tasks and squeeze time for them to focus on more meaningful projects. Even better, Nearpod, a powerful interactive teaching platform, provides teachers with abundant interactive activities and immediate feedback as well as analysis through AI to enhance students' engagement and learning experience [2]. Similarly, intelligent tutoring systems such as Squirrel AI provide teachers with detailed feedback on student performance

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through abundant data analysis, enabling teachers to identify weaknesses and adapt their instructional strategies accordingly. Teachers can create high-level cognitive demand activities in the course designs with functions like collaborative boards, formative assessments, and virtual field trips, which require complicated and non-algorithmic thinking of students to truly investigate the core of the subject content [3].

However, technology emerges in a continuing way, and so does the challenge. How to effectively and efficiently integrate technology into course designs and ensure that it facilitates students' cognitive development has become the main issue for educators to resolve. In this regard, the building of the TPACK (Technology, Pedagogy, and Subject Content Knowledge) competency is particularly urgent as a theoretical framework to overcome the issues. The TPACK model emphasizes teachers' ability to integrate technology in their course designs and the use of technology to elevate students' learning experiences and support their knowledge development. Therefore, this paper will delve into the existing challenges brought by digitalization, examine how the construction of the TPACK competency will help teachers to better address the issues, and suggest specific coping strategies to improve their informational literacy, highlighting the essentiality of the TPACK model and providing feasible guidance for educational practices.

2. AI in Education: The Challenges Ahead

With the application of AI and other technology in the classroom, educators are anticipated to a)master basic technological skills, b)leverage technology with proper design of pedagogical activities, and c)select appropriate teaching content from diverse digital resources. This section will focus on exploring and analyzing the main challenges faced by educators from these perspectives.

2.1. Adapting to the Technological Demand

The first challenge comes from the teacher's ability to understand and apply technology. Prensky emphasized the importance of educator's technological competency. He also refers to students as advocates of digital technology who are fluent in using computers and the Internet. Teachers, on the other hand, are expected to catch up with the trend [4]. Unfortunately, not every educator realizes the significance of the issue or is competent enough to conquer it. A great number of teachers face both psychological and technological pressures in learning and adapting to new technology. Teachers in old age usually do not encounter systematic training in technology or do not have the chance to learn and apply technological tools in depth. They normally feel overwhelmed when operating software and tools. This situation is not limited to the application of complex technologies, but also with the operation of basic tools along the lines of online teaching platforms and learning management systems. The seriousness in this context is that teachers' lack of proficiency and confidence in using technology often results in inefficient teaching and failing learning objectives. The technical competency of educators directly impacts how effectively technology can be incorporated into education to avoid these negative circumstances.

2.2. Designing Technology-Enhanced Teaching Practices

Even though some teachers have mastered the basic operations of AI tools, it is worth considering whether or not they leverage the effect of technology in complex teaching situations, such as using AI to design interactive activities that require cognitive thinking of students to strengthen their understanding of the knowledge and cultivate their inquiry skills. To better understand, in the case of a Chemistry class, online lab platforms can indeed simulate chemical reactions and provide a comparatively safe environment for students to explore, but it would be tough to stimulate students' interest and scientific thinking if teachers only implement technology to demonstrate the experiment

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without designing any interactive activities. Another successful example in a Physics class, instead of just simply displaying an available simulation of Newton's laws, teachers lead students to conduct interactive practices with an online Physics platform to experiment with variables such as mass, force, and friction and observe their impacts on acceleration. The essence is to enrich the course with self-learning rather than passive receiving. Traditional instruction is no longer the most ideal choice in classrooms in the digital age, and this is where the second challenge comes from - the integration of technology has led to the conventional "teachers-students" dichotomy into a "teachers-students-technology" triad, and the introduction of technology calls for teachers' strong pedagogical competency to utilize appropriate methods to integrate technology for the most ideal learning achievements [5].

2.3. Navigating Teaching Resources

Traditional teaching resources mainly rely on textbooks with teachers' explanations and students' extracurricular reading, whereas teaching resources have become richer and more diverse with globalization, and the limitations of the traditional resources have thus become particularly prominent. Modern education requires teachers not only to use traditional teaching resources, but also to access and integrate various online teaching resources, including but not limited to open courses, digital textbooks, academic journals, educational videos, and interactive learning platforms. Teachers are faced with the third challenge - to extract the most appropriate teaching content from the huge amount of information based on their understanding of the subject to meet students' learning needs and teaching objectives. The transfer of content knowledge is no longer just static textbooks and handouts, but a dynamic and interactive educational process, in which one constantly updating own knowledge systems, keeping up with the latest disciplinary developments and research findings, and remains sensitive to emerging theories and technologies are all challenging factors for the educators to address.

3. Definition and Adaptability of TPACK

3.1. Definition of TPACK

Technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) are all vital factors in successful teaching. In 2006, Mishra and Koehler proposed a model, rather than treating these capabilities as separate bodies of knowledge, their model additionally emphasizes the complex interactions of three bodies together in educational practice, which is the birth of the Technological Pedagogical Content Knowledge (TPACK) model [6]. The TPACK model has long been recognized as an important theoretical framework of modern education, and Shulman's theory that the interaction of content knowledge and pedagogical knowledge is the key to teachers' professional development initially laid a solid foundation for it [7]. Mishra and Koehler extend Shulman's study by introducing technological knowledge and highlighting its essentiality in the context of digitalization. Specifically, they discuss the need for educators to transfer content knowledge appropriately through technological tools to promote the intellectual growth of the students.

In the TPACK model, TK refers to educators' ability to understand and master digital technological tools, including operating computer hardware and standard sets of software, as well as installing and removing equipment and software programs, and creating and categorizing documents [6]. This competency enables teachers to support the students by effectively integrating technology into course designs and being professional and flexible enough to respond to the rapidly changing technological environment. PK describes educators' in-depth knowledge of teaching and learning processes, practices, and methods, which contains the issues of student learning, classroom management, course design, and student assessment [6]. This process usually involves comprehending how students

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construct knowledge, acquire skills, and develop positive learning habits. This competency allows teachers to make good decisions to design interactive activities that match the needs of the students thereby promoting their cognitive development. CK stands for teachers' nature of the knowledge and their understanding of the content to be taught, including key theories and procedures, frameworks that organize and link these ideas together, as well as the standards of evidence in the discipline [6,7]. This competency empowers teachers to explain and link different content logically, ensuring that students acquire clear and adequate knowledge with a comprehensive understanding of the discipline.

3.2. Adaptability

Building the TPACK competency seems to be especially important when facing the evolving educational landscape nowadays. Digitalization occurs in education, and technology is more than a tool, but a powerful support in the teaching and learning process, and the TPACK model provides a framework to practice the technology in a smart way to adapt to the complex challenges that it brings. The logical connotations of this model satisfy the requirements of educators in the digital age. This section will elaborate on this viewpoint in the following three aspects.

3.2.1. Technological Knowledge

TK aims to help educators master the foundational knowledge to operate and implement technology into teaching, thereby improving educational effectiveness. The foundational knowledge can serve as the base for further using higher-order technology. From the basics to more complex applications, a strong technological competency benefits educators to quickly understand and practice different tools. While specific operating software or systems may become obsolete over time, mastery of methods and techniques for learning new technology enables educators to comfortably work through the potential challenges posed by updates. The flexible and dynamic nature of TK at this point makes it possible for educators to continuously learn and adapt to evolving technological environments. Thus, TK empowers educators with sustainable skills to keep up with the times and to avoid undermining the effectiveness of teaching due to technological backwardness. Furthermore, the establishment of such competency has a positive effect on eliminating educators' psychological pressure caused by poor technological skills, and gradually building up their confidence, which improves overall teaching efficiency and inspires educators to actively explore more technology and dive deeper to support education in the long run.

3.2.2. Pedagogical Knowledge

PK is crucial in assisting educators to scientifically implement technology to transfer knowledge and facilitate studying. Specifically, it supports educators in transforming conventional instructional methods into new approaches that leverage the advantages of technology. When educators possess powerful pedagogical competency, they are capable of selecting appropriate instructional techniques, methods, and strategies to design meaningful and challenging learning activities that promote higher-order thinking, which contributes to students' growth in critical thinking and creative problem-solving [8]. In the previous Chemistry class instance, if the proper pedagogy is involved in the case, the interactive student-centered inquiry activities are supposed to be carried out rather than mere technology demonstrations, offering students more autonomy and strengthening their ability to think independently, thus compensating for the limitations of traditional teaching models. Similarly, in the previous Physics class example, educators' competency in pedagogy makes the course designs successfully incorporate tasks with high-level cognitive demand by using technology to guide students to investigate the effects of variables through interactive practices. PK's adaptability is

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reflected in its power to allow educators to tailor technology-enhanced activities in the classrooms and to enrich the versatility of the learning and teaching process.

3.2.3. Content Knowledge

Faced with an increasingly diverse range of available teaching resources and massive information, educators with solid CK can accurately identify and assess which contents fit the learning objectives well, so that they would avoid information overload, allowing them to better connect their academic knowledge with modern teaching resources to enhance the relevance and effectiveness of their instructions. On the contrary, educators with poor CK may feel stressed from the abundance of information and are unable to gather and integrate the beneficial resources smoothly. Besides, powerful knowledge competency is the basis for educators to grasp the core contents of the disciplines, together with the stimulation of the motivation for active learning and self-renewal. By exercising CK, educators are capable of keeping awareness of cutting-edge developments in the fields, using the existing academic frameworks to comprehend and incorporate emerging theories and findings, and assessing the value of possible applications in the classrooms, thus guaranteeing the continuous updates of their instructional materials. CK provides educators with the mandatory knowledge base and adaptive capacity to consistently maintain forward-looking in a changeable and unpredictable educational environment.

In essence, the construction of the TPACK competency serves as an ideal solution to confronting the difficulties brought by technology in education both individually and collectively [9]. By leveraging the TPACK model, educators are confident to incorporate technology in a systematic manner and be empowered to face the iterating challenges thoroughly.

4. The Recommendations

For better building and refining the TPACK competency and proceeding with the integration of technology in modern education, a few recommendations to enhance teachers' technological literacy, pedagogical strategies, and content knowledge are proposed.

To start with, professional training programs focusing on technology about AI applications should be developed. These training programs should provide educators with the experience to choose, access, and apply technology in their classrooms, improving their technological literacy and confidence. During the process, educators can take advantage of their personal experiences to investigate technology's capabilities and limitations, and how it can be integrated into specific subject content.

Besides, educators should also be engaged in ongoing pedagogical development campaigns. This could involve workshops, seminars, and collaborative teaching communities to discuss new technology and its integration into teaching practices. The campaigns should always be dynamic to incorporate the latest advancements in technology. On top of that, reflections always matter. Educators should also engage in regular reflections to assess how well AI tools are performing in the classrooms. The reflective process, as well as the feedback sharing among the groups, offers convincing evidence to modify the course arrangement and teaching strategies by setting future goals, providing information on progress, and seeing what is not understood [10]. It allows educators to always stay adaptable and fosters a responsive setting of instruction.

Additionally, educators are anticipated to establish social networks to regularly participate in academic sharing with their peers and scholars and stay in touch with these groups to make sure that they catch up with the latest theoretical advances and research findings in their fields. The sharing is not limited to face-to-face seminars, but can also take place in the form of education platforms, online forums, and social media. Meanwhile, educators are leveraging the effect of technology to update and

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expand their knowledge. Accessing the latest academic resources through journal databases and open course platforms is another self-oriented way to improve. The platforms usually cover various materials and course designs, in which teachers have the chance to conduct immersive learning by themselves and benefit from the experience of modifying their teaching content.

5. Conclusion

The widespread application of digital technological tools has evoked profound impacts on the educational system and unprecedented challenges to teachers' instructional abilities. In particular, how teachers can effectively integrate technology into their curriculums, how they can leverage technology to boost cognitive development, and how they navigate vast resources to align teaching content with learning objectives are the core issues.

To address these challenges, the strengthening of the TPACK competency to manage the integration of technology in teaching practices will work. Technical knowledge enables educators to be equipped with the foundational skills to apply technology, pedagogical knowledge supports them in selecting appropriate instructional approaches, whereas content knowledge provides them with the capability to deal with massive teaching resources.

In response to these challenges, it is recommended to launch specialized technological training programs, pedagogical development, reflective campaigns, and academic sharing and self-oriented learning to always be well-prepared. These measures are valuable in constructing solid TPACK competency and will ultimately advance educational essentiality.

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