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The Transformation of the Teacher's Role in STEM Education in the AI Era

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Abstract. Currently, the continuous improvement of artificial intelligence (AI) technology is receiving widespread attention in STEM education. However, existing literature on the challenges and role transformation needs faced by STEM teachers in the AI era is still lacking. This article summarizes six application modes and development trends of AI technology in STEM, and analyzes the benefits and dilemmas that AI technology brings to STEM teachers. AI technology can not only assist STEM teachers in efficiently managing classroom activities but can also simulate complex or dangerous scientific experiments. However, the lack of digital literacy, as well as issues of bias and fairness in AI, force a transformation in the role of STEM teachers. In response to the challenges faced by STEM teachers, this article provides the following suggestions: the role of STEM teachers needs to shift from traditional knowledge transmitters to diversified professional roles. Simultaneously, a hierarchical certification framework for teachers' artificial intelligence capabilities must be put in place.

Keywords: Artificial Intelligence, STEM Education, Teacher Role

1. Introduction

With the advancement of AI technology, the changes brought about by this technology in various industries have become a hot topic of social concern. In recent years, AI technology has deeply infiltrated the entire process of STEM teaching. For example, in the process of science education, the incorporation of virtual experiment platforms (such as the PhET simulation system) supports student autonomous exploration, and these technological advancements are reshaping traditional teaching processes and teacher-student interaction models.

However, the deep integration of AI technology with STEM education brings both benefits for STEM teachers and new challenges to their roles. Currently, the literature on AI and STEM education is gradually increasing, mainly focusing on discussing the changes that AI brings to STEM education. Since this research field started relatively late, the research framework is still not well-established. For example, there is a lack of research on disciplinary differences; existing literature often views STEM teachers as a homogeneous group and overlooks the significant differences in AI application needs and technology acceptance between different subjects, such as mathematics teachers and engineering teachers.

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This research has important theoretical and practical significance. On the theoretical level, this paper systematically sorts out the diverse application patterns of AI in STEM and its development trends, pointing out the challenges and suggestions faced by the integration of AI and STEM education, providing a new viable solution for constructing a 'human-machine collaborative' educational ecosystem. On the practical level, the research reveals the need to improve teachers' digital literacy, providing empirical evidence for the setting of teacher training courses and the optimization of human-machine collaboration models in schools.

2. The application and development trends of AI in the field of STEM education

2.1. The application of AI in STEM education

In recent years, the application of AI tools in STEM education has shown a rapid development trend. As an emerging field, it is worth researchers' in-depth exploration of how to apply diverse AI technologies within the STEM education system. The applications of AI in STEM education can be summarized into six typical models [1].

First is the learning prediction system, where STEM teachers can utilize machine learning algorithms to predict students' learning performance and conditions in advance, thus adjusting the teaching process. For example, Buenaño-Fernández et al. applied machine learning techniques and educational data analysis to estimate students' final grades by analyzing their past performance in computer engineering courses [2]. Another subcategory can identify high-risk students in STEM education. For instance, the random forest model developed by Yang et al. can proactively identify high-risk students in physics courses [3]. This can help teachers design special teaching strategies in advance for these students to intervene in their learning processes and methods.

Secondly, the intelligent tutoring system provides personalized and adaptive learning support through adaptive algorithms, divided into three subcategories: the delivery of teaching content, the recommendation of personalized learning paths, and the provision of resources [1]. The first subcategory can provide teaching content for STEM teachers through ITS, and research by Hooshyar et al. shows that such systems can improve learning efficiency by 30% [4]. The second subcategory offers personalized learning paths based on students' profiles in STEM education; the third subcategory provides corresponding learning resources according to students' needs in STEM education [1].

Next is the student behavior analysis technology, which can track students' learning behaviors, patterns, and characteristics, including monitoring and analyzing student behavior. This technology can help STEM teachers analyze students' potential learning behaviors and track their learning in STEM areas. This way, teachers can promptly identify the problems students encounter in STEM learning and quickly address them. For example, Hsiao et al. successfully identified typical behavior patterns and learning strategies of students in programming learning through hidden Markov models [5].

The fourth is the automated assessment system, which is divided into automated evaluation and automatic question generation [1]. The former helps accurately and efficiently assess student assignments, while the latter, which automatically generates learning questions, alleviates the teaching burden of STEM teachers. Next is the educational robot as an emerging application, which differs from the previous categories in that it allows students to acquire knowledge through interactive means. Finally, AI is also applied in areas such as AI textbooks and group formation.

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2.2. The development trends of AI technology in the field of STEM education

The current integration of AI technology with STEM education is deepening, which means that researchers not only need to consider the past and present applications of AI in the STEM education field but also need to think about its future development trends. Yuqin Yang has summarized the following four key pathways for the application of AI in STEM education: improving exploratory STEM teaching through design principles; seamlessly integrating emerging AI technologies into STEM education; practically applying new AI tools in STEM classrooms; and investigating the ability of AI to enhance student enthusiasm and academic performance in STEM subjects [6]. Based on the above information, future development trends can be glimpsed.

Firstly, AI technology is continuously impacting STEM education, and its combination with teaching methods has also become tighter. The application of AI in the STEM field is shifting from being a 'common teaching tool' to a 'deep integration of AI-STEM systems'. The application of AI is no longer simply about 'plugging' technology into traditional STEM classrooms, but about designing lesson plans based on modern STEM teaching concepts such as 'inquiry-based learning' and 'interdisciplinary learning' even before the course begins. For example, AI tools like educational robots and virtual laboratories play an important role as they can support students in independent exploration and practice. The development and application of these AI tools represent a shift of AI technology from 'assisting teaching' to 'participating in teaching'.

Secondly, AI technology itself is becoming more intelligent and transparent, providing students with highly personalized learning experiences. Intelligent tutoring systems, learning prediction systems, and automated assessment systems are manifestations of this trend. The intelligent tutoring system can provide one-on-one adaptive guidance like a human tutor. The learning prediction system can analyze data to proactively identify students who may be at risk and implement interventions. The automated assessment system can provide immediate and in-depth feedback on open-ended assignments such as programming and mathematical proofs. These technologies are dedicated to achieving scalable personalized education. The fundamental reason for their development is that traditional large class teaching struggles to cater to the different needs and paces of each student, whereas AI technology can process vast amounts of data and provide instant feedback to genuinely address this fundamental challenge.

3. Opportunities brought by AI to STEM teachers

The emergence and development of AI technology have brought new opportunities for STEM teachers. However, it is significant to know that the integration of AI technology is not meant to replace STEM teachers, but to provide them with powerful technical support to help them with some minor tasks, among other things, which can be viewed from the following two aspects.

First, AI technology can assist STEM teachers in efficiently managing classroom activities. STEM education emphasizes students as the main subjects of the classroom, requiring them to develop the ability to solve real-world problems through continuous exploration, while teachers act as facilitators, assisting students in completing a series of tasks. The integration of AI technology can help STEM teachers oversee the collaborative learning process, identify conflicts or imbalanced participation among members, and provide summary reports, allowing STEM teachers to manage classroom activities more effectively. For example, the intelligent assistants in the research by Casamayor et al. can provide teachers with summaries of each group member's progress, notifications of participation types, and alerts about conflicts [7]. Thus, in slightly larger classes, the

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issue of STEM teachers being unable to monitor the task completion status of each group member can be significantly reduced.

Secondly, AI tools can simulate complex or dangerous scientific experiments, compensating for the lack of school laboratory facilities while ensuring student safety. STEM courses often require students to engage in hands-on practice to solve problems through experiments and thereby learn relevant knowledge. However, during the design of experimental content, STEM teachers may face certain challenges. For example, the inadequacy of school laboratory equipment, or the high difficulty or risk level of experiments. Yet, the development of AI technology provides solutions to these issues. Research by Ibáñez et al. points out that AI-driven tools can simulate complex scientific experiments, providing practical learning experiences [8]. For instance, the emergence of many virtual experiment platforms (such as the phET virtual experiment platform) can simulate real experimental environments, allowing students to conduct complex or dangerous scientific experiments safely and at a low cost. This enables the implementation of experimental content that may be difficult to achieve in actual classrooms, providing strong teaching tool support for STEM teachers.

4. Challenges and suggestions

4.1. Current challenges

Integrating AI technology into the STEM education system faces multiple challenges. In terms of technological adaptability, statistics from Xu and Ouyang show that the applicability of existing solutions in engineering and mathematics subjects is only 60% of that in scientific subjects [1]. This proves that the adaptability of existing AI tools to the four different subjects in STEM education is inconsistent and does not take into account the differences in needs and applications of AI tools across different subjects. Regarding the relationship between teachers, students, and technology, as AI technology increasingly intervenes in the teaching process, UNESCO points out that there is a need to transform the traditional 'teacher-student' binary relationship into a 'teacher-technology-student' triadic relationship [9]. The inclusion of AI technology means that the interaction between teachers and students is transforming into a triangle, and STEM teachers need to be empowered to make AI a facilitator of knowledge production. Regarding the issues of AI bias and fairness, research shows that gender, race, and other factors continue to affect students' learning processes and performance in STEM [10]. This indicates that STEM education needs to consider this issue when adopting AI, consciously reducing bias to promote fairness.

Based on the challenges mentioned above and existing research, it can be analyzed that STEM teachers are also facing a series of intertwined challenges in adapting to the era of AI. At the technical level, the prevalent "digital literacy gap" means that many teachers can only perform basic operations, making it difficult to truly integrate AI deeply into teaching. In terms of teaching practice, the absence of "AI teaching methods" has led to weak links in human-machine collaboration strategies and classroom interaction design in intelligent environments. From an ethical perspective, some STEM teachers cannot identify data privacy risks and algorithmic biases, reflecting a deficiency in their ethical judgment. Meanwhile, rigid disciplinary barriers further hinder STEM teachers from engaging in interdisciplinary collaboration, affecting the promotion of AI-integrated innovation. These challenges together form a complex matrix of transformational dilemmas that require systematic solutions.

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4.2. Suggestion

In the face of the challenges of transforming STEM education in the AI era, a multi-dimensional, systematic support framework needs to be established. In terms of professional development, a hierarchical AI competency certification system should be established, with progressive training pathways from basic operations to advanced integration. Additionally, a 'dual-mentoring' training program for the 'AI discipline' should be developed, demonstrating human-machine collaboration strategies through real teaching cases to cultivate STEM teachers' abilities to utilize AI. On the technical support level, collaborations between the government and enterprises can provide cloud computing power and smart terminals, designing AI-assisted tools that are suitable for different STEM subjects. In terms of ethics and bias identification, practical risk assessment toolboxes must be developed, including data privacy checklists and algorithm bias identification guidelines, incorporating AI ethics into STEM teacher evaluation criteria. To promote interdisciplinary integration, it is recommended to establish a collaboration platform for STEM teachers to share innovative teaching cases in intelligent environments.

Meanwhile, the role of STEM teachers needs to shift from traditional knowledge imparting to a diversified professional role. Firstly, STEM teachers need to become learning facilitators, integrating digital technology with teaching strategies, balancing digital and face-to-face teaching, and guiding students to use AI tools correctly for autonomous learning, such as conducting language learning activities through ChatGPT [11]. Secondly, STEM teachers need to become technology integrators, mastering the operation and application of AI tools such as educational robots. Additionally, due to the limitations of AI in emotional recognition, STEM teachers need to strengthen their role as emotional supporters, focusing on students' emotional needs and social skills development. Research also indicates that STEM teachers need to develop capabilities in 'AI pedagogy,' including designing human-computer collaborative teaching strategies and assessing the effectiveness of AI-assisted teaching [12]. Finally, STEM teachers need to become ethical norms enforcers, enhancing professional training in data privacy protection and algorithm bias identification.

5. Conclusion

Overall, this article clarifies the application and development trends of AI technology in the field of STEM education, analyzes the opportunities and challenges that AI technology brings to STEM teachers, and offers related suggestions. Nowadays, the connection between AI technology and the STEM education system is becoming increasingly close. While AI technology provides opportunities for STEM teachers, it also presents multidimensional challenges regarding the transformation of their roles. The research found that STEM teachers face multiple dilemmas, such as technological adaptation barriers, insufficient innovation in teaching methods, and a lack of awareness of ethical risks. Therefore, STEM teachers need to transition from knowledge transmitters to multifaceted roles as learning facilitators, technology integrators, emotional supporters, and ethical coordinators. By undergoing this series of role transformations, STEM teachers can continually advance towards being leaders in STEM education.

Based on the current research gap, future studies could focus on the following directions. Firstly, cultural adaptability research: comparing the differentiated patterns of teachers' AI adaptation in different cultural backgrounds; secondly, the development of assessment tools: constructing a scientific and effective framework for evaluating AI teaching capabilities, with a focus on teachers' human-machine collaborative decision-making abilities; finally, interdisciplinary deep integration: exploring the distinctive integration paths of STEM disciplines with AI technology. These research

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directions will help build a more comprehensive and systematic theoretical framework for the development of STEM teachers in the AI era, providing stronger theoretical support for educational practice.

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