

The Impact of Personalized Learning Driven by Artificial Intelligence on STEM Education in Primary and Secondary Schools

Lanlan Zhang¹, Jinshuai Qu¹, Zhenping Zhang^{2,*}

¹Yunnan Minzu University, Kunming, Yunnan, 650500, China

²Kunming Institute of Precision Machinery, Kunming, Yunnan, 650500, China

*Corresponding author

Abstract: *With the rapid development of artificial intelligence technology, personalized learning has gradually become an important trend in STEM education in primary and secondary schools. This paper explores the multifaceted impact of personalized learning driven by artificial intelligence on STEM education in primary and secondary schools. By analyzing adaptive learning platforms, intelligent feedback systems, and data-driven teaching strategies, we found that artificial intelligence significantly improves students' learning outcomes, making teaching more flexible and efficient. Personalized learning enables students to learn according to their individual needs and interests, enhancing their learning experience and sense of participation. At the same time, teachers can use artificial intelligence tools to monitor and adjust teaching content in real time, thereby improving the pertinence of teaching. Although the application of artificial intelligence has brought many advantages, it also faces challenges such as data privacy and technological dependence. Future research should focus on these challenges and explore how to better balance the application of technology with educational ethics. Overall, personalized learning driven by artificial intelligence has a profound impact on STEM education in primary and secondary schools, providing new opportunities for innovation and progress in the field of education.*

Keywords: *artificial intelligence, Personalized learning, STEM education in primary and secondary schools*

1. Introduction

In today's rapidly developing information technology, artificial intelligence (AI) has penetrated into various fields of society, including education. The traditional education model emphasizes unified teaching content and standardized evaluation methods, but with the advancement of artificial intelligence technology, the education field is gradually exploring more flexible and personalized teaching methods. Especially in primary and secondary schools, STEM (Science, Technology, Engineering, and Mathematics) education, as an important component of cultivating students' comprehensive abilities and future professional qualities, faces unprecedented challenges and opportunities. Personalized learning systems driven by artificial intelligence, such as intelligent tutoring systems and adaptive learning platforms, can provide customized educational content based on each student's unique needs and learning styles by analyzing their learning data. This technology not only helps students receive immediate feedback during the learning process, but also dynamically adjusts teaching strategies based on their learning progress, thereby enhancing learning effectiveness and motivation. However, the application of these artificial intelligence tools in STEM education in primary and secondary schools has also brought new problems and challenges. For example, how to effectively integrate AI technology with existing teaching methods? What changes will occur in the role and responsibilities of teachers under this new model? How do students react to this personalized learning experience? These issues require in-depth exploration.

This study aims to explore the specific impact of AI driven personalized learning on STEM education in primary and secondary schools. By systematically analyzing the application of AI technology in educational practice, evaluating its impact on teaching effectiveness, teacher role, student learning experience, and other aspects, we aim to reveal how AI personalized learning can play a role in practical teaching, as well as the challenges and improvement directions it may bring.

This study will provide guidance for educators on the use of personalized learning tools based on artificial intelligence, helping them integrate these new technologies more effectively and improve teaching quality. From a theoretical perspective, this study will enrich academic research in the fields of personalized learning and STEM education, providing a reference for future educational reforms. In addition, by identifying and analyzing the specific impact of AI driven personalized learning on STEM education in primary and secondary schools, this study will also provide recommendations for policymakers to promote the effective application of educational technology and enhance educational equity and quality.

2. Literature review

2.1 Application of artificial intelligence in education

The application of artificial intelligence (AI) in the field of education has made significant progress in recent years, especially in personalized learning and intelligent tutoring systems [1]. AI technology can provide real-time feedback and support through methods such as big data analysis, machine learning, and natural language processing. These technologies are used to develop intelligent education platforms, such as intelligent teaching assistants, automated assessment systems, and virtual reality (VR) learning environments. Research has shown that these AI driven tools can customize content based on students' learning progress and performance, improving their learning efficiency and motivation [2]. For example, platforms such as Knewton and DreamBox dynamically adjust teaching content by analyzing students' learning data to meet their personalized needs. Further research has also explored the potential of AI technology in identifying students' learning difficulties, providing immediate intervention, and improving learning strategies.

2.2 Theoretical basis of personalized learning

The theory of personalized learning emphasizes providing tailored educational content based on students' unique needs, interests, and learning styles. This theory originates from educational psychology and teaching theory, particularly the ideas of constructivism and differentiated instruction. Constructivist theory holds that learning is a process in which students actively construct knowledge, therefore teaching should focus on students' cognitive development and individual differences. Differentiated teaching advocates that teachers should adjust teaching strategies based on students' abilities and needs to maximize support for each student's learning. The core of personalized learning lies in providing flexible learning paths and instant feedback through technological means, thereby helping students learn at their own pace. In recent years, with the advancement of AI technology, the implementation of personalized learning has become more feasible, AI systems can accurately analyze student data and provide them with personalized learning advice and resources [3].

2.3 Characteristics and needs of STEM education in primary and secondary schools

STEM education (science, technology, engineering, and mathematics) in primary and secondary schools aims to cultivate students' scientific literacy, technical abilities, engineering thinking, and mathematical skills [4]. This educational model emphasizes interdisciplinary integrated learning, aiming to enhance students' comprehensive abilities and problem-solving skills. The characteristics of STEM education include emphasis on practical operation, interdisciplinary integration, and connection with the real world. STEM education in primary and secondary schools faces various demands, including the need for abundant teaching resources, flexible teaching methods, and curriculum design that can stimulate students' interest [5]. In addition, due to the complexity and diversity of STEM education, teachers need to constantly update their knowledge and teaching methods to adapt to the rapidly changing technological environment. The application of personalized learning technology in this area can help teachers provide suitable learning content based on students' interests and abilities, thereby improving the effectiveness of STEM education and student participation.

3. Personalized learning tools driven by artificial intelligence

3.1 Introduction to main tools

Personalized learning tools driven by artificial intelligence have played an important role in the

field of education. These tools utilize advanced technology to analyze student data and provide tailored learning experiences. Here are several main AI driven personalized learning tools:

(1) Intelligent tutoring systems (ITS)

The intelligent tutoring system provides personalized teaching support by monitoring students' learning progress and comprehension ability in real-time. These systems can not only track students' learning data, but also analyze their answering habits and knowledge mastery to make precise personalized adjustments. With the help of advanced algorithms and data analysis, intelligent tutoring systems can simulate one-on-one tutoring experiences and provide students with tailored learning content. They dynamically adjust teaching content to adapt to students' learning pace and provide immediate feedback and guidance when students encounter difficulties, helping them quickly overcome obstacles. Common intelligent tutoring systems (ITS) include Khan Academy's Khanmigo, which can be adjusted to meet the specific needs of students and provide additional exercises and resources; And Carnegie Learning's MATHia, which provides precise math tutoring through in-depth algorithm analysis to help students master complex concepts. These systems not only improve learning efficiency, but also enhance students' self-learning and problem-solving abilities.

(2) Adaptive learning platforms

The adaptive learning platform utilizes advanced machine learning algorithms to conduct in-depth analysis of students' performance data, thereby achieving personalized learning experiences. These platforms can automatically evaluate students' knowledge mastery and learning progress, and adjust the difficulty and content of learning materials based on these evaluation results to maximize learning effectiveness. For example, DreamBox Learning utilizes data-driven methods to adjust the difficulty of math courses in real-time, ensuring that each student can learn at the most suitable level for their current ability. It dynamically adjusts teaching content by analyzing students' error patterns and success strategies, providing targeted exercises and feedback. Another typical platform is Smart Sparrow, which continuously optimizes learning paths and content through interactive and feedback mechanisms to meet the individual needs of each student. Smart Sparrow's adaptive technology can adjust courses based on students' real-time performance, providing personalized learning experiences and helping students maximize learning outcomes within their abilities. The dynamic adjustment function of these platforms not only improves students' learning efficiency, but also enhances their learning motivation and sense of participation.

(3) Virtual reality (VR) learning environment:

Virtual reality technology creates highly immersive learning experiences, allowing students to practice and explore in realistic simulated environments. This technology transforms traditional learning methods into more interactive experiences, allowing students to personally participate in virtual scenes and deepen their understanding of complex concepts and skills. The AI driven VR learning environment not only provides an immersive experience, but also allows for real-time adjustment of virtual scenes and tasks based on students' interactive behavior and performance, ensuring that each student receives personalized learning support. For example, zSpace utilizes its advanced virtual reality platform to create interactive science laboratories and engineering design environments, allowing students to conduct virtual scientific experiments, explore 3D models, and conduct engineering simulations. This virtual learning environment allows students to conduct experiments and project design without actual equipment or materials. EngageVR is also a similar platform that provides various virtual learning spaces, from historical reenactment to engineering design, supporting students to engage in in-depth learning and exploration in the virtual world. These platforms not only enhance the fun of learning, but also provide rich practical opportunities to help students better understand and apply the knowledge they have learned.

(4) Smart learning assistants

Intelligent learning assistants interact with students through advanced natural language processing technology, understand and respond to their questions, provide tailored learning advice, and guide them to complete learning tasks. These assistants can provide personalized answers and guidance based on students' questions, learning progress, and habits, thereby helping students learn more efficiently. For example, when students ask questions, intelligent learning assistants can not only provide instant answers, but also recommend relevant learning resources or explain concepts based on students' knowledge mastery. In addition, these assistants can also help students develop study plans and set reminders to ensure that they complete various learning tasks according to the plan.

In the field of education, voice assistants such as Google Assistant and Amazon Alexa have gradually been widely used. These assistants provide intelligent support to students by integrating various educational resources and course content. For example, Google Assistant can help students learn vocabulary, practice math problems, and provide quick access to scientific knowledge. It can also connect to educational applications and online courses, helping students obtain the necessary learning materials and answer questions. Similarly, Amazon Alexa also plays a role in education by integrating skills and applications to support students in language learning, answering subject questions, and providing interactive learning games. These intelligent assistants not only enhance students' learning experience, but also make personalized education more feasible and popular.

3.2 Functions and applications of tools

AI driven personalized learning tools have multiple functions, making the educational process more efficient and accurate. The main functions include real-time feedback and evaluation, adaptive learning paths, data-driven insights, virtual practice and simulation, intelligent content recommendation, as well as personalized coaching and support. The real-time feedback function enables students to quickly correct errors and receive targeted explanations and suggestions, enhancing learning effectiveness. The adaptive learning platform designs personalized learning paths based on students' abilities and progress, automatically adjusting course content to meet students' needs. Data analysis tools provide educators with insights into learning patterns, weaknesses, and progress, helping to develop effective teaching strategies. Virtual reality environments provide immersive practical opportunities for students to conduct experiments and explore in simulated environments. The intelligent content recommendation function recommends relevant learning resources based on students' interests and learning history, helping them expand their knowledge base. The personalized tutoring system provides customized support through simulated dialogue and interaction, effectively addressing the issue of insufficient teacher resources. These functions collectively enhance educational outcomes, provide students with more learning choices and support, and offer powerful tools for teachers to optimize the teaching process. As shown in Figure 1.

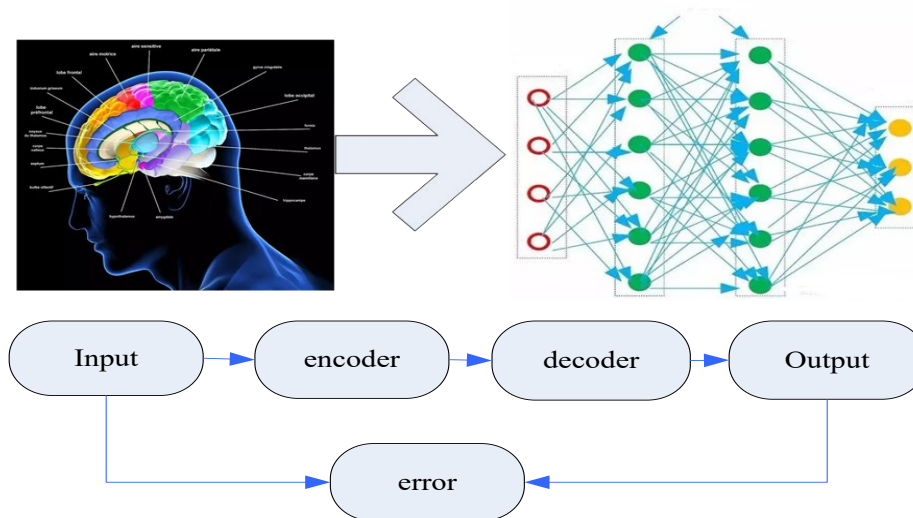


Figure 1: AI driven personalized learning platform

4. The impact of personalized learning on STEM education in primary and secondary schools

4.1 Learning outcomes

Personalized learning has significantly improved the learning outcomes of STEM education in primary and secondary schools. The traditional teaching model often operates in a unified manner, making it difficult to meet the individual needs of each student. Personalized learning, on the other hand, achieves tailored educational resources and learning tasks through adaptive learning platforms and AI tools. This tailored approach allows students to learn at their own pace, gradually mastering knowledge within their comfort zone. For example, students can choose the most suitable learning materials based on their personal understanding speed and learning style, avoiding anxiety caused by

not keeping up with the pace or feeling bored due to overly simple learning content. In addition, the real-time feedback function greatly improves learning efficiency. Students can receive immediate feedback after completing tasks and exercises, which allows them to quickly identify and correct errors. Through this instant feedback mechanism, students' understanding of complex concepts can be deepened, as they are able to make adjustments in the initial stages of errors rather than realizing the existence of problems after long-term error accumulation. This approach not only enhances students' learning ability, but also strengthens their confidence in solving problems.

The design of personalized learning paths ensures that each student can take on challenges within their own abilities, thus avoiding the frustration that traditional one size fits all teaching methods may bring. By setting learning tasks and goals of different difficulty levels, students can continuously improve through appropriate challenges, rather than feeling powerless due to high or low demands. This personalized challenge setting effectively stimulates students' learning motivation and interest, enabling them to gain a sense of achievement in the process of constantly surpassing themselves. In addition, data-driven insights further enhance teaching effectiveness. AI tools and adaptive learning platforms can collect and analyze a large amount of data, including students' learning progress, error rates, and engagement. These data provide valuable insights for teachers, enabling them to accurately identify students' weaknesses and progress. Based on these insights, teachers can adjust teaching strategies more targetedly, provide personalized tutoring and support, and thus enhance overall learning outcomes. This data-driven approach not only makes teaching more scientific and effective, but also provides powerful tools for teachers to better meet the needs of each student.

4.2 Teaching methods

The introduction of personalized learning has significantly changed traditional teaching methods, making education more flexible and efficient. In traditional teaching models, teachers mainly play the role of imparting knowledge, and lectures are usually given in a unified manner in the classroom. However, within the framework of personalized learning, the role of teachers has shifted to being guides and supporters of the learning process. With the help of AI driven tools, teachers can monitor students' learning progress in real time, understand their learning habits, mastery level, and weak links through data analysis. This enables teachers to adjust teaching content and methods according to the specific needs of each student, thereby providing tailored learning experiences for students. For example, teachers can adjust the difficulty of courseware, provide additional learning resources, or adopt different teaching strategies based on students' learning progress and interests to meet their individual needs to the greatest extent possible.

This personalized approach not only improves the pertinence and effectiveness of teaching, but also makes teaching more dynamic and adaptable. Teachers can identify and solve problems encountered by students more quickly, thereby promoting their comprehensive development. At the same time, the application of virtual practice and simulation technology has further enriched teaching methods, enabling teachers to create more interactive and practical classroom experiences. Through virtual laboratories and simulated environments, students can conduct practical operations and experience the problem-solving process in real scenarios, which is difficult to achieve in traditional teaching. This practical learning approach particularly stimulates students' interest and participation in STEM (Science, Technology, Engineering, and Mathematics) subjects, encouraging them to actively explore and deepen their understanding of complex concepts and technologies. Overall, personalized learning not only improves the effectiveness of teaching, but also makes students' learning process more participatory and interesting, promoting innovation and development of educational models.

4.3 Learning experience

Personalized learning significantly improves students' learning experience, making it more enjoyable and productive. Students can choose content based on their interests and learning styles in a personalized learning environment, which increases their autonomy and enthusiasm for learning. Virtual reality and simulation technology provide immersive learning experiences, allowing students to experiment and explore in simulated environments without being limited by actual resources. This immersive experience not only enhances students' practical abilities, but also strengthens their scientific thinking and problem-solving skills. In addition, intelligent content recommendation systems help students discover new materials and resources related to their interests, thereby maintaining their enthusiasm and motivation for learning.

5. Conclusion

The personalized learning driven by artificial intelligence has significantly optimized the learning outcomes of STEM education in primary and secondary schools. Through customized learning paths, real-time feedback, and data analysis, students can master complex concepts at their own pace, while teachers can adjust teaching strategies according to students' specific needs, thereby improving overall learning effectiveness. This method breaks the limitations of traditional teaching and allows for more flexible and efficient teaching. In addition, personalized learning improves students' learning experience by providing self-directed learning content and immersive practical opportunities, stimulating students' interest and participation.

However, although the application of artificial intelligence in education has brought significant benefits, attention should also be paid to its potential challenges, including data privacy and technology dependency issues. Therefore, future research should focus on balancing the application of technology with educational ethics to achieve more comprehensive educational outcomes. Overall, personalized learning driven by artificial intelligence has brought revolutionary changes to STEM education in primary and secondary schools, and has the potential to further promote innovation and progress in the field of education.

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