

Application and Challenge of Artificial Intelligence and Big Data Technology in Adaptive Learning

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Abstract:

AI systems can accurately assess learners' knowledge and interests, and provide tailor-made learning content and suggestions. During the learning process, learners can also identify the key factors that affect their learning outcomes, predict their learning progress, and adjust their learning strategies in a timely manner. This data-driven approach not only enhances the accuracy of learning but also provides a scientific basis for individual learning. However, the application of AI and big data analysis in education also faces many challenges, such as personal privacy protection, fairness and transparency of AI systems, and how to cultivate learners' understanding and application ability of AI. This article aims to explore how AI and big data analysis reshape the experience of adaptive learning, analyze its current application status in education, and discuss the challenges it faces and future development directions.

Keywords:

AI, Big Data Technology, Adaptive Learning, Natural Language Processing Technology, Large Language Model, Education

1. Introduction

In recent years, with the increasing maturity of artificial intelligence and big data technologies, adaptive learning has made remarkable progress in the field of education. The traditional standardized education model has limitations in meeting the unique needs of each learner. However, with the rapid development of AI technologies such as deep learning and natural language processing, as well as the collection and accumulation of educational big data, learning methods and contents are being redefined [1]. Adaptive learning emphasizes adjusting learning content and methods according to the characteristics, needs and learning conditions of each learner. Through big data analysis, learners can have a more comprehensive understanding of their learning process and achievements. The AI system can accurately assess learners' knowledge and interests, and provide tailor-made learning content and suggestions. During the learning process, learners can also identify the

key factors that affect their learning outcomes, predict their learning progress, and adjust their learning strategies in a timely manner. This data-driven approach not only enhances the accuracy of learning but also provides a scientific basis for individual learning. However, the application of AI and big data analysis in education also faces many challenges, such as personal privacy protection, fairness and transparency of AI systems, and how to cultivate learners' understanding and application ability of AI. This article aims to explore how AI and big data analysis reshape the experience of adaptive learning, analyze its current application status in education, and discuss the challenges it faces and future development directions.

2. The Current Application Status of AI and Big Data Analysis in Education

2.1. AI technology and big data analysis enhance the learning experience

The application of AI and big data analysis in the field of education has demonstrated remarkable development potential. Luan et al. (2020) pointed out that education is moving towards precise education and adaptive learning supported by big data analysis and AI technology [2]. This trend indicates that the application of AI in education has gradually shifted from focusing solely on technical performance in the early days to comprehensive research that combines cognitive theories with individual differences. This means that AI is not only a tool for enhancing learning efficiency, but also a means to understand and adapt to the needs of learners. By integrating educational theories such as cognitive load theory and social constructivism into the design of AI systems, learners can promote the cultivation of in-depth understanding and critical thinking.

In terms of the application of educational big data, Fischer et al. (2020) proposed a multi-level analytical framework, which is divided into three levels: Micro, Meso, and Macro [3].

At the micro level, it focuses on the operational behaviors of learners on online learning platforms, such as clicks and browsing time, and can accurately capture the learning process and behavioral patterns. By analyzing these details, the system can understand the learner's concentration, learning strategies, and preferences for different learning resources, thereby providing real-time learning suggestions.

At the meso level, focus on the text generation of learners, such as homework and discussion articles, and analyze cognitive and emotional responses through natural language processing techniques. For instance, one can assess a learner's understanding of a certain concept, the display of critical thinking, and even their learning motivation and emotional state, and then adjust the learning content or provide appropriate support.

The macro level covers comprehensive information of schools or educational institutions, including course arrangements, examination results, and the usage of learning resources, etc. These materials can be used to predict learning trends, identify common learning problems, and provide personalized course suggestions for learners. Meanwhile, educational institutions can also optimize resource allocation and improve the overall teaching quality accordingly. Through this multi-level analysis, educational big data can comprehensively understand the needs of learners and the characteristics of the learning environment from micro individual behaviors to macro overall trends, providing a solid foundation for the realization of adaptive learning.

2.2. Application of Natural Language Processing Technology in Education

Shaik et al. (2022) explored the application of natural language processing techniques in education, particularly the progress made in feature extraction, feature selection, and topic modeling [4]. These technologies can improve the learning environment. For example, automatic scoring, sentiment analysis and knowledge graph construction. NLP technology can automatically analyze learners' text input, providing real-time feedback and personalized learning suggestions. For instance, in language learning, NLP can automatically correct grammatical errors, offer vocabulary suggestions, and analyze learners' language abilities. In addition, on discussion forums or online learning platforms, NLP can be used to analyze learners' engagement and emotional states, assisting educators in understanding learners' needs and thereby adjusting teaching strategies.

2.3. Application of AI in the Process of Optimizing Learning

The systematic review by Dogan et al. (2023) points out that the application of AI technology in education mainly focuses on optimizing the learning process, identifying and predicting learner behavior, and promoting the implementation of adaptive learning [5]. The application of AI makes the presentation of learning content more accurate and can provide real-time feedback, further promoting cooperative learning among learners. By analyzing learners' learning paths and participation, AI technology can predict possible learning difficulties and provide timely suggestions. Furthermore, the AI system can make dynamic adjustments based on the learner's progress to achieve the goal of adaptive learning.

3. AI-driven Learning Systems and Analysis

3.1. Integration of Adaptive Learning Systems and large language Models

Adaptive learning systems have become a representative application of AI-driven adaptive learning. They can dynamically adjust the learning content and difficulty based on the learner's learning progress, performance and needs, thereby enhancing learning efficiency and experience. Natriello (2017) proposed that adaptive learning can be explored from seven key viewpoints [6]:

(1) Natural Tasks Perspective: Focusing on the learning tasks of learners in daily life and the natural environment, it aims to relate the learning content to the needs of the real world and enhance the practicality and interest of learning.

(2) Constructed Learning Tasks Perspective: Emphasize the design of specialized learning activities and tasks to support specific learning goals and make adjustments based on the needs and abilities of learners.

(3) Learning Analytics Perspective: Utilize data analysis techniques to collect and interpret the behavioral and performance data of learners, provide real-time feedback, and support the formulation of personalized learning paths.

(4) Assessment Perspective: Focus on the assessment of learners' knowledge, skills and abilities, adopt diverse assessment methods, and provide precise data support and improvement suggestions for adaptive learning.

(5) Content Model Perspective: It involves the organization and structuring of learning content, establishing content models to support personalized learning paths and ensuring the relevance and coherence of learning content.

(6) Instructional Strategy Perspective: Explore and apply various teaching strategies and methods, select the most suitable teaching approach for learners, and enhance learning outcomes and participation.

(7) Social Networking Perspective: Consider the interaction and collaboration among learners, and leverage the power of social networks and community learning to promote knowledge sharing, collaborative learning and common growth.

(8) The integration of these viewpoints provides guidance for the designers and practitioners of adaptive learning systems, aiming to meet the individualized needs of learners and enhance the learning experience and learning outcomes. By continuously collecting and analyzing learners' learning data, the system is constantly optimized to build a more precise and efficient personalized learning path, supporting the all-round development of learners.

Recent research has further explored how to integrate Large Language Models (LLMs) into adaptive learning systems to enhance their performance. Kuo, Chang and Bai (2023) put forward a variety of blend in LLMs nets material to eligibility digital learning platform method [7]. For example, LLMs can be used to analyze learners' open-ended responses, accurately diagnose learning weaknesses, and thereby reduce the number of test questions. In the remedial teaching process, chatbots that can have Socratic conversations with learners are utilized to provide more in-depth learning support. LLMs can also identify learning weaknesses across grades through interaction with learners and generate customized assessment questions to meet individual needs.

3.2. The Role of AI Technology in Learning Prediction and Support

AI systems can analyze learners' learning data, predict future learning performance, identify possible learning difficulties in advance, and enable learners to adjust their learning strategies in a timely manner. Gencoglu et al. (2023) examined learners' views on learning experiences by using machine learning and expert analysis [8]. The research analyzed open-ended responses from over 170,000 learners, and the results showed that clear explanations, supportive learning atmosphere, curriculum diversity, and interest stimulation were the key themes. This method emphasizes the importance of understanding effective learning from the learner's perspective and can be used to optimize the quality of learning.

Furthermore, AI technology has also demonstrated potential in supporting diverse learners. Evmenova et al. (2024) explored the application of generative AI tools, such as ChatGPT, in supporting diverse learners [9]. The study found that these tools can assist English learners and those with special needs by providing translation support and language practice. For example, AI can generate dialogue exercises of appropriate difficulty based on the language proficiency of learners, or provide vocabulary explanations and cultural background information for specific articles, etc.

AI technology not only enhances learning efficiency but also helps learners understand their own needs more comprehensively and formulate targeted learning strategies. Through learning analysis and prediction, learners can assess their learning performance more accurately, identify learning difficulties in a timely manner, and thereby improve their learning methods. These developments demonstrate the application value of AI in education and also show its potential in enhancing the overall quality of learning.

4. Challenges and Future Development Directions of AI and Big Data Analysis in Education

AI and big data analysis have shown great application potential in education, but more consideration is still needed on how to balance the relationship between technological progress and the essence of education. Several aspects of suggestions:

4.1. Challenges and Deficiencies at the present Stage

Although AI and big data analysis technologies have shown great application potential in the field of education, they still face some challenges at present. Firstly, some studies may have overlooked the deep integration of learning methods and AI technology, resulting in the failure to fully exert the application effect of the technology. Secondly, in terms of technical aspects such as NLP, there are still difficulties in handling the complexity of professional domain language, understanding irony and ambiguous semantics, as well as interpreting emojis and special symbols. These problems may affect the accurate analysis of learners' texts by AI systems, and thereby influence the effect of adaptive learning. In terms of data usage and AI ethics, regulation and standards still need to be improved, especially when dealing with large and complex educational data, which requires a high level of data science skills. At the same time, privacy issues must be carefully considered to ensure that while making full use of data, the privacy rights of learners are protected. Future research should explore in greater depth how to effectively combine these technologies with educational theories, and strengthen the emphasis on ethical issues in the practical application process to promote the continuous development of the education field.

4.2. The Impact of AI Tools on Learning Outcomes

The impact of AI tools on learning outcomes has attracted widespread attention. The research by Bastani et al. (2024) pointed out that the improper use of generative AI (such as GPT-4) may have a negative impact on learners' learning outcomes [10]. Although AI tools can significantly improve learners' performance on practice questions in the short term, in formal exams without AI assistance, the performance of learners who once relied on these tools has declined. This phenomenon reveals the duality of AI tools, emphasizing that educators need to carefully evaluate how to balance the benefits of real-time learning and long-term learning goals during the deployment of AI technology to ensure that learners do not lose the ability to think independently and master core skills.

4.3. Promote the development of AI literacy among educators

The research by Kim and Kwon (2023) indicates that educators have relatively weak confidence in AI-related content knowledge, especially technical knowledge, but are more confident in teaching knowledge [11]. Through interview analysis, the research identified five major challenges faced in AI education and proposed 22 capabilities required by primary school educators in AI education, which were classified according to the TPACK framework. The research emphasizes that in order to successfully promote the implementation of AI courses, it is necessary to attach importance to the professional development of instructors, especially strengthening their training in AI content knowledge. Furthermore, instructional design and the redesign of the learning environment are extremely important for improving teaching

effectiveness. How to develop the ability model based on the actual teaching experience of educators is important.

4.4. Develop learner-centered AI systems

Developing learner-centered AI systems is one of the key focuses for future development. Diaz and Nussbaum (2024) analyzed the current application status of AI in K-12 education through a systematic literature review and found that although AI tools have made technological progress, they have not fundamentally changed the traditional learning methods [12]. The research proposed the framework of “Learner-centered AI” as the guideline for the future application of AI in education. It is emphasized that AI technology should assist rather than replace learners' autonomous learning and should be based on effective learning strategies and theoretical foundations. This echoes the proposition of Luan et al. (2020) that the integration of AI technology should adopt an interdisciplinary approach, encouraging cooperation among academia, practical fields and industry to ensure that the application of AI technology can truly serve the learning objectives [2].

Although the application of AI in education shows broad prospects, its effectiveness and sustainability depend on whether the above-mentioned challenges can be properly addressed. Future research should continue to explore how to integrate AI technology more appropriately into the learning process, ensuring that the application of technology always aims to enhance learning outcomes and promote the all-round development of learners.

5. Conclusions and Suggestions

Artificial intelligence and big data analysis are opening a new chapter for adaptive learning. By providing personalized learning experiences, precise learning analysis and predictive assessment, these technologies are changing the way learning is done. AI applications such as adaptive learning systems, intelligent learning platforms, and learning analysis tools provide learners with tailor-made learning paths. Big data analysis provides learners with a new perspective to deeply understand the learning process and improve learning methods. However, while enjoying the benefits brought by emerging technologies, we must also be cautious about the challenges involved, including issues such as data privacy, ethical considerations, and insufficient AI literacy among learners. The application of technology should not replace the essence of learning, but rather be regarded as an enhancement and extension of learning services, assisting in achieving the core goals of learning. To fully leverage the potential of AI and big data analysis in adaptive learning, the following specific suggestions are put forward:

(1) Enhancing the AI literacy of educators: Teachers can actively participate in professional training related to AI to understand the basic principles and application methods of AI technology. It will help to effectively integrate AI tools in the classroom and design teaching activities that meet the needs of learners.

(2) Carefully select and use AI tools: When introducing AI tools, it is necessary to consider their long-term impact on learners' learning outcomes. Excessive reliance on AI should be avoided, and learners should be encouraged to cultivate the ability of independent thinking and problem-solving.

(3) Develop learner-centered teaching design: In the teaching process, teachers should adopt learner-centered teaching strategies, utilize AI technology to provide

personalized learning support, and at the same time promote learners' autonomous learning and collaboration abilities.

(4) Strengthen ethics and privacy education: Emphasize the significance of data privacy and ethics in teaching, educate learners about their responsibilities and risks when using AI and big data, and cultivate their digital citizenship literacy.

(5) Establish a platform for cooperation and sharing: Encourage educators to build a collaborative network, jointly share the application experience and resources of AI in teaching, and promote the common growth of the teaching profession.

(6) Continuous follow-up research and practice: Educators and researchers should collaborate to conduct long-term follow-up research, assess the impact of AI technology on learning outcomes, provide reliable basis for educational practice, and constantly improve teaching methods. In the future, with the continuous development of AI and big data analysis technologies, there will be opportunities to create more efficient, personalized and inclusive learning environments. Through the active participation and prudent application of educators, we can assist learners in adapting to the challenges of future society, cultivating innovative abilities and the capacity for lifelong learning, and contributing to the innovation and progress of education.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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