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Analysis of Digital Education Ecosystem Based on Large Language Models

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Abstract. With the arrival of the new era of Industrial Revolution 4.0, the development trend of artificial intelligence has become unstoppable. Of course, in the field of education, AI technology is also changing the way teachers teach and students learn. It is extending and improving the education ecosystem in a digital way. By 2025, the AI application rate of Chinese primary and secondary school teachers is expected to reach 81% (with a daily usage rate of 26.2%). This paper has a general-specific-general structure and mainly investigates the digital education ecosystem based on chatbots included in large language models, ChatGPT analysis, and reinforcement training from expert systems and personalized learning systems. Through case studies of related examples, it analyzes the breakthroughs they have made, discusses further research, explores future prospects and shortcomings in the new era, and proposes ideas for the innovative development of AI. Finally, it summarizes the digitalization process of the education ecosystem under the influence of large language models.

Keywords: Artificial Intelligence, Education, Large Language Model

1. Introduction

Since the concept of artificial intelligence was proposed, with the continuous improvement of information technology, the whole world is undergoing a transformation related to AI, and therefore AI is an inevitable product of the development of the current era. In the field of education, the involvement of AI is mainly aimed at promoting educational equity and reducing the educational gap. This is mainly reflected in traditional education, which usually adopts a "one-size-fits-all" teaching method, thereby ignoring students' individual differences and interests. The rise of artificial intelligence technology has brought a completely new direction and resources to personalized education, while also making a significant contribution to balancing educational resources among students [1].

As of today, an increasing number of artificial intelligence devices have entered people's view in classrooms. For example, the emergence of chatbots, and AI functions such as Deepseek's exam preparation and AI grading. It is expected that by 2027, AI teaching assistants will cover up to 75% of the target. Large language models, as the core interaction hub in AI, play a crucial role in digital education. After 2023, both academia and industry have significantly promoted research on large

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language models (LLMs). A notable development is the release of ChatGPT (a powerful AI chatbot developed based on LLMs), which has attracted widespread social attention [2]. The technological evolution of LLMs is having an important impact on the entire AI community. In the field of education, it possesses human-like abilities in understanding, generating, reasoning, and interacting, and can deeply engage in all aspects of teaching, learning, assessment, and research. Based on large language models, the learning of students and the teaching of teachers are constantly improving from two technical aspects.

In personalized learning for students, artificial intelligence mainly uses the technology of personalized learning systems, which are based on learner models, knowledge graphs, and adaptive algorithms, to diagnose learning conditions in real-time, plan paths, push resources, and evaluate outcomes, forming a closed loop. Personalized learning systems generally aim to use various teaching tools to achieve an integration of real and virtual learning through the use of reinforcement learning. Fully replacing or at least improving the role of human tutors through personalized learning systems is the end goal of the systems. To achieve guided learning methods, these systems will have to share the role of teaching along with the teachers [3].

AI is utilized through the means of expert systems. When teachers implement expert systems, they have to convert the teaching experience of the subject 'masters' and the organizing principles of the knowledge points into a synonym logic for the computer systems. Large amounts of data are stored in the 'invisible' neural network layers. With this data, the system can perform the mechanical work of student learning diagnostics, personal tutoring, and test generation. This allows teachers to better understand the areas of student weakness and further diagnostics on the optimization of teaching and the reduction of the teachers' workload.

Of course, in the current era there are still some tasks that AI cannot accomplish. It cannot truly provide critical or innovative answers to related questions. Moreover, for language models, they are easily misled and biased, inheriting gender, regional, and occupational biases from the training data, and can also be easily induced to produce inappropriate content. More errors in accuracy are likely to be present. All in all, the influence of AI is substantial in education. Digital education with large language models is the focus of this article. AI assistants in digital education will be analyzed to create the framework for the role of AI in education, and will guide people in examining its benefits and challenges, as well as what the future may hold. AI assistants are shown to help personalize learning, simplify repetitive tasks, and offer feedback. However, there is potential for the overdependence of automation, smart technology helps provide instruction, as well as feedback in the digital classroom. AI eases and helps innovation in learning. Digital assistants may also help learning. AI implementation is characterized positively, almost exclusively, in education settings. However, there are backdrops and blocks. An application of large language models in education, guided by pedagogical principles, featuring broad equity and human oversight, is the ultimate goal strving to place people on the center of learning, not learning on the center of people.

2. Overview of related technologies

2.1. AI learning assistant

AI learning assistant are intelligent support tools centered on artificial intelligence, designed for learning scenarios. They can accompany, tutor, and assist with various learning tasks throughout the process, enabling efficient autonomous learning, answering knowledge questions, organizing key points, providing learning support, and offering personalized guidance. Of course, in the current era, AI learning assistants are mainly available as mobile applications. AI-assisted learning tools can also

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be used by students, offering broad support and guidance, and have long been considered a potentially powerful application of artificial intelligence in education [4]. For example, AI applications like ChatGPT are relevant tools. As the most popular large language models of recent times, they have been widely used in students' daily lives to effectively answer questions through learning from large amounts of data. Currently, the overall satisfaction of middle and high school students and university students with AI learning assistants is around 65%–75%, and more than 80% of students have used AI tools in their studies. AI learning assistants also include projects like chatbots. Chatbots are computer programs designed to simulate human conversation, enabling interaction with people through text or voice interfaces [5]. In recent years, chatbots have been increasingly used in education to provide personalized support, automate administrative tasks, and offer new engagement opportunities for students. Research on AI chatbots and second language learning shows that they can enhance language proficiency, learning motivation, reduce anxiety, and increase engagement, with the most notable improvements in speaking and writing, making them efficient language learning tools. The optimal model is human-machine collaboration: AI assists with basic skill practice while teachers provide in-depth guidance. Future research should focus on emotional intelligence, cultural adaptation, and multilingual support [6]. Thus, it is evident that AI learning assistants can improve student education to a certain extent.

2.2. Evaluative AI

Automated formative assessment applications are research-based and commercialized applications that combine natural language and semantic processing with other AI-assisted technologies to provide actionable feedback on students' writing or other student outputs. Although they have potential in supporting student learning, they may face difficulties in automatically providing accurate and helpful feedback. Regarding these assessment AIs, they mainly focus on teachers and students summarizing their feedback and classroom outcomes. Currently, there are still few related applications implemented on the market, and their related applications are only in a superficial stage because they require large amounts of data combined with student-related information. Meanwhile, research at Stanford University evaluated an automated scoring AFA system that provides feedback on programming tasks completed by 12,000 students in a computer science course. Students agreed with the feedback about 98% of the time, slightly higher than their agreement with feedback from human teachers [7]. This data indicates that assessment AI cannot yet handle complex situations, but as the AI most likely to be realized in the future, its impact on education is very positive. It helps teachers and students save most of the time spent on providing feedback on a day's learning, and to some extent, it relaxes students and effectively helps them address their own problems.

2.3. Personalized learning system

AI has been applied to education, and has brought about personalized learning, revolutionizing the learning experience. Personalized learning is a learning approach that caters to the individual needs, abilities, interests and learning styles of students [8]. A Personalized Learning System is an intelligent educational system with a human-centered approach that integrates data, artificial intelligence and educational science. It adaptively adjusts the content, path, speed, and feedback of learning based on individual levels of knowledge, learning ability, preferences and progress, with the aim of achieving "teaching students according to their abilities" and delivering a "one-on-one" experience [3].

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Artificial intelligence is essential for personalized learning because it uses data mining via machine learning algorithms to identify learning patterns based on students' learning preferences, behaviours and learning performance [8]. AI can then leverage this information to provide a personalized learning experience according to the needs of the individual. For instance, AI can suggest learning materials, pinpoint areas of weakness, and increase or decrease the complexity of learning tasks. The benefit of personalized learning is that it helps ensure students get the support and guidance they need to achieve their full potential. Personalized learning can enable students who are falling behind to catch up, and challenge students who are excelling [9].

In applied AI-based personalized learning systems, there are K12 smart classrooms on-campus, which mainly adopt a model of smart classrooms, tablets/learning devices, and learning analytics platforms, with big data, AI and cloud computing technologies underlying it. This model creates a new paradigm for primary and secondary schools (elementary to high school) classrooms with data-driven teaching, precision teaching, personalized learning and real-time feedback. With an integrated "cloud-network-terminal" structure, the whole process of pre-class, in-class and post-class activities is digitalised. The High School of Beijing Normal University has applied the AI personalized learning system with an average score increase of 30 points for high school students and the rate of key topic mastery has increased 15%. This demonstrates that the personalized learning systems have developed from concept to routine use. In the future, the application of personalized learning systems will be more comprehensive, enabling 1:1 learning matches, applying data analysis to real-world problems, truly thinking from the students' perspective, and teaching based on the students' abilities [3].

2.4. Expert system

The concept of Expert Systems was officially proposed in 1965 by artificial intelligence pioneer Edward Feigenbaum at Stanford University in the United States, with the hallmark being the birth of the world's first expert system, DENDRAL. An expert system refers to an intelligent program system based on the knowledge of domain experts, using an inference engine to simulate expert thinking to solve complex problems in a specific field. In the field of education, expert systems are database-based algorithms that solve problems through methods such as machine learning. Research in artificial intelligence in education (AIEd) shows that dynamic and comprehensive expert systems can assist in teaching planning and fully unleash the potential of learning management systems (LMS) in teaching and learning [10]. Researchers have investigated the impact of fuzzy expert systems on the mathematics learning outcomes of elementary students in Taiwan. In this study, students in the experimental group performed better in mathematics learning than the other two groups. Additionally, the study found that adaptive learning models combining emotional and cognitive performance analysis could effectively reduce mathematics anxiety among fifth-grade students in Taiwan [11]. In TR, the expert system regards traditional teachers as educational experts responsible for developing teaching content and instructional knowledge to facilitate student learning. A large amount of data has proven that the implementation of expert systems in education has a promising future [1]. In practical applications, in expert systems, the intelligent error diagnosis and personalized tutoring system is used on learning machines. When a student makes a mistake, it will generate the corresponding wrong questions and related problems to help the student solve the issues.

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3. Application of related algorithms in educational AI

This article conducts a certain amount of retrieval and analysis of peer research papers related to artificial intelligence education, and further studies them through learning related topics.

3.1. Cross-entropy loss formula

This paper conducts certain searches and analyses of peer research papers related to artificial intelligence education, and delves deeper into their study through learning relevant topics. Secondly, this paper also conducts an in-depth study of the algorithmic basis of large language models, and infers their results by analyzing the cross-entropy loss formula of large language models. Cross-Entropy Loss is a function for measuring the difference between two probability distributions and is widely used in machine learning and deep learning models, especially in classification tasks to optimize model performance.

$$L_{CE} = -\sum_{i=1}^{n} y_i \log\left(\hat{y}_i\right) \tag{1}$$

y_i is the true label, $\hat{y}_i$ is the model's predicted probability distribution, n is the number of classification categories.

The cross-entropy loss function plays a crucial role in classification tasks. By minimizing the loss function, neural networks can gradually learn more accurate classification boundaries. Different variants of cross-entropy can adapt to different types of classification tasks. It is a formula that measures how much the model's predictions differ from the true answers. By studying this formula, it is found that large language models will produce increasingly accurate answers as their databases continue to improve, and the probability distribution predicted by the model will be as close as possible to the real text. With the continuous development of large data models, the improvement of digital ecological education systems will also be better.

$$L\left(N\right) = \left(\frac{N_c}{N}\right)^{\alpha_N}, \quad \alpha_N \sim 0.076, N_c \sim 8.8 \times 10^{13} \tag{2}$$

$$L\left(D\right) = \left(\frac{D_c}{D}\right)^{\alpha_D}, \quad \alpha_D \sim 0.095, D_c \sim 5.4 \times 10^{13} \tag{3}$$

$$L\left(C\right) = \left(\frac{C_c}{C}\right)^{\alpha_c}, \quad \alpha_c \sim 0.050, C_c \sim 3.1 \times 10^{8} \tag{4}$$

And at the early stage of the creation of large language models, the OpenAI team first proposed modeling the power-law relationship between the performance of neural language models and three main factors: model size (N), dataset size (D), and training compute (C). Given a compute budget c, they experimentally validated the three fundamental formulas of the scaling laws. These three formulas also indirectly reflect that as technology advances, large language model systems become more refined. Applications in education will be more accurate [2].

3.2. Reinforcement learning

During the class, problems can be more easily solved for students through expert systems. Moreover, in personalized learning systems, this paper also studies reinforcement learning.

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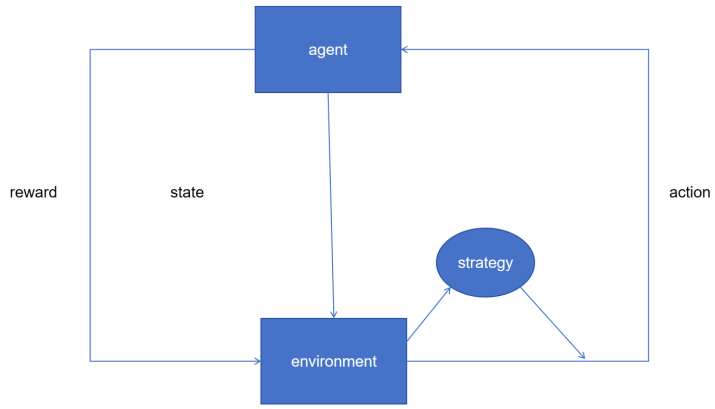

Figure 1. Reinforcement learning system architecture (picture credit: original)

The main algorithm for personalized learning systems is reinforcement learning. As shown in figure 1, the state can be seen as the mastery of knowledge points, the action is to recommend the next learning content, and the reward is the improvement in learning efficiency. Through the entire process,It achieves a match with personalized learning systems, thereby enhancing students' interest in learning. This case of a reinforcement learning system demonstrates the predictability of reinforcement learning. Interactions between students and teachers in the classroom are recorded by the agent's reinforcement learning, thereby enhancing its personalized system. Therefore, personalized learning exercises have good prospects in education.

4. Discussion

4.1. The application value of artificial intelligence in education

Supported by large language models, artificial intelligence (AI) in education transcends its traditional role in teaching and answering questions. AI encourages pedagogical equity, management, and refinement of teaching and learning environments. Today, AI in education has emerged in a completely new form, presenting exciting prospects in personalized learning, improving learning outcomes, and decreasing teachers' workload so they can concentrate more on the learning process [12]. AI in education is surely the most logical conclusion of the times, and its prospects are boundless. In the near future, students will work with energetic smart desks, receive assistance from AI in knowledge self-summation, and receive support from smart pedagogues. Improvements in learning outcomes will provide a rational basis for teachers to embrace AI in teaching. Evidence from recent studies on the use of AI in higher education has demonstrated a positive effect on learning outcomes. Today, about 81% of the respondents (students and teachers) support the use of AI in higher education. The students' support was even more positive at 83%. However, AI is still very much at an initial stage of development [13].

4.2. The drawbacks of artificial intelligence in education

At the same time, the shortcomings of artificial intelligence are also very obvious. So far, privacy issues are a challenge that artificial intelligence must face in education. In terms of privacy, once an AI system is breached, a large amount of information about students and teachers may be leaked.Second, large language models are flawed where, regrettably, they provide answers that, at times, can be incorrect. There is a lack of effort on the side of the large language models, where they

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bypass the necessary steps to, for instance, correctly construct relevant answers that use correct scientific derivation or formulation. Answer construction in the humanities is even more disappointing, in that they follow a framework yet lack relevant depth. Large language models are also affected by the hallucination problem in that they can create information that is simply incorrect, yet does not exist in a way that students can be easily misled to unconsciously memorize incorrect information. These models are also affected by being outdated in that they can provide answers that are based on the most outdated information, positive or negative, and can also create a knowledge gap in that the responses are not based on the most recent policy documents and textbooks. Finally, there may be a tendency to develop a kind of lazy mentality in that students are prompted to develop the habit of simply asking the large language model a question, which can result in the model answering the question. These are huge challenges that large language models for AI, if integrated in the educational system, can bring [14].

5. How to enhance innovation with artificial intelligence

With the rapid development of technology and algorithms in today's era, for artificial intelligence to become an important productive force in social development, it also needs to be updated and iterated. Therefore, innovating in artificial intelligence is also a current focus. The most important aspect of enhancing innovative artificial intelligence is the collaborative innovation of software and hardware. Hardware innovation mainly involves improvements in chips; by reducing transistor sizes and increasing density, speed, and energy efficiency, it provides the most fundamental path for performance enhancement. Secondly, software improvement lies in algorithm and model structure innovation. For example, Transformer can enhance algorithmic computing power starting from improving inference and planning capabilities, thereby strengthening predictive computation results. Additionally, in terms of artificial intelligence safety, AI systems also need to be reinforced, improving model security, data security, content security, ethical and social security, as well as system and supply chain security. It is necessary to establish comprehensive laws and regulations concerning artificial intelligence to protect users' information privacy. In the future, improvements in artificial intelligence may become clearly visible, and the realization of artificial intelligence serving humanity, as depicted in movies, may no longer be a distant dream [15].

6. Conclusion

Under the digital ecological education system of large language models, the convenience and features AI brings to students are undeniable. As the era continues to advance, AI will be widely applied in education, including AI-assisted assistants, personalized learning systems, and potentially future physical educational robots (serving as assistant teachers to manage classrooms and help students learn). From a practical perspective, the use of these technologies will bring significant reforms. Of course, regarding the drawbacks of large language models, their safety must be ensured, and the government should enact corresponding laws to prevent AI abuse and raise public awareness of AI. In addition, the improvement of AI requires more attention, including enhancements in hardware and software, the refinement of big data, optimization of model foundations, reduction of knowledge hallucinations, and the need to achieve dynamic updates and timeliness. Finally, regarding educational equity, education-level AI standards and evaluation systems need to be established to promote inclusiveness and fairness, with schools and governments providing free and compliant educational AI tools to narrow digital gaps between regions and families.

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