

Artificial Intelligence in Education: Logical Foundation, Current Progress and Future Prospect

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Abstract: Artificial intelligence is profoundly transforming human society and reshaping new forms of education. The research on the recent progress and development trend of artificial intelligence in education helps to promote the deep integration of technology and education. This paper reveals the mathematical logic foundation of artificial intelligence, namely Cognitive Computability Theory, and points out the artificial intelligence and the significance of human cognition. On this basis, this paper reviews the research and development status of artificial intelligence in education from several aspects mainly about teaching and learning. The article further points out that artificial intelligence brings a series of challenges while bringing development opportunities to the education field, and points out the development trend of education in the future. This paper aims to provide theoretical guidance for the innovative development of artificial intelligence in educational.

1. Introduction

The rapid development of artificial intelligence is attracting close attention from all aspects of human society. In the field of education, new educational agents are constantly emerging and reshaping new forms of teaching and learning. Education is undergoing a profound transformation. Smart education has entered a new stage of innovation and development, and intelligently leads the new journey of educational informationization. Artificial intelligence optimizes the learning environment, and the intelligent tutor system reshapes the process of learning and teaching. Specifically, medical education is realizing the transition from the information age to the intelligent age[1], intelligent robots help medical health science education teaching[2], providing technical support for online education and mixed learning. Intelligent tutor systems have greatly promoted students' learning in mathematics and other disciplines[3], and personalized feedback has improved the learning effect[4]. Artificial intelligence empowerment education 4.0. adaptive and personalized learning systems supported by machine learning algorithms and learning analysis technology can

help college students learn proficiently[5]. In the new era of artificial intelligence, the field of education is booming and prosperous, and the development of educational informationization is particularly striking. However, how can artificial intelligence promote and cause such a huge and profound change in the field of education? What kind of educational application forms does this change highlight at the application level? What is the future of artificial intelligence in education? This article will stand on the shoulders of the giants in the related research fields, comprehensively summarize and further think about the above problems in order to promote the innovative development of artificial intelligence in education.

2. Logical Foundation of Artificial Intelligence: Computational Cognition

Historically, Leibniz opened the precedent of modern logic. The mathematics master Hilbert's formalism mathematical view and its formal logic thoughts have had a profound impact on the mathematical world. Under the guidance of the sages, countless mathematicians have gone forward to establish a magnificent and perfect mathematical logic building. Gödel's incompleteness theorem proves that any formal system, as long as it includes a simple description of elementary number theory, is self-consistent, and it must contain propositions that are allowed in some systems to prove neither true nor false. The theorem overthrew the assumptions and expectations of the completeness and consistency of mathematics. Later, a British young mathematician Alan Turing published an epoch-making paper, *On Computable Numbers, with an Application to the Entscheidungs problem*, which proved that not all propositions can be judged, that is, the undesirability of mathematics. At the same time, he proved the possibility of building a machine that can perform any function calculation in a finite number of steps, and proposed an abstract calculation model of the "Turing machine", which defines the computable function from a new perspective and gives "computation" to complete the meaning of the determination. The Turing machine laid the foundation for modern computing logic. The huge iceberg of modern mathematics is emerging, and mathematical logic has played an important role and ushered in the birth of computational science. The universal Turing machine quickly became the conceptual model of modern general-purpose computers, laying a theoretical foundation for the realization of electronic computers. In 1950, in his paper entitled *Computing Machinery and Intelligence*, Turing imaginatively and creatively raised the question "Can machines think?". Then he proved that just as long as the machine is properly programmed, it will be possible that the machine thinks like a human. Furthermore, he proposed a way to judge whether the machine is intelligent or not, that is, the famous "Turing test". Because of his remarkable thinking and outstanding contributions, Turing is known as the father of artificial intelligence. Influenced by Turing, another science giant, the father of digital computers, American mathematician Von Neumann, was committed to the establishment of a unified theory of computation in his book entitled *The Computer and The Brain*. The book expresses to the world the idea that computers and human brains are computers. From the budding process of artificial intelligence we can be seen that the pioneers opened up a vast territory of artificial intelligence. The milestone in the history of artificial intelligence development is the Dartmouth Conference in 1956. The field of "artificial intelligence" was formally established. In line with Turing and von Neumann's point of view, American cognitive psychologists Herbert Alexander Simon and Allen Newell believed that the brain, mind and computer are the same to symbolic operating system. They firmly believed that the processing of discrete symbols is both necessary and sufficient for any intelligent activity. These have become the theoretical basis of the research paradigm of symbolism in artificial intelligence. In 1965, American neuropsychologist Warren Sturgis McCulloch and mathematical logician Walter Harry Pitts published a paper entitled *A Logical Calculus of Ideas Immanent in Nervous Activity*. Based on mathematical logic, they constructed a neural network mathematical model of brain

information processing, namely MP model. This model created the research paradigm of artificial intelligence, and opens up the artificial neural network method of AI. The artificial neural network method also plays an important theoretical foundation for deep learning today.

On the basis of learning and inference by mathematical modeling and computer simulation, Cognitive Computable Theory is gradually perfected and systematic. The important support of cognitive computing theory is logic. In particular, mathematical logic has realized that cognitive research shifted from philosophical speculation to logical computing, laying a solid theoretical foundation for the development of cognitive science. The basic assumption of cognitive computing theory is that the human brain, mind, and computer are all computing systems. Cognitive computable theory and its logical computing ideas have spawned a variety of artificial intelligence method genres, and provided a variety of methods and techniques for artificial intelligence education applications, providing intelligent solutions for solving many problems in the field of education. The development of wisdom education has laid a solid foundation for realization. Now the relationship between human cognition and computation is the core basic scientific problem of a new generation of artificial intelligence.

3. Current Progress of Artificial Intelligence in Education

In this part, this paper will systematically expound the research and application status of artificial intelligence in the field of education in categories of instruction, educational assessment, and educational games and STEM teaching.

3.1. Artificial Intelligence in Instruction

In the field of education, personalized teaching has always been the desire pursued by learners. Intelligent Tutoring System, shorted for ITS, is such a system that can simulate human teachers to achieve one-to-one intelligent teaching. The typical intelligent tutor system is mainly composed of three parts: domain model, tutor model and learner model. The domain model, also known as expert knowledge, contains the basic concepts, rules, and problem-solving strategies of the learning domain. It is usually represented by hierarchies, semantic networks, frameworks, ontology, and production rules. Its key role is to complete knowledge calculation and reasoning. The tutor model determines the learning activities and teaching strategies that are suitable for the learner. The learner model dynamically describes the cognitive style, ability level and emotional state of the each student in the learning process. In fact, the tutor model, learner model and domain model are the three elements in instruction - the computer program implementation of teachers, students, and teaching content. Among them, the domain model is the basis of intelligent realization. The tutor model is the bridge between the domain model and the learner model. Its essence is to make adaptive decision-making and provide personalized learning services. According to the domain knowledge and its reasoning, the tutor model makes adaptive decisions based on the learner's current knowledge and skill level and emotional state reflected by the learner model, and provides personalized recommendation services to learners. ITS respects the personality characteristics of learners, such as learning style, interests, specialties, etc., to meet the individual needs of learners.

3.2. Artificial Intelligence in Automated Assessment

Evaluation is an important part of instructional activities. The application of automated assessment techniques has led to profound changes in the methods and forms of evaluation. The automated assessment system enables objective, consistent, efficient, and highly available assessment results, providing immediate feedback, greatly reducing the burden on teachers, and providing a true and

reliable basis for teaching decisions. Existing automated assessment studies cover several categories of applications such as automated assessment of ICT skills, automated assessment of essays and short answers, and speech assessment. Among them, the automated assessment of ICT skills can effectively develop students' computational thinking. The automated programming assessment can promote students' learning of programming language and improve students' programming ability through real-time feedback and accurate evaluation. Automated assessment of essays and short answers uses natural language processing techniques and machine learning techniques to achieve computational analysis and semantic understanding of short texts, and promotes the ability of students to write short essays. Automated speech assessment uses speech recognition and other techniques to achieve automated testing and evaluation of spoken language in multiple languages. Acoustic models and linguistic models are the key to speech recognition. The technique uses natural language processing and speech processing algorithms to calculate and evaluate speech features of the language, such as fluency, pronunciation, vocabulary use, grammatical complexity, and rhythm. Automated oral assessment technology can help learners create a rich language learning environment, realize one-to-one personalized interaction, and improve the efficiency and effectiveness of language learning.

3.3. Artificial Intelligence in Educational Games

With the continuous development of artificial intelligence, educational games are increasingly becoming an important way to promote students' cognition and learning. Games not only provide a way of entertainment, but also promote the player to acquire new knowledge and skills in the game. Educational games have clear, meaningful goals, multiple target structures, scoring systems, adjustable difficulty levels, random surprise elements, and attractive fantasy metaphors. Educational games provide a new perspective for observing and understanding the human world by building a fully open game framework and environment. Puzzle gamers not only use game tools to solve problems, but also use their knowledge and skills. In role playing, players must survive and gain new knowledge in harsh environments. In all of these cases, observation and reaction to the surrounding space is a test and exercise of the player's attention, patience, professional knowledge and logical thinking. For example, the Chicago Museum of Science and Industry's website allows visitors to play the game of "survival mode"[6]. The game is designed for young people. It focuses on the changing process of the main body system that occurs in human body in extreme situations. Gamers not only overcome many obstacles, but also understand the structure of the human body. In addition, teenagers learn to use robots and stylus to learn to write simple survival search and other robot programs.

3.4. Artificial Intelligence in STEM Education

STEM(science, technology, engineering and mathematics) education is an emerging research hotspot in the field of educational technology. Moreover, educational robots play an important role in STEM education. On the one hand, educational robots can develop students' computational thinking skills. More and more schools are introducing educational robots as an innovative learning environment for improving and building students' high-level thinking skills. The skills are complementary tools to improve students' learning motivation and abstract conceptual understanding as well as helping students solves complex problems. On the other hand, educational robots are multidisciplinary and provide a constructive learning environment that helps students better understand scientific knowledge and play an important role in STEM education. In STEM teaching, robots can help teachers realize the practical application of engineering and technical

concepts, and concretize the concepts of science and mathematics in the real world, helping to eliminate the abstraction of science and mathematics.

Artificial intelligence can simulate human teachers to realize personalized teaching through knowledge representation, calculation and understanding. Relying on problem space theory, artificial intelligence in education helps realize automated assessment and evaluation of knowledge and skills. Based on speech recognition technology, artificial intelligence in education helps solve text and spoken speech assessment with natural language processing and the lexical analysis, grammar discrimination and semantic understanding. Through educational games and educational robots, the new connotation of “education is fun” is given in the way of intelligent enhancement.

4. Future Prospect of Artificial Intelligence in Education

A new generation of artificial intelligence gives new opportunities for education. However, the uncertainty of artificial intelligence in education has become more prominent, and the future of education will also face new challenges.

First of all, the learning environment in the era of artificial intelligence needs to realize the unified construction of technical characteristics and cultural characteristics. Artificial intelligence establishes a new interaction between the learner and the technical environment. For example, the brain-computer interface technology can decode human psychological activities and directly affect brain mechanisms under cognitive, emotional and will decisions. However it also includes the problems and challenges brought by this complex relationship. Since the teaching environment is gradually open to real problem-solving situations, increasing the complexity of teaching and the difficulty of implementation. While the school education system maintains its own structure, learning has begun to extend and expand beyond the classroom to informal and workplace. Under this circumstance, the learning environment is gradually integrated into the social environment and is subject to specific cultural norms. From the perspective of culture, there is a certain social mechanism for learning. The smart education supported by artificial intelligence technology needs to be objectively and comprehensively and forward-looking to consider the various possible effects of technology, especially for the negative effects of technology. As the Asiloma artificial intelligence principle tells us, in the face of doubts and concerns about people’s identity, initiative and privacy caused by technologies such as brain-computer interface, neuroscience and artificial intelligence need to consider the primary. Ethical issues and suggestions have been proposed, including privacy and informed consent, initiative and identity, human empowerment, and prejudice. In order to prevent data from being abused, rights threatened, identity and initiative seriously disrupted, and inequality aggravated, it is important and urgent to establish the related social standards and ethical standards. In this way, thical education in the era of artificial intelligence is extremely important.

Secondly, the coexistence of authenticity, complexity and challenge has been the new characteristic of the educational practice activities in the era of artificial intelligence. In fact, a new wave of artificial intelligence has accelerated the natural science shift in education research, the breakthrough progress in brain science will provide a new scientific basis for educational innovation, and the prospects are expected. When artificial intelligence technology is seamlessly integrated into education, the changes it brings are no longer limited to the intelligence, automation and synergy features brought by technology. The greater value is inspired by smart technology. People are eager for knowledge, curiosity about the unknown world, exploration and reconstruction of the knowledge system, conceptual framework and structural order, full release of personality and comprehensive development of personality, and even the establishment of new values. These all give new meaning to learning. However, the practice of education in the era of artificial intelligence

is a contradictory unity of authenticity, complexity and challenge. Determined by the educational environment and its technical characteristics, educational activities will increasingly approach the real situation and complex issues in real life. In short, learning scenes tend to be real and highly complex. Educational content will increasingly tend to be real problems. Ways of learning are increasingly moving toward experiential learning, real-life learning, and collaborative learning. The result is an increase in the complexity of teaching practice: (1) the complexity of tasks from routine calculations to problem-based learning; (2) the complexity of teaching objectives from simple memory to information search and integrated applications; (3) the complexity of required capabilities from verbal literacy to media literacy such as technology and information; (4) the complexity of classroom interaction and coordination, such as from supporting individuals to supporting team interactions. The extension of the educational environment also means that the future educational practice will be a comprehensive integration of classroom activities, teaching activities, practical activities and extracurricular activities. Learning, especially lifelong learning will become the characteristics and development trend of the times. In the face of these challenges, educational practice research must consider the question of how to help teachers support students to become better learners through technology, and use technology and other means to turn these challenges into opportunities.

Thirdly, the goal of education in the era of artificial intelligence needs to be reshaped. Reviewing the application and development of artificial intelligence in education, from early knowledge reasoning machines, programmatic teaching and expert systems, to intelligent tutor systems today, automated assessment, educational robots, etc., artificial intelligence shows the powerful advantages of computers in storage and computing, and even more smarter. Nowadays artificial intelligence constantly improves logical reasoning ability through machine learning. With main forms of computer hardware and software, educational intelligence continues to expand and extend the breadth and depth of learning. This poses a challenge to human learning and knowledge. At the same time, artificial intelligence is reshaping our learning patterns and further infiltrating. It acts on our culture to accelerate the progress of modern civilization. It can be said that the relationship between “human” and “knowledge” in the field of artificial intelligence is being repositioned. The traditional view of knowledge is being subverted. New values are nurtured and lead the development of individuals. The orientation of educational goal in the era of artificial intelligence has begun to shift from fostering a social workforce with a strict knowledge system to supporting and promoting students to become adaptive talents and lifelong learners. The technical characteristics and cultural connotation of smart education will carry the important task of spreading and constructing the knowledge view and values in the intelligent age.

5. Conclusions

Artificial intelligence is causing profound changes in the field of education. Focusing on the topic of artificial intelligence in education, this article begins with the germination of artificial intelligence and introduces the important ideas and viewpoints put forward by the pioneers of cognitive computability theory. The article reveals the fundamental importance of cognitive computability theory to the development of artificial intelligence. On this basis, it introduces several important aspects of the application of artificial intelligence technology in the field of education, including intelligent tutor systems, automated assessment, educational games and educational robots. Finally, the article points out that artificial intelligence bring new development opportunities as well as huge challenges for education. In the era of artificial intelligence, we need to rethink the basic question about the relationship among education, knowledge and intelligence.

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