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AI Application in Secondary School STEM Education

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Abstract

This article provides a literature review to understand the application of AI in STEM, including the research methods, tools, subjects, ethics, etc. Pay attention to the process of cultivating students' technical skills, core technical literacy, curriculum reform in technical education, and relevant international comparisons. Artificial Intelligence in Education (AIEd) primarily focuses on the development of "computers that perform cognitive tasks," typically related to the human brain, particularly in learning and problem-solving. Applications and tools driven by artificial intelligence technology, such as intelligent robots and adaptive learning systems, are increasingly being utilized by educators and learners in K-12 and university environments. Artificial intelligence technology provides learners with the opportunity to achieve personalized learning to meet their individual needs.

Keywords

AI, STEM, Artificial Intelligence in Education

1. Introduction

There is a growing interest in the integration of modern information technology with education (curriculum, teaching, etc.) (Cai, 2018) and the possible impact of big data, image video, and artificial intelligence on the future of education and educational research, etc. (Cao, 2018; Tang, 2018; Li, 2018; Wu, 2019). While emerging technologies have triggered reforms in educational teaching practices, they have also triggered theoretical concerns and reflections among education scholars, which is an uncommonly proactive and swift response of education scholars to external technological changes. Therefore, with the advent of the AI era and in the face of the challenges of AI, people's perceptions of where and how pedagogy should go are largely confused, and they have yet to see the future direction.

For "educational technology", the focus in recent years has been on "educational information technology", with an emphasis on "integration" with curriculum and teaching, (deep) learning change and reform of smart education, creativity and STEM education, the transformation of information technology in education, etc. In line with 'educational technology', there is also a great deal of research on 'technology education jungle', focusing on students' technological skills, the process of developing core technological literacy, curriculum reform in technology education and relevant international comparisons. Along the roadmap of technology, artificial intelligence is the latest stage in its development, with the possibility of human-like intelligence and even superhuman intelligence in the future. “Although super AI may not come true, it is not science fiction, but a serious and dangerous endeavour by scientists, and as such it is a serious philosophical issue.” (Zhao, 2017, p. 98)

Pedagogically, while emphasising the need for young people to learn 'technical knowledge', Herbart provides a clear specification of the teaching process as clear, connected, systematic and methodical (Herbart, 2017, p. 16). This pedagogical idea was developed by Ziller, Stoy and Laing into the "Five Stage Approach", which has been widely disseminated around the world and is still influential today. The influence of this technological theory of teaching and learning led to the emergence of the "design approach", the "Dalton system", the "activity approach", the "procedural approach", and so on, and even the current "process approach". "The 'design approach', the 'Dalton system', the 'activity approach', the 'procedural approach' and so on, and even today there are still a number of 'models' of teaching and learning.

Based on artificial intelligence, the future shape of education practice will undergo significant changes in the ecology of education (school), education time and space, education system, education mechanism, education content (resources), education (teaching) methods, interaction (communication) methods and so on. For a long time, the core issue of the basic theory of education has been the two classical issues of the relationship between education and people and education and society, in order to build the theoretical system of education. The advent of the age of artificial intelligence will facilitate the emergence of new possibilities for these old problems, in addition to generating new problem areas. It will not only focus on the impact of technology on education and pedagogy, but will also further explore the impact of education and pedagogy on the development of new technologies represented by artificial intelligence, so that the development of technology in the age of artificial intelligence will add a new value coordinate and basic scale of education and pedagogy. At the same time, the development of AI will also advance the study of the relationship between education and nature, which is a pedagogical response to new technologies such as AI that facilitate human reflection on the relationship between humans and nature. This is a pedagogical response to the fact that new technologies such as artificial intelligence are facilitating human reflection on the relationship between humans and nature. In addition, there are other new issues arising from artificial intelligence that are relevant to education itself, such as the human-machine (integration) relationship in the context of artificial intelligence, ethical choices, privacy protection, control and loss of control, equity and justice, and so on. If pedagogy in the age of AI is to achieve enlightenment and ensure the dignity of human beings in the face of the new technological system represented by AI, it must change its course and break the bonds of "plasticity", moving away from technologically shaped human beings towards the promotion of human liberation and freedom.

In 2017, the Chinese government released the "Development Plan for a New Generation of Artificial Intelligence", which specifies the strategic situation and deployment of AI development and emphasises the inclusion of AI as a key common technology system for research on the collaboration and sharing of group intelligence, human-machine integration and enhanced intelligence. With the help of intelligent technologies such as deep learning and brain-like computing, the development of human-centred artificial intelligence has become a new trend. In 2018, Fei-Fei Li, head of the AI Lab and Vision Lab at Stanford University, launched the HumanCentered AI Initiative (HAI), arguing that the benign development of AI requires humanistic guidance, reflecting the depth of human intelligence and ensuring that every step is taken in a human-centred way. In 2019, UNESCO released the Beijing Consensus - Artificial Intelligence and Education, which explicitly states the need to support forward-looking research on cutting-edge issues related to the impact of the development of emerging artificial intelligence, and to promote the exploration of effective strategies and practical models for using artificial intelligence for educational innovation. The Beijing Consensus - Artificial Intelligence and Education The European Centre for Political Strategies (ECPS) released "The Age of Artificial Intelligence: Towards a Human-Centred European Strategy", which insists that human-centredness is the basic guideline for the integration of AI and education, and that human-centred AI creates new opportunities for the innovative development of education in the future.

Artificial intelligence has been flourishing since its emergence, particularly with the advent of artificial neural networks (ANN) and deep learning (DL). Artificial Intelligence in Education (AIEd) focuses on the development of "computers that perform cognitive tasks", often related to the human brain, particularly learning and problem solving. Applications and tools powered by AI technologies, such as intelligent robots and adaptive learning systems, have been increasingly utilised by educators and learners in K-12 and university settings. AI technologies offer learners the opportunity to personalise their learning to meet their individual needs. In addition, AI technology provides opportunities to support the engagement of learners with learning disabilities. With the increasing use of AI technology in teaching and learning, teachers have the opportunity to move away from repetitive and tedious tasks and respond to students in a timely manner, thus advancing the process of adaptive and personalised teaching and learning. In particular, advances in hardware, such as the high speed of graphics processing units and the accessibility to various software libraries, have stimulated the use of AI technologies, especially with the boom in DL research and the implementation of data analysis techniques. Furthermore, to a large extent, the future of education will be closely linked to the development of artificial intelligence.

The purpose of the NSF-funded workshop was to explore the ways in which artificial intelligence (AI) is changing the employment landscape and the knowledge sets and skills that educators should be imparting to students before they graduate. To best address these questions, engineering researchers, policy advocates and industry leaders were brought together to discuss the future of society in the age of STEM and AI. From the field of engineering education, workshop participants were aware of the fundamental breakthroughs in AI that have led to their widespread adoption in society, and how these breakthroughs may impact the type of work that future engineers will do. Pre and post-survey data was obtained from participants to quantify the differences in terms such as AI and STEM. The disconnect between artificial intelligence and its potential impact in transforming STEM education and the STEM workforce was a key driver in organising the workshop.

The AI+STEM Symposium takes place on December 2 and 3, 2019 on the Carnegie Mellon University campus. The purpose of the two-day AI+STEM Symposium is to bring together expert and non-expert areas of AI and STEM education to discuss ways in which industry, academia, and government can better collaborate. (1) Exploring how the field of STEM education might benefit from advances in AI. (2) To propose education and knowledge acquisition strategies for a 21st century work environment that requires lifelong learning and may lead to an entire professional shift. (3) Possibly due to the same AI technologies that can enhance STEM education) and (3) Engage policy and decision makers in order to ensure ethical guidelines that may mitigate against adversarial AI algorithms and possibly mitigate against adversarial AI algorithms with vulnerable populations. The diversity of perspectives on how best to harness the power of AI for lifelong learning and to combine AI and STEM education was a key theme throughout the workshop. The format of the workshop included keynote sessions, providing high-level perspectives from both policy and industry perspectives. In addition to the keynote speeches delivered each day of the workshop, attendees participated in a series of panel sessions focusing on unique but complementary STEM+AI themes. The panel sessions were organised according to specific themes, with the first day focusing on the role of AI in STEM and workforce development, and the second day focusing on ethical, bias and safety issues related to AI and its potential use in STEM. Finally, participants themselves have the opportunity to contribute to the advancement of AI+STEM themes through a series of breakthrough sessions, each focusing on a unique but complementary AI+STEM theme.

2. Review of the Literature

2.1 Artificial Intelligence

In the 1950s, Alan Turing proposed a solution to the problem of when a human-designed system was "intelligent". In 1956, John McCarthy proposed the first and most influential definition: "The study of artificial intelligence is based on the idea that aspects of learning or other features of intelligence can in principle be described so precisely that machines can simulate it.

Since 1956, we have discovered various theoretical understandings of AI influenced by advances in chemistry, biology, linguistics, mathematics and artificial intelligence solutions. We can define artificial intelligence (AI) as a computational system capable of engaging in human-like processes such as learning, adaptation, synthesis, self-correction and the use of data in complex processing tasks.

2.2 Artificial Intelligence in Education (AIED)

Artificial Intelligence in Education (AIED) includes everything from AI-driven, step-by-step personalised teaching and dialogue systems, exploratory learning supported by AI, analysis of student writing, intelligent agents in a game-based environment, student support chatbots, AI facilitated student/tutor matching and giving students firm control over their own learning. It also includes one-to-one student-computer interaction, a whole-school approach, student use of mobile phones outside the classroom, and much more. In addition, AIED can illuminate learning and educational practices. the field of AIED is derivative and innovative. On the one hand, it brings theories and methods from related fields such as artificial intelligence, cognitive science and education. On the other hand, it generates its own larger research questions and issues: What is the nature of knowledge and how is it represented? How can a student be helped to learn? Which teaching and learning interaction methods are effective and when should they be used? What misconceptions do learners have? Develop AI-based tools to support learning and use these tools to help understand learning (how learning occurs and other questions that have long been studied by learning science and that may be applied in the classroom with or without the use of AI). For example, by modelling how students solve arithmetic problems and identifying misconceptions that educators may not be aware of, researchers and teachers can begin to further their understanding of the learning process itself, which may then be applied to mainstream classroom practice.

3. Research Questions

(1) What are the characteristics of AI applications in STEM education?

(2) What are the problems that students need to overcome in the application of AI in STEM education?

(3) How can teachers facilitate the use of AI in STEM education?

4. Theoretical Framework

A new dimension of hybrid intelligence in educational applications. From the point of view of its relationship with human intelligence, its development is guided by the idea of "human-centredness", from the stage of "supporting intelligence" to the stage of "enhanced intelligence" and finally to the stage of "human-machine co-intelligence". The development is guided by the idea of "human-centred", from the stage of "supported intelligence" to "enhanced intelligence" and finally to the stage of "human-machine co-intelligence".

In the form of supported intelligence, AI is mainly data-driven intelligence, which is realised through knowledge representation, symbolic computing, probability statistics, automatic reasoning and search methods, etc. Its essence is to perform standardised processes based on certain rules, and to complete complex calculations with high speed and accuracy. In the educational arena, supportive intelligence takes on the role of a simple aid to teaching and learning. From the learner's perspective, it provides learners with simple support functions such as searching for and downloading rich course resources, submitting online assignments to teachers, and conducting synchronous and asynchronous discussions with peers; from the pedagogue's perspective, it helps teachers collect learner learning data, understand learner progress, manage classes, and distribute courseware resources. From the administrator's point of view, it provides learner database creation, digital teaching and learning quality management, and campus management system construction, facilitating the digital and convenient management of the campus.

Augmented intelligence is actually an extension of human intelligence, such as the extension of human perception - hearing, seeing and touching - and is a product of the development of artificial intelligence to a certain stage.

Human-machine synergy is a reliable path for the integration of human-centred AI and AIED. The integration of the two should be guided by the promotion of all-round human development, the establishment of teaching methods, learning environments, assessment and monitoring, and other educational systems that promote the development of human knowledge, skills, ethics and values in synergy with machines.

Artificial intelligence in education is a complex system consisting of multiple elements such as educators, educated people, the educational environment, technology and its applications. It contains several core elements, including multiple types of subjects, an educational environment with interconnected human-machine objects, intelligent supporting technologies and complex application scenarios.

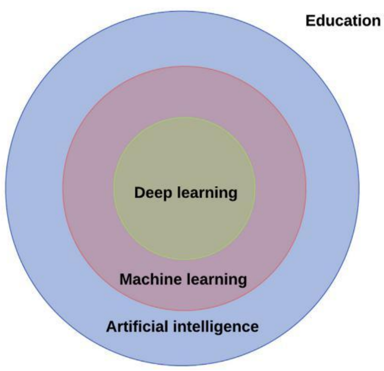

Figure1. Artificial Intelligence in Education (AIEd)

Figure 1 can be thought of as a combination of three main fields, including computer science, statistics and education. In addition to these three fields, AIEd is also an interdisciplinary field involving, but not limited to, fields such as cognitive psychology and neuroscience. The intersection of these three main fields also generates other subfields that are closely related to AIEd, for example, Educational Data Mining (EDM), Learning Analytics (LA) and Computer Based Education (CBE).

5. Research Methodology

5.1 Research Design

5.1.1 VR/AR Applied to STEM Education

The use of VR and AR technologies in structural chemistry courses has been used to compare and analyse the advantages and disadvantages of conventional teaching and "AI+STEM education" models, but there is no specific literature on the differences between the two and whether they can facilitate the development of students' spatial thinking and improve the quality of teaching. Inspired by the APPLE TREE system by Professor Wenli Chen of Nanyang Technological University, I intend to develop a series of courses and a system that integrates teaching resources, teaching processes and evaluation, which is a research gap in this field worldwide.

Firstly, three classes will be selected in Year 10 in Singapore. To ensure the reliability and validity of the experiment, a control variable approach will be used. Each class will be controlled to have a maximum of 30 students, taught by the same teacher, and pre-tested using the Spatial Thinking Ability Test scale to understand the basic conditions of the students.

During the experiment, class A will be taught using conventional teaching methods, class B will be taught using video and picture aids, and class C will be taught using AR/VR and other technologies. A post-test was conducted using the Spatial Thinking Ability Test scale to understand the use of different teaching materials for teaching the same chemistry content and to gain insight into the impact of AI on chemistry education. Applying AI to chemistry education, the interview method is used to understand the difficulties students encounter in the learning process.

To ensure the reliability and validity of the experiment, I will select 15 people as a pilot for the experiment.

5.1.2 Eye-Tracking Applied to Chemistry Education

Eye-Tracking has been applied to the teaching of the periodic table in the literature, but only in relation to the learning of the elements of the periodic table and the study of declarative knowledge in memory chemistry. Could it be used to study procedural knowledge, such as the "acid-base neutralisation titration" experiment, to see if the same conclusions can be drawn?

This experiment will be conducted with a reduced number of participants due to the high demands of the experiment. For this experiment, 40 people will be selected and divided into two groups of 20, with Group A using Eye-Tracking for teaching the periodic table (representing declarative knowledge) and Group B using Eye-Tracking for teaching "Acid-base neutralisation titration" (representing procedural knowledge).

5.2 Research Equipment

AR/ VR/Eye-Tracking

5.3 Data Collection

All classroom sessions will be videotaped and I will examine the experimental material from the groups to determine the number of groups that have successfully solved complex problems and the diversity of solutions proposed by the groups. At the end of the session I will collect quantitative data such as questionnaires and qualitative texts of students' written work such as notes, design charts and audio interviews with students and teachers. I will obtain informed consent from all participants before collecting data. The anonymity, confidentiality, disclosure and any other ethical considerations of all information will be reviewed by the consultant and the University Ethics Committee to ensure the privacy and security of all participants. An experiment to understand how teachers can facilitate the use of AI in STEM education.

5.4 Data Analysis

This study identifies the characteristics of AI applied to STEM education through a qualitative research method and the impact of AI applied to STEM education through a quantitative research method.

6. Conclusion

AI + STEM, however, is also the way forward for the subject of chemistry. Currently, the integration of information technology and chemistry has given rise to research on, among other things, virtual chemistry laboratories, online and offline STEM education, handheld technology applied to chemistry education, AR/VR applied to chemistry education, and the application of eye-tracking to chemistry classrooms. These involve a high degree of integration of STEM, education, psychology, sociology, brain science and information technology, and require high research conditions and researcher backgrounds, resulting in this part of the research not being common and a hot spot for future chemistry education research.

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