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Research Article

A Review on Artificial Intelligence in Education

Jiahui Huang

Salmiza Saleh*

Yufei Liu

School of Educational Studies,
Universiti Sains Malaysia, Malaysia
*Corresponding Author

Abstract

The emergence of innovative technologies has an impact on the methods of teaching and learning. With the rapid development of artificial intelligence (AI) technology in recent years, using AI in education has become more and more apparent. This article first outlines the application of AI in the field of education, such as adaptive learning, teaching evaluation, virtual classroom, etc. And then analyzes its impact on teaching and learning, which has a positive meaning for improving teachers' teaching level and students' learning quality. Finally, it puts forward the challenges that AI applications may face in education in the future and provides references for AI to promote education reform.

Keywords: artificial intelligence, education, teaching

1. Introduction

At present, with the development of global science and technology, AI technology has also been improved by leaps and bounds. AI technology is continuously updated and widely used in various fields (Pannu, 2015). It is an indisputable fact that AI has increasingly penetrated into the educational environment and teaching process of schools. In the process of development, more and more people pay attention to the importance of this technology in the field of education. AI has been widely used in the education field and has shown substantial application advantages, which has a profound impact on the teaching process and classroom management (Chassignol, Khoroshavin, Klimova, & Bilyatdinova, 2018; Roll & Wylie, 2016). AI can continuously optimize and improve the learning environment, stimulate the enthusiasm, initiative and creativity of students (Colchester, Hagras, Alghazzawi, & Aldabbagh, 2017; Yang & Bai, 2020). At the same time, it can significantly improve the classroom management level of teachers and ensure that classroom management is more reasonable and efficient (Tuomi, 2018; Wang, 2020). With the rapid development of modern science and technology, AI technology is also advancing. The research results in related fields have enabled AI to be further applied to the education field, and it has shown sound application effects, contributing to teaching reform. The application of AI in the field of education has realized the full integration of

teaching and learning, and also provided an opportunity for the reform of teaching and learning. This article comprehensively summarizes and analyzes the application of AI in education.

2. The Application of AI in Education

In 2016, after AlphaGo defeated the world Go champion Lee Sedol (Borowiec, 2016) with a high score of 4:1 in the Go game, research on AI is attracting more and more attention from the world. More and more research on AI and education mainly focus on applying AI technology to assist teaching, build a smart campus, and realize intelligent learning, teaching, and management. Image recognition technology, face recognition technology, adaptive learning and other AI technologies are applied to the education field, initiate a series of changes in the field of education, improve teachers' work efficiency (Kuo, 2020) and students' learning experience (Cui, Xue, & Thai, 2019). In addition, AI technology and big data are combined to dig and analyze teaching data in-depth, it can also promote teaching reform and improve teaching quality (Williamson, 2018). Next, we will review the literature on the impact of AI on adaptive learning, teaching evaluation, virtual classroom, smart campus, and intelligent tutoring robots.

2.1 Adaptive learning

AI promotes the development of adaptive learning, in which data mining, intelligent teaching systems, learning analytics, and real-time analysis are applied in adaptive learning. Adaptive learning attempts to incorporate all aspects of testing, teaching, learning, and practice into the adaptive learning system to facilitate students' learning (Van Der Vorst & Jelicic, 2019). The adaptive learning system can collect student learning behavior data (Cui et al., 2019), plan the optimal learning path for students based on the analysis of student abilities, and complete the closed-loop learning process by pushing learning content as online teaching videos. There are some problems that encountered and cannot be solved after class study, the human-computer interaction technology provided by AI can assist teachers in answering questions for students online (Goel & Polepeddi, 2016). Nowadays, many companies provide adaptive learning systems, such as DreamBox Learning(Grams, 2018), BYJU'S (Tripathy & Devarapalli, 2020), and IBM Watson Education (Russo-Spena, Mele, & Marzullo, 2019), which are relatively mature companies with adaptive learning systems, and teachers apply the systems in class to improve classroom teaching effects.

Assessment and Learning in Knowledge Spaces (ALEKS), a Web-based artificially intelligent assessment and learning system, is widely used in the USA. Yilmaz (2018) investigated the effects of ALEKS on math achievement of middle school students. Results of the analysis showed that ALEKS instruction had a statistically significant positive impact on students' end–of–year mathematics scores. However, Fang, Ren, Hu, & Graesser (2019) conducted a meta-analysis to assess the effectiveness of ALEKS on learning, and their results revealed that ALEKS was as good, but not better than traditional classroom teaching, unless when ALEKS was used for shorter periods rather than longer periods. This research can better inform teachers using the ALEKS learning system to promote students learning.

Similar to ALEKS, BYJU'S, which is popular in India, is also a learning app for AI in teaching. BYJU'S fully integrates online lectures and exercises, and combines teachers' explanations with animations to explain difficult-to-understand science concepts through animation scenarios to facilitate students' understanding. The gamified operation interface forms an entertaining teaching mode. In addition, BYJU'S system can recommend courses according to students' abilities (Kulkarni, Rai, & Kale, 2020). Sruthi & Mukherjee (2020) found that BYJU's app has transformed Indian education scenarios by incorporating constructive teaching and learning methods. Most of the respondents said the app is interactive, comfortable and practical. BYJU's also can promote deep conceptual understanding in students, and how BYJU's promotes deep conceptual understanding has been analyzed in India (Casanova, 2018). However, the price may also prevent some students from using it.

English learning has always been an essential part of education. In English courses, the number

of students is too large and teachers cannot conduct one-to-one oral training. Speech recognition and semantic analysis technology are widely used in English teaching (Liu 2020; . It can assist teachers and students in one-to-one oral practice, and correct students' wrong English pronunciation. Duolingo provides multilingual learning through the game mode, focusing on customized learning. Tsai (2016) found that by learning with Duolingo, the autonomous learning ability of the learners was increased, in terms of their self-regulation on learning on accessing time to learn, self-regulation on a regular basis, finding more materials to learn, evaluating one's learning, and adjusting learning strategies to have more effective learning. Zou (2017) established a college English teaching platform and used AI to analyze the needs and knowledge of students. This platform can adjust teaching progress and content through AI algorithms. The results of the study show that the average score of students who use the platform to learn English is higher than those who do not use the platform, and it can improve students' autonomous learning ability and English ability. Bin & Mandal (2019) also designed a college English assisted teaching system based on AI technology, which is used in English teaching to improve the quality and effectiveness of English teaching.

2.2 Teaching Evaluation

AI technologies such as image recognition, prediction system and computer vision provide convenience for teaching assessment. In the teaching process, the assessment of students is an essential part. In traditional teaching, it takes a long time for teachers to complete the assessment tasks, such as question preparation, scoring, performance evaluation, and test paper analysis. AI makes teaching evaluation methods more diverse, the evaluation process more scientific, and the evaluation results more accurate.

AI technology not only can generate exam questions (Rahim, Aziz, Rauf, & Shamsudin, 2018), but also can automatically correct the assignments and test papers (Li et al., 2018). Correcting homework and test papers are routine tasks for teachers. Correcting time is long, teachers are prone to fatigue when correcting homework and test papers for a long time. Therefore, there will be some errors in correcting test papers after a long time. Image recognition technology helps teachers to free themselves from the heavy work of correcting homework and scoring(Li, Cao, & Lu, 2017), and the error rate is low. AI technology is applied to the examination paper correction, and it can also detect blank papers and suspected identical papers, saving teachers' working time.

IFLYTEK and New Oriental jointly launched RealSkill, aiming at better learning of IELTS and TOEFL via smart correction and oral practices. Students can learn IELTS and TOEFL through this RealSkill online platform, and the system can perform intelligent scoring, sentence-by-sentence correction, behavior analysis, essay intensive lectures and learning records to improve their test preparation level(Deloitte, 2019). The American Educational Testing Service (ETS) designed and launched E-rater (Chen, Fife, Bejar, & Rupp, 2016), a tool for automated evaluation of student essays. E-rater can accurately and efficiently evaluate students' composition, including structure, grammar and overall score, not only improve the teacher's assessment efficiency, but also guide students to improve their writing skills. ETS has also used AI technology in spoken English assessment and developed a SpeechRater engine to help users excel in spoken English assessment(Chen et al., 2018).

Except for the volumetric teaching evaluation, AI also provides a new way and perspective for schools and teachers to evaluate student physical education courses. Ge, Yin, & Feng (2018) designed an AI-based college student sports autonomous learning system which realized in the browser/server system architecture, the Visual Studio integrated open environment, and the SQL Server database under the Windows platform. This platform can help students conduct self-assessment tests, get learning feedback in time, help college students improve their exercise levels, and reduce teachers' teaching pressure. Yong (2018) also designed a sports intelligence evaluation system based on AI expert decision-making system, which is used in the evaluation of sports teaching. The research results affirm that the AI-based physical education evaluation system provides new development strategies for the application and development of modern sports technology, and also provides theoretical support and guidance for the further development of science education technology.

2.3 Virtual Classroom

The development of virtual reality (VR), augmented reality (AR), hearing and sensing technologies is conducive to the reform of teaching environment. Utilize ubiquitous computing technology to realize the integration of physical space and virtual space to create virtual classrooms and virtual laboratories(Encalada & Sequera, 2017; Krumm, 2018).

Virtual classrooms use virtual technology to simulate teaching scenes that are difficult to explain, and for natural phenomena or changes in things that cannot be observed or hard to observe in real life, it can be presented in a smart classroom to create a contextual learning environment for students. Multi-dimensional presentation of learning content, mobilizing students' vision, hearing, kinesthetic and other senses to participate, allowing students to feel a strong sense of reality, it makes abstract concepts and theories more intuitive and visualized, stimulate students' interest in learning, and improve teaching effects. The hybrid virtual classroom is very promising regarding flexibility in course attendance (Lakhal, Bateman, & Bédard, 2017) since students can choose to come to the campus or to attend the lecture at home.

Virtual simulation laboratory refers to the virtual reproduction of real experimental scenes through 3D modeling with the help of multimedia, simulation and virtual reality technologies, create related software and hardware operating environments on the computer that can assist, partially replace or even replace all the operating links of traditional experiments (Wang, Wu, Wang, Chi, & Wang, 2018). By constructing a highly simulated virtual experimental environment and experimental operating objects, and with the help of advanced somatosensory interactive equipment for virtual and real interaction, the experimenter can complete various experimental projects as if in a real environment (Xu, Ye, Lv, Wu, & Gu, 2017). There is no need to worry about the damage caused by experimental operation errors or miss some classic experiments due to experimental conditions. The experimental results obtained are equivalent to or even better than those obtained in the real environment. Virtual experiments are based on a virtual experimental environment (platform simulation), focusing on the interaction of experimental operations and the simulation of experimental results (Liu, Valdiviezo-Díaz, Riofrio, Sun, & Barba, 2015). Experiments in biology (Dyrberg, Treusch, & Wiegand, 2017), physics (Gunawan, Nisrina, Suranti, Herayanti, & Rahmatiah, 2018), chemistry (Herga, Cagran, & Dinevski, 2016) and other courses (Cheong & Koh, 2018) can be carried out in the virtual laboratory. The interactive operation of the virtual simulation laboratory helps to cultivate students' practical ability. At the same time, the virtual experimental equipment also saves resource consumption and avoids experimental risks (Orobor & Orobor 2020; Rocca, Rosa, Sassanelli, Fumagalli, & Terzi 2020). However, according to Makransky, Terkildsen, & Mayer (2019), although its motivating properties, learning science in VR may make learners cognitive overload and distract, resulting in poorer learning outcomes.

2.4 Smart Campus

The campus is an important place for talent training, and the application of AI technology to build a smart campus has become a new development trend in the education field (Dong, Zhang, Yip, Swift, & Beswick, 2020). AI plays an essential role in campus management and services. Face recognition, hearing and sensing technologies are applied in the construction of smart campus (Zhou 2020, An & Xi 2020). By collecting and analyzing big data, intelligent management methods are established (Villegas-Ch, Molina-Enriquez, Chicaiza-Tamayo, Ortiz-Garcés, & Luján-Mora, 2019). Managers and AI form a human-machine collaborative decision-making model (Liu, Ma, & Jin, 2018),which can discover problems in the operation of the education system in time, realize more efficient resource allocation, and effectively improve campus safety.

For dormitories, laboratories, libraries, and other places that need to be prevented from entering by non-school personnel, identity authentication is performed through face recognition technology to effectively prevent suspicious personnel who have not passed the audit from entering (Afra & Alhajj,

2020). At the same time, face recognition can also avoid the phenomenon of changing cards and fraudulent use of other people's certificates, ensuring campus safety (Zhou, 2020). Face recognition technology can also be used to borrow and return books in the library (Upala & Wong, 2019), complete identity verification through facial information, and realize autonomous borrowing and return of books through the book lending and returning machine, which improves the efficiency of library work and saves labor costs. In canteens and campus supermarkets (An & Xi 2020, Liu, Zhou, Zou, Yeh, & Zheng, 2018), a camera can be placed at the checkout counter to automatically identify and calculate the price of dishes or commodities through image recognition (Ramdani, Virgono, & Setianingsih, 2020), and then facial recognition is used to realize checkout and self-service shopping. Infrared fences can be installed on the school wall to monitor whether there are outsiders intruding or students leaving the school over the wall. When someone touches the infrared, the triggered alarm information and the on-site photos captured by the camera will be sent to the relevant person in time to remind the person in charge to conduct on-site surveys or call the police in time (Muhamad, Kurniawan, Suhardi, & Yazid, 2017).

2.5 Intelligent Tutoring Robots

Tutoring robots are multi-disciplinary and cross-field scientific research involving education, computer science, automatic control, materials science, psychology, optics and other fields. From the perspective of the development process of robots, the research and development of early robotics technology was mainly based on industrial robots (Grau, Indri, Lo Bello, & Sauter, 2017). With the popularization of robotics technology, the educational value of robots has also attracted increasing attention. The earliest educational robot came from the AI laboratory founded by Professor Papert of the Massachusetts Institute of Technology in the 1960s(Catlin & Blamires, 2019), and gradually became intelligent. Educational robots are specially developed for the education field, aiming at cultivating students' analytical ability, creativity and practical ability. It has the characteristics of teaching applicability, interactivity, openness and scalability (Miller, Nourbakhsh, & Siegwart, 2008). Tutoring robots are equipped with a variety of AI technologies such as voice recognition technology, emotion recognition that analyzes expressions and tones, and bionic technology that can present beautiful joint technology similar to human actions, and has human-like listening, seeing, thinking and communication capabilities (Yang & Zhang, 2019).

Different intelligent tutoring robots have different functions, which can be mainly divided into 5 functions: robot-subject instruction, robot-assisted instruction, robot-managed instruction, robot-represented routine and robot-directed instruction(Hsieh et al., 2020). Spolaôr & Benitti (2017) reviewed the literature on educational robotics applications grounded in learning theory on tertiary education. They explored studies that the use of robots can benefit to the learning of subjects and skills development. Most of the studies used robot to support computer science education. Tutoring robots are different from traditional passive learning methods, where robots first solve students' interest problems (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018). The teaching mode of robots can well stimulate students' interest in learning. For example, SoftBank's pepper robot (Eguchi & Okada, 2018) can provide teaching services to students at different stages of elementary school, middle school, and university, which is to cultivate students' interest in learning AI by playing. At the University of Nottingham Ningbo China, the SoftBank Pepper humanoid robot was introduced to the campus as an AI ambassador and provided multi-language communication, courses and library information inquiry services (Robot, 2018). The tutoring robots of Adaptive Systems Research Group of the University of Hertfordshire are known for assisting children with autism (Wood, Zaraki, Robins, & Dautenhahn, 2019). The research results show that children with autism are very active and positively responding to the interaction with tutoring robots.

In recent years, with the advancement of AI technology, the development of robots has gradually become intelligent and humanized. Intelligent and humanized robot products will be more suitable for the future education and teaching environment.

3. Impact of AI in Education

The continuous improvement of AI technology has been widely used in all walks of life, and the education field is no exception. AI simulates human listening (machine translation, speech recognition) (Delić et al., 2019), speaking (speech synthesis, human-computer dialogue) (Chiba, Nose, Kase, Yamanaka, & Ito, 2019), watching (computer vision, image recognition, text recognition) (Paglen, 2019), thinking (Theorem Proving) (Sarma & Hay, 2017), learning (machine learning, intelligent adaptive learning) (Colchester et al., 2017) and action (robot) (Khandelwal et al., 2017). In particular, AI technologies such as computer vision, natural language processing, and intelligent adaptive learning have changed traditional education and teaching (Yufei, Saleh, Jiahui, & Abdullah, 2020), and have provided universities and teachers with new ideas for teaching reform.

One of the importance of AI in education is it plays a role in promoting personalized teaching and learning. AI has changed the way teachers teach and the way students learn. It can form a personalized learning plan according to the needs and learning situation of students (Dishon, 2017), provide immersive learning experience (Ip et al., 2019) and intelligent learning tracking to help students improve their learning ability and efficiency. AI can deeply evaluate students' daily and test performance based on big data and machine learning, and provide personalized teaching guidance for students' difficult knowledge and difficulties(Bingham, Pane, Steiner, & Hamilton, 2018), shortening students' learning time (Quer, Muse, Nikzad, Topol, & Steinhubl, 2017) and improving learning efficiency (Kong et al., 2019). Adaptive learning technology can help implement one-to-one personalized teaching between machines and students. Intelligent adaptive learning technology is an AI education technology that simulates the process of one-to-one teaching by teachers to students and gives the learning system personalized teaching capabilities (Kakish & Pollacia, 2018). The United States' adaptive education started early, in the 1990s. It has excellent adaptive education companies such as Knewton (Conklin, 2016), Cognitive Tutor (Elazhary & Khodeir, 2017), etc., in which the teaching content focuses on higher education. Compared to the United States, China's adaptive education development started late, and the technology is not as mature as the United States. It has only developed rapidly in the last ten years. The education content of companies such as New Oriental and Yixue Education-Squirrel AI (Knox, 2020) that do better in intelligent adaptive education focuses on K12 Tutoring and English tutoring.

Another importance of AI in education is it can reduce the burden on teachers and make teachers more focused on humanistic care. Nowadays, much of the teachers' time is spent on correcting homework and examination papers. These repetitive tasks occupy teachers' teaching and research time and teacher-student interaction time. Intelligent tutor systems (Holstein, McLaren, & Aleven, 2017), intelligent assessment systems (CUI & LI, 2019), educational robots (Chevalier, Riedo, & Mondada, 2016) and other AIs can help teachers solve many mechanically repeated daily tasks, such as correcting homework and correcting test papers, alleviating the pressure of teachers in various tasks, and freeing teachers from heavy knowledge transfer. AI technology can also enhance teachers' abilities, help teachers provide students with personalized and precise teaching guidance (Murphy, 2019) that they could not offer before, and significantly improve the efficiency of imparting knowledge. In addition, AI allows teachers to have more time and energy to communicate with students, allowing teachers to focus on the cultivation of students' morality and ability, and have more time and energy to focus on the overall physical and mental development of each student. To achieve student-centeredness and give more humane care to students, the role of teachers has also changed from disseminators of knowledge to facilitators of student learning.

The third importance of AI in education is it promotes the construction of smart campuses (Du, Meng, & Gao, 2016). The appearance of AI technology has changed traditional education and teaching methods. Face recognition, text recognition, human body recognition, voice interaction, AR and other AI technologies provide technical support for the construction of smart campuses (Kwet & Prinsloo, 2020). With the help of AI, campus management and services such as campus safety, classroom effect monitoring and school attendance can be improved (Muhamad et al., 2017), giving students and

teachers a higher-quality teaching and learning experience, and reducing management costs. There are a large number of students living in the student hostel, and the management staff cannot fully identify the outsiders. Face recognition and human body recognition technology bring convenience to the management of the dormitories (Zhou, 2020). Face recognition through AI can efficiently identify suspicious outsiders and improve the safety of the student hostel. In the classroom, through AI technologies such as face recognition, human body analysis, and image recognition, students' head-up frequency, frequency of mobile phone usage and smile frequency are monitored and analyzed during class to obtain relevant data (Kim, Soyata, & Behnagh, 2018) so that teachers and parents can understand the students' classroom performance, which also enables teachers with deficiencies to improve their teaching methods in time. Besides monitoring the classroom effect, face recognition technology can also help teachers to check attendance, and output the attendance results through face recognition (Mekala, Vinod, Manimegalai, & Nandhini, 2019), so that teachers can know in time which students are not in class, therefore teacher can put more focus on them.

Fourthly, AI technology promotes the realization of education equity (Qiu, 2020). Different countries and regions have educational inequities due to economic development or geographical problems. AI technology can help break regional differences and reduce the inequality of educational resources between students in areas with scarce teaching resources and students in big cities due to geographical regions. By integrating the Internet and AI technology, remote personalized teaching can be provided (Karen Hao, 2019). For remote areas lacking teachers, one teacher can be used to conduct remote online teaching for students in multiple areas, provide opportunities for students to interact and learn with outstanding teachers, and realize resource sharing of high-quality teachers. At the same time, intelligent homework correction is carried out through AI (Azad, Chen, Fowler, West, & Zilles, 2020), and teaching data is automatically generated, which solves the problem that teachers can't correct homework that students submitted from different areas. It also allows teachers in remote areas to focus more on students' personalized teaching, intelligent adaptive learning and ability development. Through online and offline mixed teaching methods, the teaching level in areas with insufficient teaching resources can be improved, and the professional development of teachers in remote areas can also be improved.

4. Challenges of AI in Education

While AI brings a series of education benefits, it will also face some unprecedented challenges. Understanding the problems that may be encountered when AI is introduced into education will help people better prepare and improve the future application of AI in education. These challenges mainly lie in the following aspects:

First of all, it is necessary to ensure fairness when applying AI in education. With the development of AI, developing countries face the risk of exacerbating the divisions in education by new technologies. Just as the digital divide has separated those who can access to the Internet from those who cannot, the ever-widening algorithmic divide now threatens to deprive many educational opportunities provided by AI. Because most AI algorithms come from developed countries, the algorithms cannot fully consider the conditions of developing countries and cannot be directly applied (Yu, 2020). The education sector must overcome significant obstacles such as lacking of basic technology and infrastructure to create basic conditions for AI to improve learning.

Secondly, we need to pay attention to the ethical and safety issues arising from collecting, using, and disseminating data. AI has raised many ethical issues in terms of providing personalized advice to students, collecting personal data, data privacy, and the ownership of responsibilities and data feed algorithms (Bodó et al., 2017; Southgate, 2020). Strengthening the supervision of AI technology and its products requires the public to discuss the ethics, responsibility and safety involved.

Thirdly, it helps teachers prepare for AI-assisted teaching. Teachers must master new digital teaching skills in order to use AI to promote teaching reform appropriately. In addition, the developers of AI teaching products must understand the way teachers work and create a teaching product usage

plan that is convenient for teachers to use.

Fourthly, the changes in learning styles have higher requirements for students' autonomous learning ability. Learning in the era of AI will be student-centered, and students are in the dominant position in learning activities (Chang & Lu, 2019; Fu, 2020). Students can generate personalized learning plans based on the intelligent teaching system, independently select learning content, arrange learning progress, and carry out group cooperative learning (Fang et al., 2019; Walkington & Bernacki, 2020; Yilmaz, 2018). Individualized learning methods have higher requirements for students' self-regulation and self-management level (Bergamin & Hirt, 2018; Tseng, Yi, & Yeh, 2019), so teachers should also pay attention to the cultivation of students' independent learning ability in the teaching process.

Fifthly, more attention needs to be paid to student-student communication. If more and more students use AI platforms for learning, and the object of their communication is machines, the student's social communication skills will become a problem. Students should promote mutual learning. To solve this problem, AI education projects can set up a distance education model that emphasizes socialization. Students can study online and interact with classmates in different camps and social activities.

In short, with the in-depth development of economic and technological globalization, the important role of AI technology in education has become increasingly prominent. And many countries have regarded the development of AI technology as a national priority. The main feature of the innovation AI-based education ecosystem is the precision, individualization and adaptation of education services and management. In the process of building the innovation educational ecosystem, schools, teachers, and students are facing various challenges and problems brought by AI. To solve these problems and realize the perfect connection between AI technology and education, teachers, students, and other education ecosystems members need to work together.

5. Conclusions

With the development of AI technology, AI will be more and more used in the education field in the future. By analyzing the application of AI in education and the challenges faced by AI technology in education, people have an overall understanding of the situation of AI + education. And help teachers and students better face and use AI technology in the teaching and learning process, improve teachers' teaching quality and students' learning methods, make students' learning styles more diversified and personalized.

Reference

Afra, S., & Alhajj, R. (2020). Early warning system: From face recognition by surveillance cameras to social media analysis to detecting suspicious people. *Physica A: Statistical Mechanics and its Applications.*

An, R., & Xi, T. (2020). Research on the Service Design of Smart Campus Based on Sustainable Strategy – Taking Smart Canteen as an Example. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 12202 LNCS, pp. 20–30). Springer.

Azad, S., Chen, B., Fowler, M., West, M., & Zilles, C. (2020). Strategies for deploying unreliable AI graders in high-transparency high-stakes exams. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics).*

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. *Science Robotics.*

Bergamin, P., & Hirt, F. S. (2018). Who's in Charge?—Dealing with the Self-regulation Dilemma in Digital Learning Environments. *Knowledge Management in Digital Change* (pp. 227–245). Springer.

Bin, Y., & Mandal, D. (2019). English teaching practice based on artificial intelligence technology. *Journal of Intelligent and Fuzzy Systems.*

Bingham, A. J., Pane, J. F., Steiner, E. D., & Hamilton, L. S. (2018). Ahead of the Curve: Implementation Challenges in Personalized Learning School Models. *Educational Policy.*

Bodó, B., Helberger, N., Irion, K., Borgesius Zuiderveen, F. J., Moller, J., van der Velde, B., Bol, N., et al. (2017). Tackling the Algorithmic Control Crisis – the Technical, Legal, and Ethical Challenges of Research into Algorithmic Agents. *Yale Journal of Law & Technology*, 19, 133.

Borowiec, S. (2016). AlphaGo seals 4-1 victory over Go grandmaster Lee Sedol Technology. *The Guardian*.

Casanova, A. (2018). BYJU's: how a learning app is promoting deep conceptual understanding that is improving educational outcomes in India.

Catlin, D., & Blamires, M. (2019). Designing Robots for Special Needs Education. *Technology, Knowledge and Learning*.

Chang, J., & Lu, X. (2019). The Study on Students' Participation in Personalized Learning Under the Background of Artificial Intelligence. *2019 10th International Conference on Information Technology in Medicine and Education (ITME)* (pp. 555–558). IEEE.

Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial Intelligence trends in education: A narrative overview. *Procedia Computer Science*.

Chen, J., Fife, J. H., Bejar, I. I., & Rupp, A. A. (2016). Building e-rater ® Scoring Models Using Machine Learning Methods . *ETS Research Report Series*.

Chen, L., Zechner, K., Yoon, S. Y., Evanini, K., Wang, X., Loukina, A., Tao, J., et al. (2018). Automated Scoring of Nonnative Speech Using the SpeechRaterSM v. 5.0 Engine. *ETS Research Report Series*.

Cheong, K. H., & Koh, J. M. (2018). Integrated virtual laboratory in engineering mathematics education: Fourier theory. *IEEE Access*.

Chevalier, M., Riedo, F., & Mondada, F. (2016). Pedagogical Uses of Thymio II: How Do Teachers Perceive Educational Robots in Formal Education? *IEEE Robotics and Automation Magazine*.

Chiba, Y., Nose, T., Kase, T., Yamanaka, M., & Ito, A. (2019). An Analysis of the Effect of Emotional Speech Synthesis on Non-Task-Oriented Dialogue System.

Colchester, K., Hagras, H., Alghazzawi, D., & Aldabbagh, G. (2017). A Survey of Artificial Intelligence Techniques Employed for Adaptive Educational Systems within E-Learning Platforms. *Journal of Artificial Intelligence and Soft Computing Research*, 7(1), 47–64. De Gruyter Open Ltd.

Conklin, T. A. (2016). Knewton (An adaptive learning platform available at https://www.knewton.com/). *Academy of Management Learning & Education*, 15(3), 635–639.

CUI, L., & LI, J. (2019). Study on Data Fields Grading Category Labeling for ERP Practical Skills Intelligent Assessment System. *DEStech Transactions on Computer Science and Engineering*.

Cui, W., Xue, Z., & Thai, K. P. (2019). Performance Comparison of an AI-Based Adaptive Learning System in China. *Proceedings 2018 Chinese Automation Congress, CAC 2018*.

Delić, V., Perić, Z., Sečujski, M., Jakovljević, N., Nikolić, J., Mišković, D., Simić, N., et al. (2019). Speech Technology Progress Based on New Machine Learning Paradigm. *Computational Intelligence and Neuroscience*, 2019, 1–19.

Deloitte. (2019). *Global development of AI-based education*.

Dishon, G. (2017). New data, old tensions: Big data, personalized learning, and the challenges of progressive education. *Theory and Research in Education*.

Dong, Z., Zhang, Y., Yip, C., Swift, S., & Beswick, K. (2020). Smart campus: definition, framework, technologies, and services. *IET Smart Cities*, 2(1), 43–54.

Du, S., Meng, F., & Gao, B. (2016). Research on the Application System of Smart Campus in the Context of Smart City. *2016 8th International Conference on Information Technology in Medicine and Education (ITME)* (pp. 714–718). IEEE.

Dyrberg, N. R., Treusch, A. H., & Wiegand, C. (2017). Virtual laboratories in science education: students' motivation and experiences in two tertiary biology courses. *Journal of Biological Education*.

Eguchi, A., & Okada, H. (2018). Learning with social robots-The World Robot Summit's approach. *ISEC 2018 - Proceedings of the 8th IEEE Integrated STEM Education Conference*.

Elazhary, H., & Khodeir, N. (2017). A cognitive tutor of arabic word root extraction using artificial word generation, scaffolding and self- explanation. *International Journal of Emerging Technologies in Learning*.

Encalada, W. L., & Castillo Sequera, J. L. (2017). Model to implement virtual computing labs via cloud computing services. *Symmetry*.

Fang, Y., Ren, Z., Hu, X., & Graesser, A. C. (2019). A meta-analysis of the effectiveness of ALEKS on learning. *Educational Psychology*, 39(10), 1278–1292.

Fu, Y. (2020). Research on the Development Trend of Online Education Industry Considering the Influence of Big Data and Artificial Intelligence. *Advances in Intelligent Systems and Computing* (Vol. 928, pp. 852–859). Springer Verlag.

Ge, X. L., Yin, Y. W., & Feng, S. (2018). Application Research of Computer Artificial Intelligence in College Student Sports Autonomous Learning. *Educational Sciences: Theory & Practice*, 18(5), 2143–2154.

Goel, A. K., & Polepeddi, L. (2016). Jill Watson: A Virtual Teaching Assistant for Online Education. *Georgia Tech Library*.

Grams, D. (2018). *A Quantitative Study of the Use of "DreamBox Learning" and Its Effectiveness in Improving Math Achievement of Elementary Students with Math Difficulties. ProQuest LLC*.

Grau, A., Indri, M., Lo Bello, L., & Sauter, T. (2017). Industrial robotics in factory automation: From the early stage to the Internet of Things. *Proceedings IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society*.

Gunawan, G., Nisrina, N., Suranti, N. M. Y., Herayanti, L., & Rahmatiah, R. (2018). Virtual Laboratory to Improve Students' Conceptual Understanding in Physics Learning. *Journal of Physics: Conference Series*.

Herga, N. R., Cagran, B., & Dinevski, D. (2016). Virtual laboratory in the role of dynamic visualisation for better understanding of chemistry in primary school. *Eurasia Journal of Mathematics, Science and Technology Education*.

Holstein, K., McLaren, B. M., & Aleven, V. (2017). Intelligent tutors as teachers' aides: Exploring teacher needs for real-time analytics in blended classrooms. *ACM International Conference Proceeding Series*.

Hsieh, Y. Z., Lin, S. S., Luo, Y. C., Jeng, Y. L., Tan, S. W., Chen, C. R., & Chiang, P. Y. (2020). ARCS-assisted teaching robots based on anticipatory computing and emotional Big Data for improving sustainable learning efficiency and motivation. *Sustainability (Switzerland)*.

Ip, H. H. S., Li, C., Leoni, S., Chen, Y., Ma, K. F., Wong, C. H. to, & Li, Q. (2019). Design and Evaluate Immersive Learning Experience for Massive Open Online Courses (MOOCs). *IEEE Transactions on Learning Technologies*.

Kakish, K., & Pollacia, L. (2018). Adaptive learning to improve student success and instructor efficiency in introductory computing course. *Proceedings of the 34th Information Systems Education Conference, ISECON 2018*.

Karen Hao. (2019). China has started a grand experiment in AI education. It could reshape how the world learns. *MIT Technology Review*.

Khandelwal, P., Zhang, S., Sinapov, J., Leonetti, M., Thomason, J., Yang, F., Gori, I., et al. (2017). BWIBots: A platform for bridging the gap between AI and human–robot interaction research. *The International Journal of Robotics Research*, 36(5–7), 635–659.

Kim, Y., Soyata, T., & Behnagh, R. F. (2018). Towards Emotionally Aware AI Smart Classroom: Current Issues and Directions for Engineering and Education. *IEEE Access*.

Knox, J. (2020). Artificial intelligence and education in China. *Learning, Media and Technology*, 45(3), 298–311.

Kong, S. H., Lv, Y., Vu, H. L., Cano, J. C., Choi, J. W., Kum, D., & Morris, B. T. (2019). Guest Editorial Introduction to the Special Issue on Intelligent Transportation Systems Empowered by AI Technologies. *IEEE Transactions on Intelligent Transportation Systems*.

Krumm, John（Ed）. (2018). *Ubiquitous Computing Fundamentals*. (John Krumm, Ed.)*Ubiquitous Computing Fundamentals*. Chapman and Hall/CRC.

Kulkarni, P. V., Rai, S., & Kale, R. (2020). Recommender System in eLearning: A Survey (pp. 119–126). Springer, Singapore.

Kuo, T. H. (2020). The Current Situation of AI Foreign Language Education and Its Influence on College Japanese Teaching. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 12193 LNCS, pp. 315–324). Springer.

Kwet, M., & Prinsloo, P. (2020). The 'smart' classroom: a new frontier in the age of the smart university. *Teaching in Higher Education*.

Lakhal, S., Bateman, D., & Bédard, J. (2017). Blended Synchronous Delivery Modes in Graduate Programs: A Literature Review and How it is Implemented in the Master Teacher Program. *Collected Essays on Learning and Teaching*, 10, 47–60.

Li, L., Lin, Y. L., Zheng, N. N., Wang, F. Y., Liu, Y., Cao, D., Wang, K., et al. (2018). Artificial intelligence test: a case study of intelligent vehicles. *Artificial Intelligence Review*.

Li, Q., Cao, H., & Lu, Y. (2017). Connecting paper to digitization–a homework data processing system with data labeling and visualization. *ACM International Conference Proceeding Series*.

Liu, C. (2020). Application of speech recognition technology in pronunciation correction of college oral english teaching. *Advances in Intelligent Systems and Computing* (Vol. 1234 AISC, pp. 525–530). Springer.

Liu, D., Valdiviezo-Díaz, P., Riofrio, G., Sun, Y. M., & Barba, R. (2015). Integration of Virtual Labs into Science E-learning. *Procedia Computer Science*.

Liu, L., Zhou, B., Zou, Z., Yeh, S. C., & Zheng, L. (2018). A Smart Unstaffed Retail Shop Based on Artificial Intelligence and IoT. *IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Networks, CAMAD*.

Liu, M., Ma, J., & Jin, L. (2018). Analysis of Military Academy Smart Campus Based on Big Data. *Proceedings - 2018 10th International Conference on Intelligent Human-Machine Systems and Cybernetics, IHMSC 2018*.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*.

Mekala, V., Vinod, V. M., Manimegalai, M., & Nandhini, K. (2019). Face recognition based attendance system. *International Journal of Innovative Technology and Exploring Engineering*.

Miller, D. P., Nourbakhsh, I. R., & Siegwart, R. (2008). Robots for Education. *Springer Handbook of Robotics*.

Muhamad, W., Kurniawan, N. B., Suhardi, & Yazid, S. (2017). Smart campus features, technologies, and applications: A systematic literature review. *2017 International Conference on Information Technology Systems and Innovation (ICITSI)* (pp. 384–391). IEEE.

Murphy, R. (2019). *Artificial Intelligence Applications to Support K–12 Teachers and Teaching: A Review of Promising Applications, Challenges, and Risks. Artificial Intelligence Applications to Support K–12 Teachers and Teaching: A Review of Promising Applications, Challenges, and Risks*.

Orobor, I. A., & Orobor, H. E. (2020). A review of virtual laboratory and justification for adoption in nigeria tertiary educational institutions. *International Journal of Open Information Technologies*, 8(2).

Paglen, T. (2019). Invisible Images: Your Pictures Are Looking at You. *Architectural Design*.

Pannu, A. (2015). Artificial Intelligence and its Application in Different Areas. *International Journal of Engineering and Innovative Technology*, 4(10), 79–84.

Qiu, Y. (2020). Education Informationization. *Proceedings of the 2020 6th International Conference on Education and Training Technologies* (pp. 40–43). New York, NY, USA: ACM.

Quer, G., Muse, E. D., Nikzad, N., Topol, E. J., & Steinhubl, S. R. (2017). Augmenting diagnostic vision with AI. *Lancet (London, England)*.

Rahim, T. N. T. A., Aziz, Z. A., Rauf, R. H. A., & Shamsudin, N. (2018). Automated exam question generator using genetic algorithm. *2017 IEEE Conference on e-Learning, e-Management and e-Services, IC3e 2017*.

Ramdani, A., Virgono, A., & Setianingsih, C. (2020). Food Detection with Image Processing Using Convolutional Neural Network (CNN) Method (pp. 91–96). Institute of Electrical and Electronics Engineers (IEEE).

Robot, S. (2018). Pepper, the star robot of Shenzhen Baoan Airport, appeared at the 2018 Shenzhen High-tech Fair. *China Ningbo News Network*. Retrieved September 7, 2020, from http://www.nbyoho.com/news/1617259410153483485.html

Rocca, R., Rosa, P., Sassanelli, C., Fumagalli, L., & Terzi, S. (2020). Integrating virtual reality and digital twin in circular economy practices: A laboratory application case. *Sustainability (Switzerland)*.

Roll, I., & Wylie, R. (2016). Evolution and Revolution in Artificial Intelligence in Education. *International Journal of Artificial Intelligence in Education*, 26(2), 582–599. Springer New York LLC.

Russo-Spena, T., Mele, C., & Marzullo, M. (2019). Practising Value Innovation through Artificial Intelligence: The IBM Watson Case. *Journal of Creating Value*.

Sarma, G. P., & Hay, N. J. (2017). Robust Computer Algebra, Theorem Proving, and Oracle AI. *SSRN Electronic Journal*.

Southgate, E. (2020). *Artificial intelligence, ethics, equity and higher education: A 'beginning-of-the-discussion' paper*.

Spolaôr, N., & Benitti, F. B. V. (2017). Robotics applications grounded in learning theories on tertiary education: A systematic review. *Computers and Education*.

Sruthi, P., & Mukherjee, S. (2020). Byju's The Learning App: An Investigative Study On The Transformation From Traditional Learning To Technology Based Personalized Learning. *International journal of scientific & technology research*, 9(30), 5054–5059.

Tripathy, S., & Devarapalli, S. (2020). Emerging trend set by a start-ups on Indian online education system: A case of Byju's. *Journal of Public Affairs*.

Tsai, C. C.-M. (2016). The Role of Duolingo in Foreign Language Learners' Autonomous Learning. *In The Asian Conference of Language Learning 2016: The International Academic Forum*.

Tseng, H., Yi, X., & Yeh, H.-T. (2019). Learning-related soft skills among online business students in higher education: Grade level and managerial role differences in self-regulation, motivation, and social skill. *Computers in Human Behavior*, 95, 179–186.

Tuomi, I. (2018). *The Impact of Artificial Intelligence on Learning, Teaching, and Education. Policies for the future*. EUR - Scientific and Technical Research Reports.

Upala, M., & Wong, W. K. (2019). IoT Solution for Smart Library Using Facial Recognition. *IOP Conference Series: Materials Science and Engineering*.

Villegas-Ch, W., Molina-Enriquez, J., Chicaiza-Tamayo, C., Ortiz-Garcés, I., & Luján-Mora, S. (2019). Application of a big data framework for data monitoring on a smart campus. *Sustainability (Switzerland)*.

Van Der Vorst, T., & Jelicic, N. (2019). *Artificial Intelligence in Education Can AI bring the full potential of personalized learning to education?*

Walkington, C., & Bernacki, M. L. (2020). Appraising research on personalized learning: Definitions, theoretical alignment, advancements, and future directions. *Journal of Research on Technology in Education*, 52(3), 235–252.

Wang, L., Hu, G., & Zhou, T. (2018). Semantic analysis of learners' emotional tendencies on online MOOC education. *Sustainability (Switzerland)*.

Wang, P., Wu, P., Wang, J., Chi, H. L., & Wang, X. (2018). A critical review of the use of virtual reality in construction engineering education and training. *International Journal of Environmental Research and Public Health*.

Wang, Y. (2020). An improved machine learning and artificial intelligence algorithm for classroom management of English distance education. *Journal of Intelligent & Fuzzy Systems*, 1–12.

Williamson, B. (2018). The hidden architecture of higher education: building a big data infrastructure for the 'smarter university.' *International Journal of Educational Technology in Higher Education*.

Wood, L. J., Zaraki, A., Robins, B., & Dautenhahn, K. (2019). Developing Kaspar: A Humanoid Robot for Children with Autism. *International Journal of Social Robotics*.

Xu, Y., Ye, Y., Lv, Q., Wu, M., & Gu, J. (2017). Reform and practice for photoelectric specialty experimental teaching based on virtual simulation experiment platform.

Yang, J., & Zhang, B. (2019). Artificial Intelligence in Intelligent Tutoring Robots: A Systematic Review and Design Guidelines. *Applied Sciences*, 9(10), 2078.

Yang, S., & Bai, H. (2020). The integration design of artificial intelligence and normal students' Education. *Journal of Physics: Conference Series*, 1453(1), 012090.

Yilmaz, B. (2018). Effects of adaptive learning technologies on math achievement: A quantitative study of ALEKS math software. *Dissertation Abstracts International Section A: Humanities and Social Sciences*.

Yong, B. (2018). Design of intelligent evaluation system of physical education teaching based on artificial intelligence expert decision system. *Advances in Intelligent Systems and Computing*.

Yu, P. K. (2020). Legal Studies Research Paper Series The Algorithmic Divide and Equality in the Age of Artificial Intelligence. *Florida Law Review*, 72(19), 331–89.

Yufei, L., Saleh, S., Jiahui, H., & Abdullah, S. M. S. (2020). Review of the application of artificial intelligence in education. *International Journal of Innovation, Creativity and Change*, 12(8), 548–562.

Zhou, X. (2020). Application Research of Face Recognition Technology in Smart Campus. *Journal of Physics: Conference Series*.

Zou, S. (2017). Designing and practice of a college english teaching platform based on artificial intelligence. *Journal of Computational and Theoretical Nanoscience*.