



# Revolutionizing education with AI: Exploring the transformative potential of ChatGPT

Tufan Adiguzel <sup>1\*</sup>

 0000-0001-6232-1246

Mehmet Haldun Kaya <sup>2</sup>

 0000-0002-0276-4886

Fatih Kürşat Cansu <sup>3</sup>

 0009-0001-8047-987X

<sup>1</sup> Sectoral Education Program, Ozyegin University, Istanbul, TURKIYE

<sup>2</sup> School of Foreign Languages, Izmir University of Economics, Izmir, TURKIYE

<sup>3</sup> Bahcesehir University, Istanbul, TURKIYE

\* Corresponding author: [tufan.adiguzel@ozyegin.edu.tr](mailto:tufan.adiguzel@ozyegin.edu.tr)

**Citation:** Adiguzel, T., Kaya, M. H., & Cansu, F. K. (2023). Revolutionizing education with AI: Exploring the transformative potential of ChatGPT. *Contemporary Educational Technology*, 15(3), ep429. <https://doi.org/10.30935/cedtech/13152>

## ARTICLE INFO

Received: 16 Feb 2023

Accepted: 28 Mar 2023

## ABSTRACT

Artificial intelligence (AI) introduces new tools to the educational environment with the potential to transform conventional teaching and learning processes. This study offers a comprehensive overview of AI technologies, their potential applications in education, and the difficulties involved. Chatbots and related algorithms that can simulate human interactions and generate human-like text based on input from natural language are discussed. In addition to the advantages of cutting-edge chatbots like ChatGPT, their use in education raises important ethical and practical challenges. The authors aim to provide insightful information on how AI may be successfully incorporated into the educational setting to benefit teachers and students, while promoting responsible and ethical use.

**Keywords:** artificial intelligence, education, chatbots, ChatGPT, personalized learning

## INTRODUCTION

Artificial intelligence (AI) has led to a new age of innovation and transformation in many fields, including education. AI technologies offer new tools and applications that have the potential to transform traditional teaching and learning methods. AI has a wide variety of potential uses in education, including improving productivity, learning outcomes, personalized instruction, instant feedback, and student engagement.

Intelligent tutoring systems, automated rating systems, and tailored learning platforms are just a few of the educational applications where AI is already being applied. These programs have a lot of potential for enhancing students' academic performance and empowering teachers to give students more individualized instruction. For instance, by offering personalized feedback and assistance, intelligent tutoring systems may adapt lessons to students' needs. Teachers may focus on more important activities like lesson planning and student support by using automated grading systems, which can save them a substantial amount of time. By offering learning experiences catered to each student's unique requirements and interests, personalized learning platforms can raise students' engagement and motivation.

Despite all its benefits, using AI in education also raises significant ethical and practical issues. These issues include the possibility that it might increase the already-existing inequalities in the educational system and inherent nature of AI algorithms that is prone to bias. Additionally, enabling teachers to successfully incorporate AI into their teaching practices needs relevant training and support.

This study attempts to present an overview of the existing literature on the application of AI in education, with an emphasis on chatbots and ChatGPT—advanced artificial intelligence systems that can generate human-like responses based on natural language models. Alongside the potential benefits of AI in education, ethical and practical considerations regarding the use of these technologies will also be discussed. By identifying key research areas, the authors aim to offer insightful information on how AI may be successfully incorporated into the educational environment to benefit both instructors and students. Authors further aim to encourage the ethical and responsible use of these technologies to enhance teaching and learning processes, as well as to contribute to the continuing discussion concerning the place of AI in education.

## ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) has attained a ubiquitous presence in daily life. A vast array of examples illustrate how AI has permeated into various aspects of human lives, including accessing information over the Web, consuming news and entertainment, surveillance systems identifying individuals, financial market performance, citizens receiving welfare payments, and how drivers and pedestrians navigate (Williamson & Eynon, 2020). As AI advances, the possibilities that were once only speculative may soon become tangible. It has the potential to revolutionize various aspects of society, spanning from the business sector, healthcare, to education (Alawi, 2023), but what exactly is it?

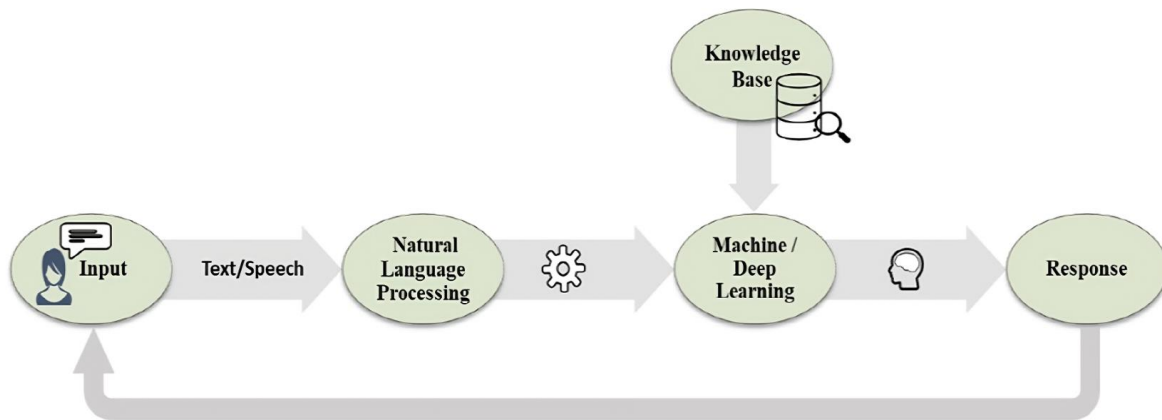
Artificial Intelligence coined by John McCarthy in 1955 refers to making a machine behave in ways that would be described as intelligent if a human was so behaving (McCarthy et al., 1955). Kurzweil (1990) also characterizes AI as the art of developing machines that can perform tasks that typically necessitate human intelligence. Although these early definitions of AI date back many decades, they present a useful starting point for defining it: whether AI is genuinely intelligent, if not what is the difference? Indeed, AI is not inherently intelligent but rather has the capacity to perform tasks that are generally considered intelligent with a certain degree of success (Chiu et al., 2022; Mertala et al., 2022).

Notwithstanding its capability to differentiate between a picture of an automobile and that of a rainbow, AI does not possess an inherent understanding of the concepts of automobiles or rainbows. The operational core of AI consists of algorithms and programs with big data as the fundamental basis (Zhang, 2023). Thus, AI is also described as a subfield of computer science that centers on investigating the essential nature of intelligence by using a set of algorithmic procedures to create intelligent artifacts that resemble human intelligence (Dwivedi, 2021); however, it has evolved into a novel multidisciplinary and interdisciplinary science that integrates various knowledge and technologies, such as computer science, statistics, information theory, and mathematics (Mata et al., 2018). Hence, it is possible to give a more comprehensive definition: any theory, methodology, or technique that facilitates the analysis, simulation, exploitation, and exploration of human thinking processes and behaviors by machines, particularly computers, can be regarded as AI (Lu, 2019).

AI is not perfect neither is any human (OpenAI, 2023). Heralded as a transformative technology (Dwivedi et al., 2021), its distinctive intelligent functions have facilitated the gradual transition of human society into the AI era (Ye, 2021). The associated technologies encompass a wide range of areas, including intelligent robotics, natural language processing, language recognition, advanced image recognition, intelligent expert systems, neural network and machine learning (Anweiler & Ramet, 2019; Mondal et al., 2020).

### Chatbots

One of the commonly utilized AI technologies for supporting teaching and learning activities is the Chatbot system (Okonkwo & Ade-Ibijola, 2020). A Chatbot is an intelligent agent that is capable of interacting with a user by answering a series of questions and providing an appropriate response (Clarizia et al., 2018). A Chatbot, as a dialogue system, should be able to understand the content of the dialogue and identify the users' social and emotional needs during the conversation. It emulates and interprets human communication, allowing individuals to engage with digital devices as though they were conversing with an actual human being (Ciechanowski, 2019). Additionally, the performance of a chatbot depends on the size and accuracy of its databases, meaning that greater database size leads to better performance (Aleedy et al., 2022). The creation of a Chatbot involves the use of Natural Language Processing (NLP). NLP is a technology that enables a



**Figure 1.** How a Chatbot functions (Aleedy et al., 2022, p. 662)

machine to comprehend, analyze and interpret natural human languages. **Figure 1** shows how a chatbot functions.

The first chatbox, Eliza, was created with the role of a psychotherapist in 1966 followed by Parry in 1972 and Alice in 1995. As technology advances, modern Chatbots are created, such as SmarterChild, Apple Siri, Amazon Alexa, IBM Watson, Microsoft Cortana, and Google Assistant (Reis et al., 2018).

### ChatGPT

Launched by OpenAI (San Francisco, CA) in November 2022, ChatGPT describes itself as “a powerful machine learning software that uses the Generative Pre-trained Transformer (GPT) algorithm to generate human-like responses to text-based inputs”. ChatGPT was trained on a vast corpus of data, including articles, websites, books, and written conversations. However, through a process of fine-tuning that includes dialogue optimization, ChatGPT is capable of responding to prompts in a conversational manner (Health, 2023). Generative Pre-trained Transformers (GPTs) are a class of advanced language models that employ deep learning to enhance their output. These models are trained on extensive datasets.

Through the identification of patterns and regularities in the data, GPTs generate appropriate phrases and words or produce relevant images in response to a user’s queries (Rospigliosi, 2023). A wide range of tasks can be accomplished by ChatGPT, including language translation, text summarization, question answering, creative writing (such as poetry or fiction), generation of high-quality long or short form content (such as blog posts), responding to prompts in conversation, explaining complex subjects, concepts, or themes, and fixing errors in existing code or generating new codes (Eke, 2023). The innate abilities of ChatGPT have been showcased in studies that indicate its success in passing a Law School examination (Choi et al., 2023) and a Master of Business Administration (MBA) examination (Terwiesch, 2023).

ChatGPT’s ability to understand natural language queries and generate human-like responses has made it a popular tool for getting quick answers to a wide variety of questions, from common to complex topics. For example, it can instantly summarize a long academic article with a single sentence, the words in which may even start with a particular letter like ‘q’ only. It not only detects what the problem is but also provides accurate solutions even when programming itself. ChatGPT has quickly established itself as a valuable resource for students and professionals. The latest version of ChatGPT (ChatGPT-4) was released on March 14, 2023 and is claimed to be more powerful and capable of performing more complex functions. ChatGPT-4 has been trained on a larger and diverse dataset. The increased size of the model allows for more advanced natural language processing capabilities. Its capacity for reasoning and understanding prompts across multiple domains makes it more adaptable and able to handle challenging tasks. For example, if a user submits an image and requests a description, it describes the image in detail. It even responds to the handwritten queries presented as graphics (OpenAI, 2023).

## ARTIFICIAL INTELLIGENCE IN EDUCATION (AIEd)

AI technologies have had a significant impact on the way we learn (Chen et al., 2020) particularly due to the rapid development with the emergence of deep learning technologies (Chan & Zary, 2019). In fact, since at least the 1980s, AI in education (AIEd) has been established as a cohesive academic research field (Williamson & Eynon, 2020). In AIEd, there are two approaches consisting of the development of AI-based tools for classrooms and the utilization of AI to gain insight, assess, and enhance learning (Holmes et al., 2019).

AIEd involves the integration of social, cultural, economic and pedagogical dimensions (Selwyn, 2016). It involves the utilization of AI technologies, including intelligent tutoring systems, chatbots, robots, learning analytics dashboards, adaptive learning systems and automated assessment, so as to support and enhance the educational process (Chen et al., 2020). Specifically, a chatbot's capabilities may vary based on its technologies including natural language processing, machine learning, deep learning, and artificial neural networks (Nirala et al., 2022). Early chatbots utilized either keyword matching mechanisms (Weizenbaum, 1966) or natural language processing mechanisms (Melián-González et al., 2021). As computer and speech recognition technology advanced, voice interactive interfaces started to emerge (Guttormsen et al., 2011). The initial chatbots lacked reliability as they were incapable of providing precise answers to students during a conversation. Their responses were ambiguous and occasionally misguided learners, rendering them of limited educational worth (Yin et al., 2021). Nevertheless, contemporary chatbots have improved significantly, boosting their potential for educational applications (Fryer et al., 2019). Thus far, chatbots have predominantly been applied in education for the purposes of health and wellness, language acquisition, feedback provision, metacognitive development, and addressing student inquiries (Chen et al., 2023).

Although the influence of AI on education is still uncertain (Holmes, 2021), it has considerable potential to improve learning, teaching, pedagogical innovations, assessment, and educational administration (Chen et al., 2020). While AI has the potential to revolutionize education, achieving positive educational outcomes requires more than just the use of sophisticated AI computing technologies (Castaneda & Selwyn, 2018). The employment of technology should be closely linked to educational and learning theories to guide instructional design and technological advancement (Bower, 2019). As for the conceptual framework of AI-supported learning, Zheng (et al. 2021) claim that the utilization of AIEd technologies, learning content, and pedagogical approaches are often interconnected and should be integrated to optimize learning efficiency and effectiveness. When designing learning activities supported by AI, teachers and practitioners should consider six crucial elements to achieve the expected learning objectives: learners, context, tasks, pedagogical approaches, interaction methods, and the application of AI technologies (Zheng et al., 2021).

### AIEd Paradigms

Ouyang and Jiao (2021) group AIEd into three paradigms:

- 1) AI-directed (where the learner is seen as the recipient)
- 2) AI-supported (where the learner is seen as the collaborator),
- 3) AI-empowered (where the learner is seen as the leader).

In the first paradigm, under the influence of behaviorism, AI is employed to represent and direct cognitive learning while learners are the recipients of AI services. In the second paradigm with cognitive and social constructive theoretical foundations, AI supports learning while learners collaborate with AI. In the third paradigm based on connectivism, AI empowers learning and learners take agency in their own learning and a synergistic collaboration among multiple entities, such as the learner, the instructor, information, and technology, in the system augments the learner's intelligence. In the realm of education, AI has been regarded as a potent tool for enabling novel paradigms in instructional design, technological advancement, and educational research that would otherwise be unfeasible to achieve via conventional modes of education (Hwang et al., 2020).

## Potential Benefits of AIEd

### *Potential benefits for students*

For students, a primary result of implementing AI is increased motivation and engagement (Xia et al., 2022). It increases their learning interest (Lin & Chang, 2020), facilitates interactive learning environments via particular tools like Smart Sparrow that promote learner engagement with educational content (Karsenti, 2019). Numerous studies have also demonstrated substantial improvements in academic performance through the aid of AI technologies (Khan et al., 2021; Kim et al., 2021). It significantly improves learning outcomes and student happiness (Winkler & Söllner, 2018), maximizing student learning abilities and achievement (Clarizia et al., 2018). One reason behind this high motivation and achievement could be promoting and enhancing personalized learning experiences (Cunningham-Nelson et al., 2019). To this end, AI-powered tools like ALEKS and Knewton create individualized learning paths. Such individualized learning experiences and materials cater to learners' unique strengths and weaknesses (Brown et al., 2020).

In AI-enabled environments, students are not only presented with individualized tasks (Hiranker & Kittisunthonphisarn, 2020) but also personalized and instant feedback by analyzing their work and learning process (Okonkwo & Ade-Ibijola, 2020; Porter & Grippa, 2020). For example, Grammarly, InstaText and QuillBot provide learners with tailored feedback on their written assignments and Codecademy on coding tasks. This step-by-step individualized guidance and timely feedback encourage self-reflection, self-directed learning and self-regulation through the identification and learning from their own errors (Chiu et al., 2023a). It also provides advice to students on academic issues thereby helping them to make some vital decisions on their various academic programs or activities (Ismail & Ade-Ibijola, 2019). The employment of AI technologies also furnishes students with twenty-first century skills, including critical thinking and creativity, thus facilitating the assessment and appraisal of complex skills (Luckin et al., 2016) and promoting deep thinking through AI (Chiu et al., 2023b).

Notably, AI facilitates ongoing dialogue and aids students in improving their communication abilities in language learning contexts (Vazquez-Cano, 2021) since it encourages collaborative learning (Ruan et al., 2019) and enhances peer communication skills (Hill et al., 2015). Additionally, such personalized learning environments not only enhance the quality of instruction, but also promote informal learning and services to underserved and vulnerable populations (Jain et al., 2018) including students in need of special education (Chassignol et al., 2018). In their study, for example, Llorente and colleagues (2021) showed that AI-based educational interventions can improve the reading comprehension of students with dyslexia. Similarly, a review by Zhang and colleagues (2020) pointed out that AI-based instructional tools can foster the learning outcomes of students with autism spectrum disorder. These findings suggest that AI has the potential to play a valuable role in supporting students with learning disabilities, and helping them to achieve their full potential.

As for the affective domain of students, it has been reported that they have a more favorable disposition and increased self-assurance in their learning outcomes due to the application of AI (Hsieh, 2020) since AI allows students to study in exciting and comfortable environments (Rooein, 2019), which enhances their confidence and reduces their learning anxiety (Kim et al., 2021). Human-robot interactions, for example, helped low-achieving students feel more confident and useful and less embarrassed (Chiu et al., 2023a). A study by Crompton and colleagues (2019) found that an AI-based educational intervention was effective in reducing anxiety among middle school students. Thus, AI has the potential to make a positive impact on the anxiety students have, helping them to develop the skills and confidence needed to succeed in their academic life.

### *Potential benefits for teachers and administrators*

For the other side of the coin, namely, for teachers, AI presents itself as an invaluable asset. Incorporating AI technologies into teaching, learning, and administration has elicited positive attitudes from them (Aldosari, 2020). First of all, the use of AI technologies has been found to improve teaching skills (Jaiswal & Arun, 2021) and teaching competence by providing inspiration and promoting self-reflection (Aldeman et al., 2021). AI introduces adaptive teaching strategies (Aldeman et al., 2021) because it enhances teachers' insight into students' learning processes and presents ways to support their learners (Jia et al., 2021; Vincent-Lancrin &



Van der Vlies, 2020). It functions in an adaptive way considering students' actions and emotions (Graesser, 2016). AI also provides teachers with professional development as it can offer them teaching evaluation models and provide suggestions for improving their teaching practices (Gunawan et al., 2021; Hu, 2021).

Markedly, AI presents assessments of students based on their performance abilities (Durall & Kapros, 2020). AI-powered Chatbots can be used to create an automated and intelligent system that enables teachers to analyze and assess a student's learning ability (Durall & Kapros, 2020). When they are submitted, the chatbots collect the results and send them to the teachers, allowing them to keep track of their students' progress and speed up activities (Okonkwo & Ade-Ibijola, 2020) via certain tools like Gradescope, Autolab, and AI tutor. Additionally, AI allows to monitor students' learning process (Chiu et al., 2023b) and capture data on student learning (Westera et al., 2020). For example, a diverse range of multimodal data, encompassing physiological sensing, eye-tracking, and electroencephalography, have been employed to acquire a multifaceted comprehension of learners' levels, enabling a high-quality prediction of their learning performance (Giannakos et al., 2019). Advanced AI features, such as speech recognition and pronunciation correction, have the potential to facilitate the acquisition of foreign language skills (Vincent-Lancrin & Van der Vlies, 2020).

With the close monitoring and the ability to predict students' performance (Akmese et al., 2021), AI technologies facilitate administrative roles as they are of use when addressing student disengagement and effectively reducing student dropout rates (Karsenti, 2019; Villegas-Ch et al., 2021) because such early warning systems based on long-term datasets facilitate prediction and identifying risks (Brown et al., 2020). Furthermore, AI technologies can replace a significant amount of repetitive work, reducing the workload of teachers and administrators (Chan & Zary, 2019). Thus, a chatbot reduces teachers' administrative workload by evaluating students' assignments, scoring, and providing feedback to students (Chen et al., 2020; Cunningham-Nelson et al., 2019). For example, AutoGradr and Repl.it automatically grade homework and tests, saving teachers many hours of time that can be spent on lesson planning, student support and professional development. AI-based learning management systems can provide numerous benefits for both students. Several universities have begun to use chatbots to answer students' questions and assist them in off-hours. They are also used in libraries, student affairs, school restaurants, and academic programs to give individualized learning, support students, facilitate administrative duties, and foster assessment (Hopcan et al., 2022). As AI technology continues to advance, it is expected to see even more sophisticated learning management systems emerge in the future (Koedinger et al., 2012, Ramesh & Lakshmi, 2018, Saha & Al Amri, 2019).

## Ethical Issues

Although the use of AI technologies is highly recommended, their limitations need to be considered. According to Rapp et al. (2021), evaluating a chatbot just based on its effectiveness, utility, and ability to fulfill and engage people does not seem to be sufficient. Firstly, it raises ethical concerns related to potential abuse and deception. Users may mistakenly believe that they are communicating with real individuals rather than with Chatbots (Adamopoulou & Moussiades, 2020). The Deputy Director General of the European Consumer Organization (BEUC) pointed out serious concerns about how ChatGPT "might manipulate and deceive people" (McCallum, 2023). It has already been banned in Russia, China, Venezuela, Belarus, and Iran as they claim that ChatGPT spreads US political propaganda (Wodecki, 2023). User privacy (Okonkwo & Ade-Ibijola, 2020) is another major issue. Italy has become the first western country to ban ChatGPT over privacy issues (McCallum, 2023). Notably, many prominent figures in AI including Elon Musk and Apple® co-founder, Steve Wozniak, did not limit their concerns to ethics or privacy but signed an open letter warning that it "can pose profound risks to society and humanity" (Vallance, 2023).

Another key challenge pertains to Chatbot development and programming (Rahman et al., 2017). According to Grosz (2018), computational linguistics and NLP systems also raise some of the most serious potential issues, such as dialogue system failure, the impact of social Chatbots on how people communicate with one another, and system performance issues. Chatbot's accuracy in delivering information is contingent upon the input data. Users have the expectation that the Chatbot system will furnish precise responses to their inquiries, which is solely feasible when the input data is accurate (Cunningham-Nelson et al., 2019). Okonkwo and Ade-Ibijola (2020) argue that building a Chatbot system is a continuous process that

necessitates consistent supervision and maintenance, which can be difficult. Additionally, it could answer harmful instructions like giving the codes of a malware. To overcome these issues, Jobin et al. (2019) delineated the following eleven ethical principles for artificial intelligence: (1) transparency (2) justice and fairness (3) nonmaleficence (4) responsibility (5) privacy (6) beneficence (7) freedom and autonomy (8) trust (9) dignity (10) sustainability and (11) solidarity.

The generic limitations of chatbots mentioned above inevitably reflect themselves when they are used for instructional purposes. In general, they raise questions about academic integrity and worries professors about using essays as a form of assessment (Eke, 2023). When asked about the potential ethical issues related to the use of Chatbots and ChatGPT in education, the following concerns are listed:

- reliability and accuracy of the information it presents
- potential biases in the data, resulting in discriminatory or misleading responses
- privacy issues since it may collect and store personal information about students
- questions about the role of teachers and the impact on the job market for educators
- lack of human interaction, reducing the quality of the educational experience for students
- over-reliance and dependency on technology
- concerns about the rights of intellectual property
- transparency and accountability as it might be difficult to identify how decisions are being made by the chatbot

Research on AIEd also reveals a weak link to pedagogical perspectives and instructional approaches, and overlooks the intricate and multifaceted challenges and risks involved in learning and teaching with AI (Guilherme, 2019; Williamson & Eynon, 2020). Additionally, Goel and Polepeddi (2018) underscore the importance of equity and accessibility for all students. It is essential to ensure that AI-based educational tools are designed with user privacy and data security in mind, and that they do not reinforce biases or perpetuate inequalities (Jia et al., 2021). Although arguing that AIEd technologies, specifically ChatGPT, undermine academic integrity, insufficient familiarity with these technologies poses challenges to their introduction and integration into educational institutions (Hussin, 2018) and academic institutions need to embrace it as an indispensable component of research and pedagogy (Eke, 2023). Considering that a version of ChatGPT, Microsoft 365 Copilot, was added to Office apps, including Word, Excel, PowerPoint and Outlook by using machine learning to analyze data from a variety of sources, including telemetry data, user feedback, and Microsoft's own expertise to provide proactive recommendations, automated issue resolution, and personalized guidance (Stallbaumer, 2023), it is not hard to predict that the impact of ChatGPT in education will grow in the following days. Therefore, further research is necessary to ascertain the potential benefits of these emerging technologies for education and how they can be properly and effectively utilized (Chiu, 2023b; Hwang & Chang, 2021) for the purpose of differentiating text- and idea-generation (Halaweh, 2023). We can help preparing the next generation of students for a future in which AI is an increasingly important part of their lives (UNESCO, 2021) by integrating AI-based educational tools into their curricula and policies accordingly.

## CONCLUSION

---

There are several advantages to using AI in education, as well as certain difficulties. AI may improve learning outcomes, productivity, and student engagement by opening up new avenues for individualized education, feedback, and assistance. Nonetheless, it is impossible to disregard the ethical and practical issues surrounding the application of AI in education. Important concerns to solve include the possibility of bias in AI algorithms and the requirement for sufficient teacher preparation and support.

Particularly, the potential for personalized learning, language instruction, and feedback applications in education is demonstrated by the usage of chatbots and ChatGPT. Recent literature has made significant advances in the understanding and practical application of AI-integrated learning and teaching environments. These contexts enable the utilization of AIEd technologies as trainers, facilitators, collaborators, or tools in a range of settings and roles. Nevertheless, these scenarios have become more comprehensive, prompting the

question of to what extent ChatGPT can revolutionize education, thereby necessitating further inquiry and exploration.

In the end, a collaborative effort involving educators, researchers, and policy-makers is needed to ensure the ethical and responsible use of AI in education. We can build a more fair and successful education system that gives kids the individualized teaching, feedback, and support they need by solving the problems posed by AI technologies and utilizing their advantages.

**Author contributions:** All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approved the final version of the article.

**Funding:** The authors received no financial support for the research and/or authorship of this article.

**Ethics declaration:** Authors declared that ethics committee approval was not required for the study since it is based on existing literature that is publicly available.

**Declaration of interest:** Authors declare no competing interest.

**Data availability:** Data generated or analysed during this study are available from the authors on request.

## REFERENCES

- Adamopoulou, E., & Moussiades, L. (2020). Chatbots: History, technology, and applications. *Machine Learning with Applications*, 2, 100006. <https://doi.org/10.1016/j.mlwa.2020.100006>
- Akmese, O. F., Kor, H., & Erbay, H. (2021). Use of machine learning techniques for the forecast of student achievement in higher education. *Information Technologies and Learning Tools*, 82(2), 297-311. <https://doi.org/10.33407/itlt.v82i2.4178>
- Alawi F. (2023). Artificial intelligence: The future might already be here. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology*, 12, S2212-4403(23)00003-2. <https://doi.org/10.1016/j.oooo.2023.01.002>
- Aldeman, N. L. S., Aita, K., Machado, V. P., da Mata Sousa, L. C. D., Coelho, A. G. B., da Silva, A. S., Mendes, A. P. D., Neres, F. J. D., & do Monte, S. J. H. (2021). Smartpath (k): A platform for teaching glomerulopathies using machine learning. *BMC Medical Education*, 21(1), 248. <https://doi.org/10.1186/s12909-021-02680-1>
- Aldosari, S. A. M. (2020). The future of higher education in the light of artificial intelligence transformations. *International Journal of Higher Education*, 9(3), 145-151. <https://doi.org/10.5430/ijhe.v9n3p145>
- Aleedy, M., Atwell, E., & Meshoul, S. (2022). Using AI Chatbots in Education: Recent Advances Challenges and Use Case. In *Artificial Intelligence and Sustainable Computing: Proceedings of ICSIS CET 2021* (pp. 661-675). [https://doi.org/10.1007/978-981-19-1653-3\\_50](https://doi.org/10.1007/978-981-19-1653-3_50)
- Anweiler, O., & Ramet, P. (2019). The reform of the Soviet educational system: Between modernization and ideological control. In *Gorbachev and the Soviet Future* (pp. 142-163). Routledge. <https://doi.org/10.4324/9780429043505-7>
- Bower, M. (2019). Technology-mediated learning theory. *British Journal of Educational Technology*, 50(3), 1035-1048. <https://doi.org/10.1111/bjet.12771>
- Brown, M., McCormack, M., Reeves, J., Brook, D. C., Grajek, S., Alexander, B., & Weber, N. (2020). *2020 Educause Horizon Report Teaching and Learning Edition* (pp. 2-58). EDUCAUSE.
- Castaneda, L., & Selwyn, N. (2018). More than tools? Making sense of the ongoing digitizations of higher education. *International Journal of Educational Technology in Higher Education*, 15(22), 2-10. <https://doi.org/10.1186/s41239-018-0109-y>
- Chan, K. S., & Zary, N. (2019). Applications and challenges of implementing artificial intelligence in medical education: Integrative review. *JMIR Medical Education*, 5(1), e13930. <https://doi.org/10.2196/13930>
- Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial intelligence trends in education: A narrative overview. *Procedia Computer Science*, 136, 16-24. <https://doi.org/10.1016/j.procs.2018.08.233>
- Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). Application and theory gaps during therise of artificial intelligence in education. *Computers & Education: Artificial Intelligence*, 1, 100002. <https://doi.org/10.1016/j.caeai.2020.100002>
- Chen, Y., Jensen, S., Albert, L. J., Gupta, S., & Lee, T. (2023). Artificial intelligence (AI) student assistants in the classroom: Designing chatbots to support student success. *Information Systems Frontiers*, 25(1), 161-182. <https://doi.org/10.1007/s10796-022-10291-4>



- Chiu, T. K. F., Meng, H., Chai, C. S., King, I., Wong, S., & Yeung, Y. (2022). Creation and evaluation of a pre-tertiary Artificial Intelligence (AI) curriculum. *IEEE Transactions on Education*, 65(1), 30-39. <https://doi.org/10.1109/TE.2021.3085878>
- Chiu, T. K. F., Moorhouse, B. L., Chai, C. S. & Ismailov, M. (2023a). Teacher support and student motivation to learn with Artificial Intelligence (AI) based chatbot. *Interactive Learning Environments*. Published online: 06 Feb 2023. <https://doi.org/10.1080/10494820.2023.2172044>
- Chiu, T. K. F., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023b). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, 4, 100118. <https://doi.org/10.1016/j.caeai.2022.100118>
- Choi, J. H., Hickman, K. E., Monahan, A., & Schwarcz, D. B. (2023). ChatGPT goes to law school. *Minnesota Legal Studies Research Paper*, 23(03). <https://doi.org/10.2139/ssrn.4335905>
- Ciechanowski, L., Przegalinska, A., Magnuski, M., & Gloor, P. (2019). In the shades of the uncanny valley: An experimental study of human–chatbot interaction. *Future Generation Computer Systems*, 92, 539-548. <https://doi.org/10.1016/j.future.2018.01.055>
- Clarizia, F., Colace, F., Lombardi, M., Pascale, F., & Santaniello, D. (2018). Chatbot: An education support system for student. *International symposium on cyberspace safety and security*. Springer. [https://doi.org/10.1007/978-3-030-01689-0\\_23](https://doi.org/10.1007/978-3-030-01689-0_23)
- Crompton, H., Burke, M., Gregory, K. H., & Johnson, L. (2019). An investigation of the effects of an AI math tutor on student anxiety. *Educational Technology Research and Development*, 67(2), 453-472.
- Cunningham-Nelson, S., Boles, W., Trouton, L., & Margerison, E. (2019). A review of chatbots in education: Practical steps forward. *30th annual conference for the Australasian association for engineering education (AAEE 2019): Educators becoming agents of change: Innovate, integrate*. Motivate: Engineers Australia.
- Durall, E., & Kapros, E. (2020). Co-design for a competency self-assessment chatbot and survey in science education. *International conference on human-computer interaction*. Springer. [https://doi.org/10.1007/978-3-030-50506-6\\_2](https://doi.org/10.1007/978-3-030-50506-6_2)
- Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., Duan, Y., Dwivedi, R., Edwards, J., Eirug, A., Galanos, V., Ilavarasan, P. V., Janssen, M., Jones, P., Kar, A.K., Kizgin, H., Kronemann, B., Lal, B., Lucini, B., ... Williams, M. D. (2021). Artificial intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 57, 101994. <https://doi.org/10.1016/j.ijinfomgt.2019.08.002>
- Eke, O. D. (2023). ChatGPT and the rise of generative AI: Threat to academic integrity? *Journal of Responsible Technology*, 13, 100060. <https://doi.org/10.1016/j.jrt.2023.100060>
- Fryer, L. K., Nakao, K., & Thompson, A. (2019). Chatbot learning partners: Connecting learning experiences, interest and competence. *Computers in Human Behavior*, 93, 279-289. <https://doi.org/10.1016/j.chb.2018.12.023>
- Giannakos, M. N., Sharma, K., Pappas, I. O., Kostakos, V., & Velloso, E. (2019). Multimodal data as a means to understand the learning experience. *International Journal of Information Management*, 48, 108-119. <https://doi.org/10.1016/j.ijinfomgt.2019.02.003>
- Goel, A. K., & Polepeddi, L. (2018). Jill Watson: A virtual teaching assistant for online education. In C. Dede, J. Richards, & B. Saxberg (Eds.), *Learning engineering for online education: Theoretical contexts and design-based examples* (pp. 120-143). Routledge. <https://doi.org/10.4324/9781351186193-7>
- Graesser, A. C. (2016). Conversations with auto tutor help students learn. *International Journal of Artificial Intelligence in Education*, 26(1), 124-132. <https://doi.org/10.1007/s40593-015-0086-4>
- Grosz, B. J. (2018). Smart enough to talk with us? Foundations and challenges for dialogue capable AI systems. *Computational Linguistics*, 44(1), 1-15. [https://doi.org/10.1162/COLI\\_a\\_00313](https://doi.org/10.1162/COLI_a_00313)
- Guilherme, A. (2019). AI and education: The importance of teacher and student relations. *AI & Society*, 34(1), 47-54. <https://doi.org/10.1007/s00146-017-0693-8>
- Gunawan, K. D. H., Liliarsari, L., Kaniawati, I., & Setiawan, W. (2021). Implementation of competency enhancement program for science teachers assisted by artificial intelligence in designing HOTS-based integrated science learning. *Jurnal Penelitian dan Pembelajaran IPA*, 7(1), 55-65. <https://doi.org/10.30870/jppi.v7i1.8655>

- Guttormsen, M., Bürger, A., Hansen, T. E., & Lietaer, N. (2011). The SiRi particle-telescope system. *Nuclear Instruments & Methods in Physics Research Section A*, 648(1), 168-173. <https://doi.org/10.1016/j.nima.2011.05.055>
- Halaweh, M. (2023). ChatGPT in education: Strategies for responsible implementation. *Contemporary Educational Technology*, 15(2), ep421. <https://doi.org/10.30935/cedtech/13036>
- Health, T. L. D. (2023). ChatGPT: Friend or foe? *The Lancet: Digital health*, 5(3), e102. [https://doi.org/10.1016/S2589-7500\(23\)00023-7](https://doi.org/10.1016/S2589-7500(23)00023-7)
- Hill, J., Ford, W. R., & Farreras, I. G. (2015). Real conversations with artificial intelligence: A comparison between human-human online conversations and human-chatbot conversations. *Computers in Human Behavior*, 49, 245-250. <https://doi.org/10.1016/j.chb.2015.02.026>
- Hirankerd, K., & Kittisunthonphisarn, N. (2020). E-learning management system based on reality technology with AI. *International Journal of Information and Education Technology*, 10(4), 259-264. <https://doi.org/10.18178/ijiet.2020.10.4.1373>
- Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Boston: Centre for Curriculum Redesign. [https://doi.org/10.1007/978-3-030-23207-8\\_20](https://doi.org/10.1007/978-3-030-23207-8_20)
- Holmes, W., Hui, Z., Miao, F., & Ronghuai, H. (2021). *AI and education: A guidance for policymakers*. UNESCO Publishing.
- Hopcan, S., Polat, E., Ozturk, M. E., & Ozturk, L. (2022). Artificial intelligence in special education: A systematic review. *Interactive Learning Environments*. Published online: 06 May 2022. <https://doi.org/10.1080/10494820.2022.2067186>
- 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*, 12(14), 5605. <https://doi.org/10.3390/su12145605>
- Hu, J. J. (2021). Teaching evaluation system by use of machine learning and artificial intelligence Methods. *International Journal of Emerging Technologies in Learning*, 16(5), 87-101. <https://doi.org/10.3991/ijet.v16i05.20299>
- Hussin, A. A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies*, 6(3), 92-98. <https://doi.org/10.7575/aiac.ijels.v.6n.3p.92>
- Hwang, G. J., & Chang, C. Y. (2021). A review of opportunities and challenges of chatbots in education. *Interactive Learning Environments*. Published online: 18 Jul 2021. <https://doi.org/10.1080/10494820.2021.1952615>
- Hwang, G. J., Xie, H., Wah, B. W., & Gasevic, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers & Education: Artificial Intelligence*, 1, 100001. <https://doi.org/10.1016/j.caeai.2020.100001>
- Ismail, M., & Ade-Ibijola, A. (2019). Lecturer's apprentice: A chatbot for assisting novice programmers. In *2019 international multidisciplinary information technology and engineering conference (IMITEC)* (pp. 1-8). IEEE. <https://doi.org/10.1109/IMITEC45504.2019.9015857>
- Jain, M., Kumar, P., Bhansali, I., Liao, Q., Truong, K., & Patel, S. (2018). FarmChat: A conversational agent to answer farmer queries. *Proceedings of ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 2(4), 1-22. <https://doi.org/10.1145/3287048>
- Jaiswal, A., & Arun, C. J. (2021). Potential of artificial intelligence for transformation of the education system in India. *International Journal of Education and Development Using Information and Communication Technology*, 17(1), 142-158.
- Jia, J., Zhang, D., & Gao, F. (2021). Learning analytics and artificial intelligence in mathematics education: A systematic review. *International Journal of Educational Research*, 107, 101831.
- Jobin, A., Ienca, M., & Vayena, E. (2019). The global landscape of AI ethics guidelines. *Nature Machine Intelligence*, 1(9), 389-399. <https://doi.org/10.1038/s42256-019-0088-2>
- Karsenti, T. (2019). Artificial intelligence in education: The urgent need to prepare teachers for tomorrow's schools. *Formation et Profession*, 27(1), 112-116. <https://doi.org/10.18162/fp.2019.a166>
- Khan, I., Ahmad, A. R., Jabeur, N., & Mahdi, M. N. (2021). An artificial intelligence approach to monitor student performance and devise preventive measures. *Smart Learning Environments*, 8(1), 1-18. <https://doi.org/10.1186/s40561-021-00161-y>

- Kim, H. S., Kim, N. Y., & Cha, Y. (2021). Is it beneficial to use AI chatbots to improve learners' speaking performance? *Journal of ASIA TEFL*, 18(1), 161-178. <https://doi.org/10.18823/asiatefl.2021.18.1.10.161>
- Koedinger, K. R., Corbett, A. T., & Perfetti, C. (2012). The Knowledge-Learning-Instruction (KLI) framework: Bridging the science-practice chasm to enhance robust student learning. *Cognitive Science*, 36(5), 757-798. <https://doi.org/10.1111/j.1551-6709.2012.01245.x>
- Kurzweil, R. (1990). *The age of intelligent machines*. MIT Press.
- Lin, M. P.-C., & Chang, D. (2020). Enhancing post-secondary writers' writing skills with a chatbot. *Journal of Educational Technology & Society*, 23(1), 78-92.
- Llorente, A. M., Ladera, V., Contreras, P., & Conde, L. (2021). Efficacy of a computerized intervention based on artificial intelligence for improving reading comprehension in students with dyslexia. *Frontiers in Psychology*, 12, 641005.
- Lu, Y. (2019) Artificial intelligence: a survey on evolution, models, applications and future trends. *Journal of Management Analytics*, 6(1), 1-29. <https://doi.org/10.1080/23270012.2019.1570365>
- Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*. <http://discovery.ucl.ac.uk/1475756/>
- Mata, J., de Miguel, I., Duran, R. J., Merayo, N., Singh, S. K., Jukan, A., & Chamania, M. (2018). Artificial intelligence (AI) methods in optical networks: A comprehensive survey. *Optical Switching and Networking*, 28, 43-57. <https://doi.org/10.1016/j.osn.2017.12.006>
- McCallum, S. (2023, April 1). ChatGPT Banned in Italy over Privacy Concerns. *BBC*. <https://www.bbc.com/news/technology-65139406>
- McCarthy, J., Minsky, M. L., Rochester, N., & Shannon, C. E. (1955). A proposal for the Dartmouth summer research project on artificial intelligence. *AI Magazine*, 27(4), 12-14.
- Melián-González, S., Gutiérrez-Taño, D., & Bulchand-Gidumal, J. (2021). Predicting the intentions to use chatbots for travel and tourism. *Current Issues in Tourism*, 24(2), 192-210. <https://doi.org/10.1080/13683500.2019.1706457>
- Mertala, P., Fagerlund, J., & Calderon, O. (2022). Finnish 5th and 6th grade students' pre-instructional conceptions of artificial intelligence (AI) and their implications for AI literacy education. *Computers and Education: Artificial Intelligence*, 3, 100095. <https://doi.org/10.1016/j.caeai.2022.100095>
- Mondal, B. (2020). Artificial intelligence: State of the art. *Recent Trends and Advances in Artificial Intelligence and Internet of Things*, 389-425. [https://doi.org/10.1007/978-3-030-32644-9\\_32](https://doi.org/10.1007/978-3-030-32644-9_32)
- Nirala, K. K., Singh, N. K., & Purani, V. S. (2022). A survey on providing customer and public administration-based services using AI: Chatbot. *Multimedia Tools and Applications*, 1-32. <https://doi.org/10.1007/s11042-021-11458-y>
- Okonkwo, C. W., & Ade-Ibijola, A. (2020). Python-bot: A chatbot for teaching python programming. *Engineering Letters*, 29(1), 25-35.
- OpenAI. (2023, March). *GPT-4 Developer Livestream* [Video]. YouTube. <https://www.youtube.com/watch?v=outcGtbnMuQ>
- Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers & Education: Artificial Intelligence*, 2, 100020. <https://doi.org/10.1016/j.caeai.2021.100020>
- Porter, B., & Grippa, F. (2020). A platform for AI-enabled real-time feedback to promote digital collaboration. *Sustainability*, 12(24), 1-13. <https://doi.org/10.3390/su122410243>
- Rahman, A., Al Mamun, A., & Islam, A. (2017). Programming challenges of chatbot: Current and future prospective. In *2017 IEEE region 10 humanitarian technology conference (R10-HTC)* (pp. 75-78). IEEE. <https://doi.org/10.1109/R10-HTC.2017.8288910>
- Ramesh, V., & Lakshmi, R. (2018). Use of artificial intelligence in learning management system for adaptive assessment. *International Journal of Innovative Technology and Exploring Engineering*, 7(7S), 240-243. <https://doi.org/10.35940/ijitee.K7373.0787518>
- Rapp, A., Curti, L., & Boldi, A. (2021). The human side of human-chatbot interaction: A systematic literature review of ten years of research on text-based chatbots. *International Journal of Human-Computer Studies*, 151, 102630. <https://doi.org/10.1016/j.ijhcs.2021.102630>

- Reis, A., Paulino, D., Paredes, H., Barroso, I., Monteiro, M. J., Rodrigues, V., & Barroso, J. (2018). Using intelligent personal assistants to assist the elderly: an evaluation of Amazon Alexa, Google Assistant, Microsoft Cortana, and Apple Siri. In *2018 2nd international conference on technology and innovation in sports, health and wellbeing (TISHW)* (pp. 1-5). IEEE. <https://doi.org/10.1109/TISHW.2018.8559503>
- Rooein, D. (2019). Data-driven edu chatbots. In *companion proceedings of the 2019 world wide web conference* (pp. 46-49). <https://doi.org/10.1145/3308560.3314191>
- Rospigliosi, P. A. (2023). Artificial intelligence in teaching and learning: what questions should we ask of ChatGPT? *Interactive Learning Environments*, 31(1), 1-3. <https://doi.org/10.1080/10494820.2023.2180191>
- Ruan, S., Willis, A., Xu, Q., Davis, G. M., Jiang, L., Brunskill, E., & Landay, J. A. (2019). Bookbuddy: Turning digital materials into interactive foreign language lessons through a voice chatbot. In *Proceedings of the sixth (2019) ACM conference on learning@ scale* (pp. 1-4). <https://doi.org/10.1145/3330430.3333643>
- Saha, S., & Al Amri, S. (2019). A review of artificial intelligence applications in learning management systems. *International Journal of Emerging Technologies in Learning*, 14(1), 162-176.
- Selwyn, N. (2016). *Is technology good for education?* Malden, Polity Press.
- Stallbaumer, C. (2023, March 16). *Introducing Microsoft 365 Copilot – A Whole New Way to Work*. Microsoft 365. <https://www.microsoft.com/en-us/microsoft-365/blog/2023/03/16/introducing-microsoft-365-copilot-a-whole-new-way-to-work/>
- Terwiesch, C. (2023). *Would chat GPT3 get a Wharton MBA? A prediction based on its performance in the operations management course*. Mack Institute for Innovation Management at the Wharton School, University of Pennsylvania. <https://mackinstitute.wharton.upenn.edu/wp-content/uploads/2023/01/Christian-Terwiesch-Chat-GTP-1.24.pdf>
- UNESCO. (2021). *Artificial intelligence in education: Opportunities, challenges and risks*. UNESCO.
- Vallance, C. (2023, March 31). Elon Musk among experts urging a halt to AI training. *BBC*. <https://www.bbc.com/news/technology-65110030>
- Vazquez-Cano, E., Mengual-Andres, S., & Lopez-Meneses, E. (2021). Chatbot to improve learning punctuation in Spanish and to enhance open and flexible learning environments. *International Journal of Educational Technology in Higher Education*, 18(1), 33. <https://doi.org/10.1186/s41239-021-00269-8>
- Villegas-Ch, W., Sánchez-Viteri, S., & Roman-Cañizares, M. (2021). Academic activities recommendation system for sustainable education in the age of COVID-19. *Informatics*, 8(2), 29. <http://dx.doi.org/10.3390/informatics8020029>
- Vincent-Lancrin, S., & Van Der Vlies, R. (2020). Trustworthy artificial intelligence (AI) in education: Promises and challenges. *OECD Education Working Papers*, 218. OECD Publishing, Paris, <https://doi.org/10.1787/a6c90fa9-en>
- Weizenbaum, J. (1966). ELIZA—a computer program for the study of natural language communication between man and machine. *Communications of the ACM*, 9(1), 36-45. <https://doi.org/10.1145/365153.365168>
- Westera, W., Prada, R., Mascarenhas, S., Santos, P. A., Dias, J., Guimaraes, M., Georgiadis, K., Nyamsuren, E., Bahreini, K., Yumak, Z., Christyowidiasmoro, C., Dascalu, M., Gutu-Robu, G., & Ruseti, S. (2020). Artificial intelligence moving serious gaming: Presenting reusable game AI components. *Education and Information Technologies*, 25(1), 351-380. <https://doi.org/10.1007/s10639-019-09968-2>
- Williamson, B., & Eynon, R. (2020). Historical threads, missing links, and future directions in AI in education. *Learning, Media and Technology*, 45(3), 223-235. <https://doi.org/10.1080/17439884.2020.1798995>
- Winkler, R., & Söllner, M. (2018). Unleashing the potential of chatbots in education: A state-of-the-art analysis. In *Academy of management annual meeting (AOM)*. <https://doi.org/10.5465/AMBPP.2018.15903abstract>
- Wodecki, B. (2023, February 24). China cracks down on ChatGPT access. *AI Business*. <https://aibusiness.com/nlp/china-cracks-down-on-chatgpt-access>
- Xia, Q., Chiu, T. K. F., Lee, M., Temitayo I., Dai, Y., & Chai, C. S. (2022). A self-determination theory design approach for inclusive and diverse artificial intelligence (AI) K-12 education. *Computers & Education*, 189, 104582. <https://doi.org/10.1016/j.compedu.2022.104582>
- Ye, H. (2021, June). A review on the application of virtual reality technology in ideological and political teaching. In *2021 2nd International Conference on Artificial Intelligence and Education (ICAIE)* (pp. 712-715). IEEE. <https://doi.org/10.1109/ICAIE53562.2021.00156>

- Yin, J., Goh, T. T., Yang, B., & Xiaobin, Y. (2021). Conversation technology with micro-learning: The impact of chatbot-based learning on students' learning motivation and performance. *Journal of Educational Computing Research*, 59(1), 154-177. <https://doi.org/10.1177/0735633120952067>
- Zhang, T. (2023). The contributions of AI in the development of ideological and political perspectives in education, *HELIYON*, 9(3), E13403. <https://doi.org/10.1016/j.heliyon.2023.e13403>
- Zhang, Y., Wei, J., Chen, J., Wang, Y., & Zhang, Y. (2020). The application of artificial intelligence in the education of children with autism spectrum disorder: A review. *Frontiers in Psychology*, 11, 1338.
- Zheng, L., Niu, J., Zhong, L., & Gyasi, J. F. (2021). The effectiveness of artificial intelligence on learning achievement and learning perception: A meta-analysis. *Interactive Learning Environments*. Published online: 19 Dec 2021. <https://doi.org/10.1080/10494820.2021.2015693>

