DIGITAL EDUCATION: ARTIFICIAL INTELLIGENCE AND NEW FRONTIERS FOR LEARNING

EDUCAZIONE DIGITALE: INTELLIGENZA ARTIFICIALE E NUOVE FRONTIERE PER L'APPRENDIMENTO

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ABSTRACT
Artificial intelligence (AI) has revolutionised education by offering personalised learning experiences, virtual tutors and realistic simulations. These innovations improve teaching effectiveness and student engagement. However, the integration of AI in education raises ethical challenges that need to be carefully managed. This study evaluates the advantages and disadvantages of AI in education, examining how it can support educators and students, and proposes reflections for responsible use.

L'intelligenza artificiale (IA) ha rivoluzionato l'educazione offrendo esperienze di apprendimento personalizzate, tutor virtuali e simulazioni realistiche. Queste innovazioni migliorano l'efficacia dell'insegnamento e il coinvolgimento degli studenti. Tuttavia, l'integrazione dell'IA nell'istruzione solleva sfide etiche che devono essere attentamente gestite. Questo studio valuta i vantaggi e gli svantaggi dell'IA nell'istruzione, esaminando come possa supportare educatori e studenti, e propone delle riflessioni per un uso responsabile.

KEYWORDS
Education, Teaching, Innovative Technologies
Educazione, Insegnamento, Tecnologie Innovative

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Introduction

Data provide human beings with a means to explore and understand their own nature. Gathered from a variety of sources, such as behaviour, social interactions, thoughts, emotions and physiological events, data provide a broader and deeper insight into the human experience. Data generated from human activities can include digital interactions, such as social media activities and online transactions, as well as biometric signals from wearable devices, and conversations, texts and multimedia content that provide valuable information about people's emotions, interests and preferences. By processing and interpreting this data, it is possible to extract the meanings and information we attribute to the human experience in order to become more aware of oneself and one's environment, and to better understand individual and collective behaviour. Data on human experience are routinely acquired through traditional methods that include: structured questionnaires and surveys that collect data on people's perceptions, opinions and experiences; in-depth interviews provide detailed qualitative data on people's experiences and feelings; focus groups that bring together groups of people to discuss specific issues related to human experience; direct observation of people's interaction with their environment provides contextual data on human experience; language used in conversations or written texts to extract meanings and interpretations of experience; monitoring of heart rate, blood pressure and other physiological signals can provide objective data on people's physical reactions to their experiences. Although these traditional methods provide valuable information, they may be limited in their ability to handle large amounts of complex data. To address this challenge, researchers from different disciplines are developing advanced methods based on artificial intelligence.

Artificial intelligence (AI) is a field of study in computer science that has made great progress in recent decades, thanks to the increased availability of data and advanced computing power (Liu et al., 2018). AI focuses on creating systems capable of performing tasks that require human intelligence but exceed the capabilities of the human mind alone. These tasks may include analysing large amounts of data to identify hidden patterns, learning and continuously improving from previous experiences, solving complex problems in a short time, and managing tasks that require precision and constant attention. AI offers the possibility of automating complex processes and making informed decisions based on advanced data and algorithms. With these capabilities, AI can be used to solve problems that would otherwise be out of reach for humans, thus improving the

efficiency and quality of solutions. Furthermore, AI can collaborate with humans, enhancing their capabilities and providing new perspectives in various fields.

In the current educational landscape, AI has taken an increasingly central role in recent years, revolutionising the way students and teachers learn and teach. Indeed, through advanced data analysis and machine learning capabilities, AI offers new perspectives to personalise instruction and maximise learning effectiveness. It enables the creation of individualised learning paths for each student, tailoring content to their specific needs, abilities and interests. AI-based technologies enable the creation and use of virtual tutors who can support students in real time, answering questions and offering additional explanations when needed. AI also enables the analysis of student progress data, identifying areas of difficulty and offering timely interventions to improve results. Teaching can be supported by the use of AI through the creation of realistic simulations allowing students to immerse themselves in learning environments that foster a deeper understanding of concepts and practical applications. In this way, AI contributes to improving the overall educational experience and creating a more efficient and engaging learning environment.
However, the introduction of AI in education has brought with it a number of challenges and drawbacks that require attention and appropriate solutions (Reiss, 2021). Firstly, the use of students' personal data raises ethical and privacy issues. It is crucial to ensure that the information collected is used responsibly and securely, respecting students' confidentiality and ensuring the protection of sensitive data. Another disadvantage is the potential dependence on technology. Excessive use of AI could limit human interaction and social learning, two fundamental aspects of traditional education. Students may lose the ability to communicate effectively or develop essential social skills due to the lack of direct contact with teachers and classmates. Unequal access to advanced technologies is another significant challenge. Finally, not all students have equal access to AI-based tools, which may increase educational inequalities between different communities and socioeconomic groups. To address these disadvantages, a balanced and responsible approach to integrating AI in education is needed, ensuring that technology is used to support education without replacing the human element.

This study aims to assess the current and potential role of AI in education, examining both advantages and disadvantages. The main objective is to understand how AI can enhance student learning and support educators in their work, identifying the challenges and risks associated with its use. Through an in-

depth analysis of the state of the art and a critical exploration of emerging issues, the study will provide a comprehensive overview of the impact of AI on education. Finally, it will suggest guidelines for the responsible and effective use of this technology in the educational context, ensuring that AI can contribute positively to students' learning experience and teachers' work.

1. Fundamentals and advances in Artificial Intelligence

The rapid technological expansion that characterised the beginning of the 21st century has given humans the opportunity to collect and store a considerable amount of data from a variety of sources, including digital devices, sensors, social media, economic transactions and monitoring systems. These sources offer detailed and diverse information on various aspects of life, such as consumption habits, social interactions and behaviour. The availability of this vast amount of data can often lead to information overload, a situation in which humans are faced with more data than they can process effectively. When the volume of available data exceeds an individual's cognitive capacity, it can be difficult to distinguish relevant from non-essential information. To address this problem, AI intervenes as an essential tool in the management of large amounts of data. Through the use of advanced algorithms, AI can filter, analyse and synthesise data quickly and efficiently. This technology allows useful information to be extracted and patterns and correlations to be identified, facilitating decision-making and improving the overall understanding of the data.

The term 'artificial intelligence' was first introduced in 1956 during a conference held at Dartmouth College in New Hampshire, USA (de Freitas et al., 2022). It was at this event that the term 'Artificial Intelligence' was first used and during the conference, the potential of creating machines capable of emulating human intelligence and solving complex problems was discussed. But as early as 1950, the British mathematician Alan Turing, in his article entitled 'Computing Machinery and Intelligence', theorised the idea of a machine capable of exhibiting human-like thinking capabilities (Turing, 2009). Tuning posed the question "can a machine think?" and to address this question, he proposed the famous 'Turing Test', which compares artificial intelligence and human intelligence by means of a textual conversation. If a human interviewer cannot distinguish between the answers of a machine and another human, the machine can be considered intelligent. This idea paved the way for further developments in the field of AI and continues to be a key benchmark for assessing the ability of machines to mimic

human behaviour, although it also raises important ethical issues that have yet to be fully resolved. The implementation of intelligent systems arises from a broad spectrum of disciplines that provide AI with the theoretical and methodological foundations necessary for the development of such systems. These disciplines include mathematics, engineering, computer science, philosophy, linguistics and cognitive science. Through the synergy between these different areas of study, AI is able to integrate advanced mathematical models, engineering design techniques and computer algorithms to create systems that can learn, reason and interact autonomously. Philosophy helps to delineate the ethical and ontological issues related to AI, while linguistics and cognitive sciences provide the basis for processing and understanding natural language and human interactions. This interdisciplinary collaboration has allowed AI to develop rapidly over time and to find applications in various fields, from medicine to business, from cybersecurity to entertainment and education, bringing innovative solutions and revolutionising the way we live, work and learn.

Several AI-based approaches have been developed to tackle a wide range of complex problems, among them machine learning (ML), deep learning (DL), artificial neural networks (ANN), sensory input (SI) and natural language processing (NNP) (for an overview of evolution of AI, ML, ANN and DL see Fig.1 Fig. 1).

Machine Learning (ML) (Mahesh, 2019) is a branch of artificial intelligence that focuses on creating algorithms and models that can learn from data and improve their performance over time without being programmed. This approach allows systems to extract patterns, make predictions and make decisions based on the data at hand. ML relies on a variety of algorithms to solve data problems and derive insights from them. These algorithms can be divided into different categories depending on the type of learning they use, which can be: supervised learning (algorithms are trained on labelled data, i.e. each instance of data is associated with a correct answer. Algorithms learn the relationship between the input data and the corresponding labels, allowing them to make predictions or classifications on new data); unsupervised learning (they work with unlabelled data and try to detect hidden patterns or structures in the data. These algorithms are useful for clustering (groups of similar data) and dimensionality reduction. An example is principal component analysis (PCA) (Greenacre et al., 2022)); reinforcement learning (focuses on how software agents, such as robots, control programmes or management systems, should act in a given environment to maximise a cumulative reward over time. In this type of learning, an agent interacts with a dynamic environment, making decisions about which action to

perform based on the current state of the environment); deep learning (DL) (Lecun et al., 2015) which uses models inspired by the structure and functioning of the human brain to solve complex problems. While ML trains AI to recognise patterns in data, DL allows models to emulate the human mind through the use of artificial neural networks with multiple layers, each of which processes data in an increasingly sophisticated way. Each layer takes the output of the previous layer as input and transforms it into new information as the network becomes deeper. This hierarchical learning process enables the models to identify complex features and patterns in the data, improving the ability to interpret and classify information.

Artificial Neural Networks (ANNs) (Krenker et al., 2011; Suzuki, 2011) are computational models inspired by the structure and functioning of the human brain. These models consist of nodes, called artificial neurons, connected to each other via artificial synapses. The nodes are organised into layers: an input layer, one or more hidden layers and an output layer. Artificial neural networks are designed to learn from input data and develop the ability to recognise patterns and make predictions. This learning occurs through a training process, in which the network is exposed to large amounts of data and adjusts the weights of connections between neurons to minimise errors between predicted and actual results. Neural networks can have different architectures, including feedforward neural networks, in which data move in a linear direction, and recurrent neural networks, which allow feedback loops between nodes to store and utilise past information.

AI exploits sensory input (Riedl, 2019) to understand and interact with the world around them. Sensory input refers to data collected by sensors that mimic human senses, such as sight, hearing, touch, taste and smell. These sensors can be integrated into various devices or machines and allow AI systems to acquire information from their environment.

Natural language processing (NLP) is a branch of artificial intelligence that combines computational linguistics, statistical models and machine learning to enable computers to recognise, understand and generate text and speech (Jain et al., 2018). This field has a wide range of practical applications that enrich users' experience with technology. NLP techniques underpin many digital solutions used on a daily basis, for example: translation software (tools such as Google Translate use NLP to translate texts into different languages, facilitating communication and access to global information); chatbots (Adamopoulou & Moussiades, 2020) (automated conversational systems that use NLP to answer users' questions and provide assistance in various fields, such as commerce, healthcare, customer

service and education) search engines (help to interpret user queries, providing relevant results and optimising the search experience); grammar correction software (tools such as Grammarly that detect grammatical and style errors in texts, helping users to write more accurately); voice assistants (systems such as siri or alexa use NLP to interpret voice commands and respond appropriately to user queries). NLP continues to evolve and improve, opening up new possibilities for more natural and intuitive interactions between humans and technology.
All these approaches find use in education, supporting learning and teaching processes. Thanks to AI, it is possible to offer more personalised and engaging education that takes into account students' individual needs and learning styles, promoting a more effective and rewarding educational experience as we will see in the next section.

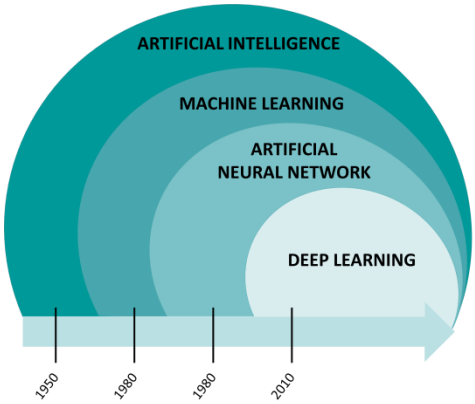

Fig. 1 Evolution of artificial intelligence, machine learning, artificial neural networks and deep learning.

2. Artificial intelligence in education

How is AI transforming the educational experience? We will try to answer this question in this section, attempting to provide a comprehensive overview of the opportunities and challenges related to the use of AI in education. AI is a rapidly evolving technology that is revolutionising educational tools and institutions, responding to the need for change and modernisation that characterises the 21st century. The introduction of the competence-based curriculum (Muñoz & Araya, 2017) has highlighted the importance of developing broader and transversal

learning skills and competences, such as metacognition, critical thinking and the ability to work in teams. These skills are essential to prepare students for a changing world of work and increasingly complex challenges. Consequently, today's educational environments are transforming to incorporate authentic learning practices, problem solving and cooperative learning. These pedagogical approaches encourage students to engage in meaningful activities and work on big problems in group settings, stimulating the development of complex skills and promoting a deeper understanding of content. To maintain its relevance and increase its impact, educational contexts, such as the education sector, must adapt to these changes by integrating innovative technologies and methods.

The perception of knowledge must change, knowledge must not be understood as a set of information that one possesses, but rather as a continuous process of acquiring, applying and creating new knowledge. This change in perspective highlights the importance of developing in the younger generation the ability to learn independently and to apply their knowledge in practical contexts. Schools need to rethink their curricula by fostering the practical application of knowledge, collaboration and self-regulated learning skills. Although the school system retains its traditional foundations, the approach to teaching and learning is evolving to embrace a broader and more integrated vision that goes far beyond the classroom. This new paradigm extends to informal and workplace learning, valuing the acquisition of skills in different contexts and encouraging lifelong learning. This approach fosters a growth mindset and encourages people to engage in constant self-improvement and contributes to the emergence of the ability to positively adapt to the challenges of the future. The evolution of the teacher's role in the classroom is one of the most significant transformations in contemporary education. Traditionally regarded as the main source of knowledge, in charge of transmitting information to students, today, the teacher facilitates the learning process. The teacher's role is to help students navigate through a vast sea of available information, teaching them to search, evaluate and integrate data from various sources. Teachers must promote students' independence, encouraging critical thinking and the ability to work collaboratively. This new role requires teachers to develop different skills, such as the ability to customise instruction to fit the specific needs of each student and to create inclusive and stimulating learning environments. Moreover, teachers must become facilitators of the learning process, guiding students towards autonomous discovery and problem-solving. With this in mind, great attention is paid to supporting learning at any time and in any place, fostering greater flexibility in educational pathways.

This openness allows individuals to acquire new knowledge and skills according to their needs and pace of life.

Within this framework, we see the importance of using AI-based tools to support these processes of change and adaptation, offering new opportunities to personalise learning, improve interaction between teachers and students, and provide teaching resources tailored to students' cognitive and learning needs and styles. Initially, AI was introduced into academia mainly through the use of computers and information technology that supported a range of administrative and teaching activities. Continuing innovations in technology later contributed to the transition from personal computers to embedded systems (Zhang & Li, 2023) and online platforms. Hwang et al. highlighted the versatility of AI in education and its potential to transform the way students learn and educators teach, identifying four main roles of AI in education: intelligent tutor, tutee, learning tool/partner and policy-making advisor (Hwang et al., 2020). Personalised learning and the implementation of intelligent learning systems are the most promising applications of AI in education, especially in recent years (Kokku et al., 2018). Personalised learning is about adapting learning paths to the needs, interests and pace of each student. The aim is to create a tailor-made educational experience that takes into account individual differences among students, promoting their motivation and involvement in learning. Personalised learning closely aligns with the concept of learner-centred learning (Reigeluth et al., 2016), an educational approach focused on learners and their specific needs. This approach emphasises the development of students' autonomous learning skills and capabilities, encouraging them to become protagonists of their own educational journey. AI plays a key role in the implementation of personalised learning systems due to its ability to analyse large amounts of data and identify patterns and trends. By analysing data on student performance, learning preferences and behaviour, AI can provide customised recommendations for the most suitable content and educational activities for each individual. Through the use of AI-based personalised learning tools, teachers can monitor students' progress in real time and intervene when necessary to provide additional support or adapt teaching strategies. This approach promotes more effective and inclusive education that takes into account students' different learning modes and helps them reach their full potential. In addition, personalised learning systems can provide timely and targeted feedback to students, helping them to identify areas for improvement (Xu et al., 2023).

This constant feedback can strengthen students' motivation and provide them with clear guidance on how to continue to progress. Finally, by engaging students in a more active and focused learning experience, personalised learning approaches can foster greater autonomy and responsibility in the learning process, contributing to the improvement of their academic performance (Zlatarov et al., 2021). Personalised learning emphasises the importance of creating a learning environment that is tailored to the individual needs of each student, a space referred to as an intelligent learning environment (Herder et al., 2017). This environment should be designed to support and foster learning, taking into account factors such as the physical layout of the space, the technology available, the level of support and interaction with teachers, and the quality of teaching resources. A personalised learning environment should offer different options for students, allowing them to choose how and where to study according to their preferences and learning style that helps them achieve the best results (Cheung et al., 2021). For example, it can include collaborative learning spaces for students by fostering interaction with peers and promoting cooperative learning. Another key example of how AI can help provide a personalised and effective learning experience is the introduction of intelligent tutoring systems into the school environment (ITS). AI-based digital assistants can support students in real time, answering questions and offering additional explanations when needed. This personalised help can complement the work of teachers and enhance student learning. ITSs provide this experience mainly in four ways (Seldon & Abidoye, 2018): monitoring of student input (ITS can track and analyse students' responses and behaviour during learning, which allows identification of areas of strength and weakness, enabling teachers to intervene early or modify the learning pathway); delivery of appropriate tasks suited to the level and needs of each student; provision of effective feedback; application of interfaces for human-computer communication (this includes the use of chatbots (Adamopoulou & Moussiades, 2020), voice assistants and other technologies to facilitate communication and make learning more interactive). AI can create immersive and realistic learning environments (Hamilton et al., 2021), fostering a deeper understanding of concepts and practical applications. These tools can make learning more engaging and meaningful for students. Immersive learning provides students with immersive and customisable learning experiences through advanced technologies such as extended or virtual reality (Curcio et al., 2016), 3D graphics and wearable devices, which enhance the learning process in a number of ways, including: arousing positive emotions in students, such as enthusiasm and creativity. Indeed, immersive experiences encourage students to create and

modify learning environments, fostering their creativity and problem solving skills. This emotional involvement can result in greater interest in the material and higher motivation to study. Immersive environments can make complex concepts more accessible, helping students overcome difficulties and feel less intimidated by the complexity of learning content. These environments allow students to interact with each other and with the learning content in a natural way, using gestures, facial expressions and non-verbal communication (Dzardanova et al., 2024). Furthermore, AI plays a crucial role in the integration of gamification in schools, offering new opportunities to enhance learning and motivate students, creating a more effective and engaging learning experience and promoting digital literacy (Koravuna & Surepally, 2020).

Although the use of AI in education offers numerous advantages, it is necessary to reflect on some issues and challenges that may arise from the implementation of these technologies in school contexts.

3. Artificial intelligence in education: ethical issues

Although it is clear how AI can contribute to radical change in education, there are several challenges and complex issues surrounding the adoption and use of these technologies in schools that need to be explored.

First of all, associating the concept of 'intelligence' with a machine is a complex and debated issue that raises philosophical, ethical and technical questions (Turing, 2009). Traditionally, intelligence is a human mental process that includes activities such as reasoning, awareness and self-awareness. AI-based digital technologies can simulate some aspects of human thinking, such as data analysis and problem solving. However, there is still debate about the ability of machines to think in the human sense of the term. Machines can follow algorithms and specific instructions to process information and generate responses, but they are not able to think for themselves or have awareness or intentions of their own. Their ability to learn and process data may seem similar to human thinking, but it is more a simulation of cognitive processes. Some branches of AI, such as machine learning and neural networks, allow machines to learn from past data and experiences to improve their future performance. This machine learning capability is a simulation of human cognitive capabilities. Another consideration concerns the impact of AI on the understanding of human thinking. The evolution of intelligent machines may lead to a redefinition of what it means to think and to a greater understanding of human cognitive capabilities. The question "can AI-

based technologies be intelligent?" depends on the definition of intelligence and the comparison between human cognitive processes and machine capabilities, which is still a hotly debated topic. Thus, although machines can simulate some aspects of human thinking and perform complex tasks, it is still unclear whether they can think the way humans do.

What are the ethical issues to be addressed when it comes to AI in education? UNESCO (2019) focused on the essential practices to ensure effective, equitable and ethical use of AI in education and in this regard identified six key challenges to ensure sustainable development of AI in education: comprehensive public policies, inclusion and equity of AI in education, teacher training, preparing AI to understand education, developing quality and inclusive data systems, making AI research in education meaningful, and ensuring ethics and transparency in data collection, use and dissemination. The introduction of AI in education raises several reflections from different perspectives, e.g. from an individual perspective. Indeed, access to AI technologies may be limited for some students due to economic, social or geographical factors. This digital divide may lead to greater inequality in learning, as students with fewer resources do not benefit from the same opportunities for personalised learning and advanced technologies as students who benefit from resources (Reiss, 2021). AI can offer opportunities for personalised learning, but it is important to ensure that these technologies do not amplify existing inequalities or perpetuate implicit biases. Therefore, these technologies should also take cultural and social differences into account. Vygotsky argues that education is a socio-cultural phenomenon (Daneshfar & Moharami, 2018), therefore, technology cannot fail to take these aspects into account. Developers and educators must continuously monitor and evaluate AI systems to ensure that they are fair and accessible to all students, regardless of their socio-economic or demographic background. It is crucial to ensure that the adoption of these AI-based technologies is done in a responsible, sustainable manner that respects the rights of all. AI technologies can collect and analyse sensitive student data, such as their academic progress, learning preferences and interactions with learning materials. It is crucial to ensure that this data is collected and used in a way that respects students' privacy, with the informed consent of all parties involved. Transparency in the use of AI technologies is essential to build trust between students, teachers and parents. This includes explaining how AI works, what data is collected and how it is used. Understanding these processes can help mitigate fears and concerns about AI in education. Therefore, training teachers and students on the conscious use of these technologies in education could mitigate the risks associated with AI and

maximise the educational benefits for all. This training should include the importance of transparency, privacy and equity in the use of AI technologies. Although AI can support teachers and enhance the learning experience, it is important to maintain human involvement in educational decisions. Teachers must remain responsible for the content and method of teaching, using AI as a complementary tool rather than a substitute. Some researchers are also focusing on the role of teachers following the advent of AI in education (Alam, 2021). AI can support teachers and improve instruction in a variety of ways, for instance by analysing data to personalise learning or by offering automated assessment tools. However, AI is most effective when used to support teachers' work rather than as a substitute. Teaching involves an essential human component, such as building relationships with students, understanding their emotional and social needs and being able to motivate and guide them. AI may not be able to fully replicate these human qualities. Teachers can offer personalised support to students in a dynamic way, taking into account their individual challenges and adapting teaching strategies according to their specific needs. AI can help facilitate this process, but it cannot replace the experience and sensitivity of a human teacher. Teachers provide more than just information; they act as mentors, guides and role models for students. This human relationship is fundamental to student development and may be difficult to replace with AI. Entrusting education completely to AI raises ethical concerns, such as accountability for student learning and transparency in educational decisions. Teachers must remain accountable for the educational process. Ultimately, while AI can offer significant benefits in education and can help optimise the learning experience, the role of teachers remains irreplaceable. AI should be seen as a tool to help teachers be more effective and to improve student learning, rather than as a substitute for teachers. A collaboration between AI and teachers could lead to optimal results for students and the education system as a whole. Schools and education systems should develop clear guidelines and policies on the ethical use of AI (Borenstein & Howard, 2021; Slade & Prinsloo, 2013). Ethical guidelines for the use of AI in education must be specific to the educational context. This may include recommendations for collecting and managing student data, creating transparent and accountable AI systems, and adopting strategies to identify and mitigate algorithmic bias. Addressing these challenges requires collaboration between AI technology developers, educators, legislators and educational communities to ensure that AI is used safely and ethically in education. This tailored approach will help maximise the benefits of AI for students and teachers, while protecting their rights and privacy.

Conclusions

AI in education offers countless benefits such as personalised learning experiences, virtual tutors and realistic simulations. These innovations can greatly improve teaching effectiveness and student engagement, contributing to deeper and more meaningful learning. However, the adoption of AI in education must be accompanied by a careful handling of ethical challenges and societal implications. It is crucial to address issues such as student privacy, transparency of algorithms, and the need to avoid bias in AI systems. Furthermore, it is important to maintain equity and accessibility for all students, ensuring that no one is excluded from using advanced technologies. To make the most of the benefits of AI in education, it is essential to develop guidelines for responsible use. These guidelines should include ethical practices for the collection and use of student data, measures to prevent algorithmic discrimination and bias, and strategies to ensure that educators are adequately trained in the use of new technologies. In conclusion, while AI offers significant opportunities to improve education, a balanced and responsible approach is essential. With careful management, AI can support educators and students, promoting a more inclusive, equitable and challenging learning environment.

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