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Generative artificial intelligence empowers educational reform: current status, issues, and prospects

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The emergence of Chat GPT has once again sparked a wave of information revolution in generative artificial intelligence. This article provides a detailed overview of the development and technical support of generative artificial intelligence. It conducts an in-depth analysis of the current application of generative artificial intelligence in the field of education, and identifies problems in four aspects: opacity and unexplainability, data privacy and security, personalization and fairness, and effectiveness and reliability. Corresponding solutions are proposed, such as developing explainable and fair algorithms, upgrading encryption technology, and formulating relevant laws and regulations to protect data, as well as improving the quality and quantity of datasets. The article also looks ahead to the future development trends of generative artificial intelligence in education from four perspectives: personalized education, intelligent teaching, collaborative education, and virtual teaching. The aim of the study is to provide important reference value for research and practice in this field.

KEYWORDS

generative artificial intelligence, educational applications, countermeasure research, development prospects, current status

1. Introduction

Generative AI is a form of artificial intelligence that utilizes machine learning and deep learning techniques to generate new data. Unlike traditional tasks such as classification and regression, generative AI has the ability to autonomously generate new data, including images, music, and text. The key component of generative AI is the generative model, which models the potential data distribution and generates new data that is similar to the original data. The applications of generative AI are wide-ranging, including image generation, natural language processing, and music generation (Lim et al., 2022). For image generation, the generative adversarial network (GAN) is a commonly used generative model that can create images that are highly similar to real images. In the field of natural language processing, models such as the recurrent neural network (RNN) and transformer network can be used to generate new textual data. In music generation, models such as the autoencoder and variational autoencoder can generate new music (Zhai, 2022).

In recent years, there has been a growing research interest in the application of generative artificial intelligence in the field of education, especially since the release of Chat GPT in November 2022, which brought the concept of generative AI to the public attention

and sparked increasing interest in its potential impact on education. Discussions about generative AI and its impact on education often focus on the challenges it presents to education practitioners (e.g., Stokel-Walker, 2022; Terwiesch, 2023) Would Chat GPT3 get a Wharton MBA, or on the opportunities it provides for educators and students (e.g., Zhai, 2022; Pavlik, 2023). In extreme cases, some view generative AI as a force that could disrupt the education system, while others see it as a reformer that brings new accessible information and automation opportunities to improve educational coverage and quality. These two perspectives highlight the inherent contradictions of generative AI and its role in education; it may disrupt some educational practices while also supporting them. In a study by Weng Marc Lim, four paradoxes were identified regarding the future of generative AI and education, namely, that generative AI is both a "friend" and an "enemy"; it is both "capable" and "dependent"; it is both "accessible" and "restrictive"; and that generative AI may even become "popular" when it is "banned." The study also discusses the need to accept generative AI in future education rather than avoid it (Lim et al., 2023).

This study focuses on the application of generative AI in education, with an emphasis on analyzing its current use and exploring its potential for innovation, limitations, and corresponding strategies for the future. Specifically, the study will take generative AI as the main research object, and analyze its core technical capabilities in the context of education. Starting from the development and technical support of generative AI, this study will conduct an in-depth analysis of its current application in education, explore the problems it faces in educational applications, and propose corresponding solutions. Furthermore, based on the future development trend of generative AI, this study will investigate its potential for innovation, limitations, and corresponding strategies for future education. The aim of the study is to provide important reference value for research and practice in this field. Given the nature and intention of the article, it is an opinion piece that utilizes macro-level logic analysis as the methodological foundation to discuss relevant viewpoints and issues.

2. Generative artificial intelligence: a creative new world

2.1. The development history of generative AI

Generative AI is an important branch of artificial intelligence and one of the fastest-growing fields in recent years. The early stages of generative AI development were from the 1950s to the 1970s. During this period, generative AI mainly focused on the field of language generation, such as natural language processing and machine translation. The early generative AI technology was relatively simple, mainly relying on rules and templates to generate text and language. In the field of natural language processing, early generative AI mainly focused on syntax and grammar analysis (Dai et al., 2020). Early language generation systems mainly used rule-based methods to encode the structure and rules of language as computer programs. These systems could generate some simple sentences and paragraphs, but lacked true semantic understanding and could not generate complex language structures (Jovanović and Campbell, 2022). In the field of machine translation, early generative AI mainly used rule-based methods to convert sentences in the source language to sentences in the target language. This method required a large amount of manual rule writing, and the maintenance and updating of rule libraries were also very difficult. Therefore, early machine translation systems often had poor performance (Oermann and Kondziolka, 2023). Although the generative AI technology during this period was relatively simple, it laid the foundation for later technological development.

The period from the 1980s to the 1990s was an important era for the development of generative AI technology. With the continuous advancement of computer technology and neural network technology, generative AI began to make progress in fields such as image processing and speech recognition. In the field of image processing, generative AI technology began to be applied to automatic image labeling, automatic image description, and image generation. Among them, automatic image labeling and automatic image description use generative models to generate descriptions and labels for images, while image generation uses generative models to generate images with specific styles and content from random noise (Noy and Zhang, 2023). These technologies have a wide range of applications in fields such as image search, automated image editing, and creative design. In the field of speech recognition, generative AI technology began to be applied to speech synthesis and speech conversion. Speech synthesis refers to the process of converting text into speech, while speech conversion refers to the process of converting one speaker's speech into another speaker's speech. These technologies can be applied in fields such as speech assistants, intelligent customer service, and entertainment (Yoo, 2019).

The period from the 2000s to the 2010s was a stage of rapid development for generative AI technology. During this period, with the development of deep learning technology, generative AI entered a new stage. The emergence of technologies such as Generative Adversarial Networks (GAN) and Variational Autoencoders (VAE) enabled generative AI to achieve a qualitative leap in fields such as image, music, and text. GAN is a generative model composed of a generator and a discriminator neural network. The generator is responsible for generating fake samples, while the discriminator is responsible for determining whether the samples are real or fake. Through repeated iterations, the generator can continuously generate more and more realistic fake samples, thereby simulating and emulating real samples (Karras et al., 2018). VAE is a generative model composed of an encoder and a decoder neural network. The encoder is responsible for encoding input data into latent variables, while the decoder is responsible for decoding latent variables into output data (Kingma and Welling, 2019). By adjusting the values of latent variables, control, and adjustment of the output data can be achieved.

From the 2010s to the present, generative AI has made significant breakthroughs in various fields, providing new ideas and methods for the development of artificial intelligence technology and bringing great value and contributions to human society. In the field of Go, AlphaGo, through the combination of deep learning technology and reinforcement learning algorithms, defeated top human players and became a milestone event (Silver et al., 2016). This event not only made people realize the potential of artificial intelligence technology, but also made

people start thinking about the application and development of artificial intelligence technology in other fields. In natural language generation, generative AI has already achieved human-level performance. For example, OpenAI's Chat GPT technology based on the GPT-3.5 model, released on November 30, 2022, can automatically generate high-quality articles, stories, and news, and it is difficult to distinguish whether they were written by a human or a machine (Abdullah et al., 2022). The application of this technology will bring more opportunities and challenges to fields such as natural language processing, online education, and intelligent customer service (Jovanović and Campbell, 2022). In addition, generative AI has also made many achievements in artistic creation. For example, computer-generated music and paintings can already rival human-created works. The application of these technologies can not only help human artists better realize their imagination and creativity, but also provide new avenues and means for art education and cultural inheritance.

Although generative AI has made significant breakthroughs in various fields, it still faces some problems that need to be solved. One of the most important issues is the adversarial sample problem. This problem refers to the generative model's inability to correctly recognize or generate the correct result when facing certain specific samples. Solving this problem will require more complex and in-depth technologies and methods (Hughes et al., 2021). The interpretability issue of generative AI is also an important challenge. This problem refers to the lack of direct connection between the generated results and the internal operating mechanism of the generative model, making it difficult to understand the source and reason of the generated results. Solving this problem will require more transparent and interpretable technologies and methods. In addition, the data privacy and security, ethical and moral issues brought about by generative AI also need to be constantly explored and solved (Zohny et al., 2023).

2.2. Technical support overview

Generative AI is an artificial intelligence technology that utilizes machine learning and deep learning techniques to construct datasets through generative models, producing various forms of art, music, text, and other outputs. The primary components of technical support for generative AI include:

2.2.1. Machine learning techniques

Machine learning techniques are one of the core components of generative AI. It is a technology that enables machines to learn automatically from data, which can help improve the accuracy and quality of generative results. In generative AI, machine learning techniques mainly include supervised learning, unsupervised learning, and reinforcement learning. Supervised learning is a common machine learning method that trains machines to learn the mapping relationship between input and output data by using labeled data. In generative AI, supervised learning can be used to train models to generate text that meets certain requirements (Arcaute et al., 2023). For example, by inputting some annotated text data into the machine and letting it learn the structure and rules of language from this data, it can generate text that conforms to grammar and semantic rules. Unsupervised learning is a learning method that does not require labeled data. It discovers patterns and rules in data through clustering, dimensionality reduction, and other processing techniques (Zhai, 2022). In generative AI, unsupervised learning can be used to train machines to automatically identify keywords and topics in text. For example, by inputting a large amount of text data into the machine and letting it automatically identify topics and keywords, it can generate text that conforms to the topic. Reinforcement learning is a learning method that continuously optimizes strategies through interaction between the environment and behavior. In generative AI, reinforcement learning can be used to train machines to generate text that meets certain requirements. For example, by inputting the machine into a dialogue system and adjusting the generated text based on the feedback from the system, the generative result can be continuously optimized.

2.2.2. Deep learning techniques

Deep learning techniques are another core technology of generative AI. It is a learning method that simulates the neural network of the human brain and can discover complex patterns and rules in data through multi-layer neural networks. In generative AI, deep learning techniques mainly include Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Variational Autoencoders (VAE), among others. CNN is a commonly used deep learning method that can effectively extract features from data and is used in fields such as images and speech (Lehmann and Buschek, 2020). In generative AI, CNN can be used for image and audio generation, for example, by training machines to recognize objects in images and then letting them automatically synthesize new images (Oermann and Kondziolka, 2023). RNN is a neural network that can process sequential data and is used in fields such as natural language processing. In generative AI, RNN can be used to generate text that conforms to language rules, for example, by letting machines automatically learn the contextual relationships of language and then generate new text that conforms to language rules. VAE is a probabilistic model-based autoencoder that can be used for data compression and generation (Zhai, 2022). In generative AI, VAE can be used to generate new data that conforms to data distribution, for example, by training machines to learn the latent variable distribution of data and then letting them automatically generate new data that conforms to this.

2.2.3. Natural language processing techniques

Natural language processing (NLP) techniques are critical to support generative AI. NLP refers to the technology that simulates human language abilities using computers, and can be used to generate various forms of textual content such as articles and conversations. In generative AI, NLP techniques are mainly applied to language models, conditional generation, and dialogue systems. Language models are an important part of NLP techniques that can model the rules and probabilities of language, thus automatically generating new text that conforms to language rules (Touretzky et al., 2019). In generative AI, language models can be used to generate various forms of textual content such as news reports, novels, and poetry. Conditional generation is a technique that uses existing information to generate new information. In generative AI, conditional generation can be used to generate text content

that meets specific conditions. For example, conditional generation techniques can be used to generate articles or news reports that meet specific topics, thus meeting user needs. Dialogue systems are another important application of NLP in generative AI. Dialogue systems can simulate human conversation processes and engage in natural and fluent conversations with users. In generative AI, dialogue systems can be used to generate various forms of dialogue content, including customer service conversations and chatbots (Baidoo-Anu and Owusu Ansah, 2023).

2.2.4. Image processing techniques

Image processing techniques are one of the crucial technical supports for generative AI. They can be used to generate various forms of images and artworks, including photos, paintings, and designs. In generative AI, image processing techniques are mainly applied to Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs). GANs are models composed of two neural networks, a generator and a discriminator (Neller, 2017). The generator learns to create new images by learning the distribution of the training data, while the discriminator improves its accuracy by distinguishing between the images generated by the generator and real images. In generative AI, GANs can be used to create various forms of images and artworks, such as photos, paintings, and designs. GANs have a wide range of applications, such as virtual reality, game design, and film production (Oermann and Kondziolka, 2023).

Variational autoencoders are a technique that uses autoencoders to generate images. Autoencoders are neural network models that compress and decompress input data. In generative AI, VAEs can be used to generate images that meet specific conditions, such as generating images with specific themes or styles specified by users. VAEs have a wide range of applications, such as virtual reality, game design, and film production. In addition to GANs and VAEs, image processing techniques have other applications, such as super-resolution, image restoration, and image segmentation. These techniques can be used to improve the quality and accuracy of images to meet different needs in various fields (Furey and Martin, 2019).

Overall, the technical support for generative AI mainly includes machine learning, deep learning, natural language processing, and image processing, among others. The continuous development and improvement of these technologies will provide more powerful and intelligent support for the application of generative AI in education, art, entertainment, and other fields.

3. Analysis of current status of educational applications

3.1. Portable educational applications

Currently, with the popularity of mobile devices such as smartphones and tablets and the development of network technology, many educational applications based on generative AI technology have emerged. These applications can provide students with convenient learning methods, help them better understand and master knowledge. At the same time, some applications can use generative AI technology to provide real-time intelligent assessment and feedback to students during the learning process, helping them better discover and correct errors and improve learning efficiency. Taking Duolingo as an example, this is a free language learning application based on generative AI technology. Users can learn multiple languages, including English, Spanish, French, German, Italian, Portuguese, Dutch, Russian, and Chinese. The core concept of Duolingo is to turn language learning into a game, helping users to learn new languages easily and happily through interactive learning methods (Lim et al., 2022). The application includes various grammar, vocabulary, listening, speaking, and reading comprehension exercises, and users can improve their language skills by completing these exercises. In addition, Duolingo also provides personalized learning plans and real-time feedback to help users better understand their learning progress and problems, and provide corresponding advice and support. Duolingo has tens of millions of users worldwide, and its simple, easy-to-use, and free open characteristics make it a popular language learning application. Therefore, educational applications based on generative AI technology have become important auxiliary tools for modern students' learning, bringing many conveniences and opportunities to their learning. The following are some common educational applications (see **Table 1**).

3.2. Educational applications

With the development of technology, the application of generative AI in the field of education is increasing. The following are some applications of generative AI in the field of education:

3.2.1. Intelligent teaching system

The intelligent teaching system generates personalized course content and teaching plans based on the student's learning

TABLE 1 Common educational applications.

Application name	Description
Duolingo	A language learning app that can automatically adjust difficulty and content based on the user's learning progress and provide a personalized learning experience. The main features include speech recognition, grammar exercises, and vocabulary memorization.
Squirrel AI	An intelligent learning app that provides personalized learning plans and teaching content based on students' learning progress and ability levels. The main features include intelligent diagnosis, personalized teaching, and real-time monitoring.
Mathway	A mathematics problem-solving app that can solve various mathematical problems, including algebra, geometry, and calculus. The main features include problem recognition, solution process display, and answer verification.
Grammarly	An English writing assistant tool that can check grammar, spelling, punctuation errors in English articles and provide correction suggestions. The main features include grammar check, spelling check, and correction suggestions.
Coursera	An online learning platform that provides online courses and learning resources for various subjects, including computer science, business management, humanities and social sciences. The main features include online courses, learning resources, and learning community.

process, thereby achieving personalized teaching. The system can automatically adjust the difficulty and content of the course based on the student's learning performance and level, providing learning tasks and exercises that are suitable for the student (Khosravi et al., 2022). In addition, the system can automatically generate corresponding learning resources and learning paths based on the student's learning habits and needs, allowing students to learn more efficiently and purposefully. At the same time, the system can provide real-time feedback and suggestions to help students correct errors and improve their learning methods. In addition, the intelligent teaching system can also interact with students' parents and teachers, allowing parents and teachers to better understand students' learning situations and performances, and provide more comprehensive and effective educational support. For example, Knewton's Adaptive Learning Platform uses AI technology to analyze students' learning data, including learning speed, mastery of knowledge points, error rates, etc., to understand students' learning needs and weaknesses, and generate personalized course content and teaching plans accordingly (Lim et al., 2022). For example, if a student performs poorly in a certain knowledge point, the platform will automatically adjust the course content and difficulty, providing more in-depth and detailed explanations and exercises for the student. In addition, the platform will provide real-time feedback and suggestions based on the student's learning progress and performance, helping students better master knowledge and skills. Through this personalized teaching method, the Knewton platform can improve students' learning efficiency and effectiveness, making teaching more flexible and efficient.

3.2.2. Intelligent homework grading

Intelligent homework grading automatically analyses students' homework, judges its correctness and errors, and provides corresponding scores and suggestions. The system can automatically detect various types of student homework, including multiple-choice questions, fill-in-the-blank questions, short answer questions, and essay questions, achieving efficient, accurate and fair homework grading. Specifically, the system can establish corresponding knowledge bases and algorithm models through learning and analyzing historical data, judge whether students' answers are correct, and provide corresponding scores and suggestions to help students improve their homework. In addition, intelligent homework grading can also provide real-time evaluation and feedback, allowing students to timely understand their learning situation and progress. Furthermore, the system can also provide teachers with more efficient and accurate homework management tools, saving a lot of time and energy. For example, Turnitin's homework detection platform uses natural language processing and machine learning technology to automatically detect and evaluate students' submitted homework. For instance, when a student submits a paper assignment, the platform automatically detects its plagiarism, grammar errors, spelling errors, etc., while providing corresponding suggestions and improvement ideas. The platform can also provide personalized evaluation and suggestions based on students' historical homework data and learning performance, helping students better master knowledge and skills. Through this intelligent homework grading method, Turnitin platform can improve the efficiency and accuracy of homework grading while ensuring fairness and objectivity, providing students with a better learning experience and support.

3.2.3. Intelligent tutoring system

The intelligent tutoring system automatically generates corresponding tutoring content and strategies based on the analysis of students' learning situations and personalized needs. The system can automatically adjust tutoring content and difficulty levels based on students' learning performance and levels, providing students with suitable tutoring tasks and practice questions. Additionally, the system can generate corresponding tutoring routes and strategies based on students' learning habits and needs, enabling students to learn more efficiently and effectively. Furthermore, the system can provide real-time feedback and suggestions to help students correct mistakes and improve their learning methods. Moreover, the intelligent tutoring system can interact with students' parents and teachers, allowing them to better understand students' learning situations and performances and provide more comprehensive and effective educational support (Zhai et al., 2021). For example, Yixue Education's intelligent tutoring system is based on artificial intelligence and facial recognition technology, which analyses students' learning situations and performances to generate personalized tutoring content and strategies. For instance, during math exercises, the system can automatically determine students' levels based on parameters such as answer speed and accuracy and provide suitable exercises and practice tasks. The system can also automatically adjust tutoring content and difficulty levels based on students' learning progress and performances, providing more in-depth and detailed explanations and practice for students. Additionally, the system supports tutoring in multiple subjects and knowledge points, including math, English, physics, chemistry, etc., providing students with comprehensive learning support. Through this personalized tutoring approach, Yixue Education's intelligent tutoring system can improve students' learning efficiency and effectiveness, providing them with a better learning experience and support (Ouyang and Jiao, 2021).

3.2.4. Intelligent speech interaction system

The intelligent speech interaction system utilizes generative AI technology and natural language processing technology to achieve speech interaction with students, in order to better understand their learning needs and questions. By learning and analyzing historical data, the system establishes a corresponding knowledge base and algorithm model, achieving intelligent speech recognition and speech synthesis, allowing students to interact with the system through voice. Specifically, students can ask questions or express their needs through voice, and the system can automatically recognize their speech content and provide corresponding answers and suggestions to help students solve problems and improve their learning effectiveness. Additionally, the intelligent speech interaction system provides real-time speech assessment and feedback, allowing students to understand their speech expression ability and pronunciation accuracy in a timely manner. Furthermore, based on the student's learning situation and needs, the system can automatically recommend corresponding speech learning resources and exercise materials, enabling students to improve their speech expression ability more efficiently and effectively. For example, VIPKID's intelligent speech teaching system. Based on generative AI technology and natural language processing technology, this system can interact with students through voice to better understand their learning

needs and questions. In English-speaking teaching, the system can automatically recognize students' pronunciation, intonation, etc., through speech recognition technology and provide corresponding correction and improvement suggestions. Additionally, the system can adjust teaching content and difficulty automatically based on students' learning progress and performance, providing personalized teaching support for students. The system also establishes a corresponding knowledge base and algorithm model based on historical data and learning status, achieving intelligent speech recognition and speech synthesis, allowing students to interact with the system through voice. Through this intelligent speech interaction method, VIPKID's intelligent speech teaching system can improve students' oral expression ability and learning effectiveness, providing better learning experience and support for students (Castelli and Manzoni, 2022).

In summary, the application of generative AI in the field of education can assist teachers in better understanding students' learning situations and needs, thus achieving personalized education and improving the quality of education and teaching.

4. Issues to be resolved

Although generative AI has great potential in educational applications, there are still some issues to be addressed, including:

4.1. Opacity and inexplicability

Due to the complexity of generative AI models, it is difficult to explain the decision-making process and the basis for generated results, which makes it hard for students to understand why they get a particular answer and how to improve their mistakes (Laupichler et al., 2022). For example, suppose there is a generative AI educational application designed to teach English grammar. When a student inputs a sentence, the program will automatically generate its grammatical structure and provide corresponding grammar rules and explanations. However, due to the complexity of the program's model, the student may not understand why the program gives a specific grammatical structure and what the basis for this structure is. Additionally, if a student makes a grammar mistake, the program may provide incorrect correction suggestions, but the student may not understand why the suggestion is correct and how to avoid similar mistakes. Therefore, opacity and inexplicability are one of the urgent issues to be addressed in this generative AI educational application. If the program can provide more transparent and interpretable decision-making processes and generated results, students will be more likely to understand and accept its teaching content, thus improving learning effectiveness (Arcaute et al., 2023).

To address this issue, interpretable generative AI algorithms need to be developed. These algorithms should provide decision explanations and visualizations so that students can understand the decision-making process and the basis for generated results of generative AI. For example, generative AI can generate some graphics or animations to demonstrate the problem-solving process, or provide some textual explanations to explain the logic of each step. This way, students can better understand the knowledge and skills they are learning and apply them more effectively (Akgun and Greenhow, 2021). Additionally, some tools need to be developed to evaluate the interpretability of generative AI. These tools can help developers identify the opacity and inexplicability in the model and provide some improvement suggestions. This will help generative AI developers and educators better understand how generative AI works, thus further improving the usability and reliability of generative AI in educational applications.

4.2. Data privacy and security

Generative AI requires a large amount of data to train its models, which may contain sensitive information such as personal identity information and academic records. If this data is leaked or misused, it will seriously affect personal privacy and security. For example, some schools and institutions use generative AI models to analyze student academic performance, interests, learning styles, and other data, in order to provide personalized learning advice and guidance. However, this data contains a large amount of personal identity information such as name, date of birth, and student ID number. If this data is leaked or misused, it will seriously affect students' personal privacy and security. In addition, since personalized learning data for students is usually provided by schools or institutions, students have difficulty controlling their own data and understanding how it is being used and shared, which may also lead to concerns and mistrust regarding personal privacy. Therefore, generative AI in educational applications needs to consider how to protect personal privacy and security, such as using secure data storage and transmission methods, strengthening data access control and permission management measures, to ensure the security and confidentiality of student data.

To address this issue, measures need to be taken to protect the privacy and security of data. Firstly, encryption technology needs to be used to protect the transmission and storage of data. Secondly, access control mechanisms need to be implemented to ensure that only authorized personnel can access the data. In addition, data anonymization and de-identification need to be carried out to protect personal privacy. In addition to technical means, relevant laws and regulations need to be formulated to protect the privacy and security of data. These laws and regulations should stipulate the standards and procedures for data collection, use, and protection, to ensure the legality and security of data (Macpherson et al., 2021). At the same time, data privacy and security should be incorporated into the development and application standards of generative AI, to promote the sustainable development of generative AI.

4.3. Personalization and fairness

Generative AI can provide personalized learning plans and tools based on students' individual needs and learning styles to improve learning efficiency and effectiveness. However, this personalized learning can also lead to unfair outcomes. For example, some schools and institutions use generative AI models to analyze students' learning styles, interests, and knowledge levels, and provide personalized learning plans and tools. This personalized learning can better meet students' needs and improve

learning efficiency and effectiveness. However, this personalized learning can also lead to unfair outcomes, as different students may face different opportunities and challenges. For example, if a student comes from a poor family, they may not have the opportunity to use high-quality learning tools and resources, which may lead to their learning achievements being inferior to those of other students. In addition, if generative AI models only focus on students' individual needs and interests, and ignore some important learning objectives and standards, this may also lead to students' knowledge and skills being less comprehensive and in-depth (Miller, 2017).

To address this issue, fair algorithms need to be developed to ensure that generative AI is fair in educational applications. These algorithms should be able to identify, analyze, and eliminate unfair factors, such as race, gender, and economic background. At the same time, measures need to be taken to ensure that the personalized learning plans and tools provided by generative AI are fair and can meet the needs of all students. For example, diverse learning materials and teaching methods can be used to meet the needs of different students. In addition, tools need to be developed to evaluate the fairness of generative AI. These tools can help developers identify unfair factors and provide improvement suggestions. This will help generative AI developers and educators better understand the working principles of generative AI, and further improve the fairness and reliability of generative AI in educational applications.

4.4. Effectiveness and reliability

Generative AI needs to be trained on a large dataset to ensure its effectiveness and reliability. These datasets need to contain sufficient data and have high-quality labeled data to improve the accuracy and robustness of the algorithm (Hughes et al., 2021). Insufficient datasets or low-quality labeled data can affect the performance and application effectiveness of generative AI. For example, in the field of education, generative AI can be used to automatically grade student essays. To train an effective automatic grading model, a large dataset of student essays and high-quality labeled data, such as scores for grammar, spelling, and logic, is required. Insufficient datasets or low-quality labeled data may cause the automatic grading model to make mistakes, miss important aspects, and affect its accuracy and application effectiveness.

To address this issue, measures need to be taken to improve the quality and quantity of datasets. First, diverse data, including data from different genders, ages, regions, and cultural backgrounds, need to be collected to ensure the widespread applicability of generative AI. Second, standards and processes need to be established to ensure the quality and consistency of labeled data. For example, multi-person labeling and interactive labeling methods can be used to improve the accuracy and reliability of labeled data. In addition to datasets and labeled data, the algorithm of generative AI needs to be optimized and improved to enhance its performance and effectiveness. For example, advanced techniques such as deep learning and neural networks can be used to improve the accuracy and robustness of the algorithm. At the same time, the algorithm needs to be optimized and adjusted to adapt to different application scenarios and needs (Kuleto et al., 2021).

In conclusion, generative AI has a wide range of applications in education, but there are also some issues that need to be addressed. These issues need to be addressed during the development and application of the generative AI algorithm to make it more suitable for educational applications.

5. Prospects for future development

Generative AI has vast potential and room for development in the field of education. The future development trend may include the following aspects:

5.1. Personalized education

5.1.1. Personalized assessment

Generative AI can provide personalized assessment and feedback by analyzing students' learning data and behavior patterns, helping them better understand their learning situation and performance, and ultimately improving learning outcomes. For example, it can automatically identify students' learning weaknesses and bottlenecks based on their learning data and provide corresponding targeted guidance and exercises (Stokel-Walker and van Noorden, 2023).

5.1.2. Personalized learning content

Generative AI can generate corresponding learning content and teaching strategies based on students' interests, abilities, and knowledge levels, providing personalized learning experiences. For example, it can generate appropriate reading materials and exercises based on students' reading interests and levels.

5.1.3. Personalized teaching route

Generative AI can automatically adjust the teaching route and difficulty based on students' learning progress and performance, providing personalized learning experiences. For example, it can generate corresponding teaching routes and plans based on students' learning data and situations, allowing students to learn more effectively and efficiently.

5.1.4. Personalized learning experience

In the future, generative AI can provide students with more realistic, vivid, and personalized learning experiences through virtual reality and augmented reality technology, enhancing students' interest and participation in learning. For example, it can provide immersive learning experiences through virtual reality technology, allowing students to understand learning content more intuitively and thoroughly (Ouyang et al., 2022).

5.2. Intelligent teaching

5.2.1. Intelligent course design

Generative AI can automatically design corresponding course content and teaching strategies based on students' learning data and behavior patterns, providing personalized learning experiences.

For example, it can automatically adjust the course difficulty and content based on students' learning progress and performance, allowing students to learn more effectively and efficiently (Huang, 2021).

5.2.2. Intelligent assessment

Generative AI can provide efficient, accurate, and fair assessment services for teachers through automated homework grading, speech assessment, and other natural language processing techniques and deep learning algorithms. Additionally, it can generate corresponding assessments and feedback based on students' learning data and performance, helping students better understand their learning situation and performance, and ultimately improving learning outcomes (Xu, 2021).

5.2.3. Intelligent interaction

In the future, generative AI can provide intelligent tutoring and Q&A services through natural language processing techniques and machine learning algorithms, allowing for natural language interaction with students. Additionally, it can automatically adjust the interaction mode and content based on students' learning data and performance, providing personalized learning experiences (Gao et al., 2021).

5.2.4. Intelligent monitoring

Generative AI can real-time monitor and analyze students' learning data to provide timely feedback and adjustment suggestions for teachers, improving the quality and efficiency of teaching.

5.2.5. Intelligent tutoring

Generative AI can automatically identify students' learning weaknesses and bottlenecks through machine learning algorithms and deep learning technology, providing corresponding targeted tutoring and exercises to help students better master learning content and skills (Salas-Pilco and Yang, 2022).

5.3. Collaborative education

5.3.1. Interdisciplinary teaching

Generative AI can establish connections between different disciplines and provide interdisciplinary teaching content and experiences. For example, through machine learning algorithms and natural language processing technology, it can automatically analyze the relationships and correlations between different disciplines and provide students with more comprehensive and systematic learning experiences (Doroudi, 2022).

5.3.2. Cross-school collaboration

In the future, generative AI can achieve cross-school collaboration and resource sharing through the Internet and cloud computing technology, providing students with more diverse and abundant learning resources and opportunities. For example, through online course platforms and virtual laboratories, students can learn and communicate with each other across different schools.

5.3.3. Cross-cultural education

Generative AI can improve students' cultural literacy and global awareness through cross-cultural communication and collaboration. For example, through online education platforms and virtual reality technology, students can communicate and collaborate with students from different countries and regions, enhancing their cultural understanding and communication skills.

5.3.4. Cross-industry training

Generative AI can provide personalized and efficient training and education services for personnel in different industries and fields through natural language processing technology and deep learning algorithms. For example, according to the needs and characteristics of different industries, it can automatically design corresponding course content and teaching strategies, providing customized learning experiences.

5.3.5. Cross-temporal and spatial teaching

In the future, generative AI can provide students with cross-temporal and spatial learning experiences and opportunities through virtual reality technology and augmented reality technology. For example, through virtual reality technology, students can experience and understand life and events in different historical periods and cultural backgrounds (Zhang and Wang, 2022).

5.3.6. Human-machine collaborative education

In the future, generative AI can combine with robot technology to realize the application and development of robot education. For example, through the interaction between robot teachers and robot students, it can provide more realistic, personalized, and diverse learning experiences and opportunities, promoting the enhancement of students' comprehensive and innovative abilities.

5.4. Virtual education

5.4.1. Virtual classroom

Generative AI can combine virtual reality technology and augmented reality technology to build and operate virtual classrooms, providing students with immersive learning experiences. For example, three-dimensional models and experimental scenes can be displayed in virtual classrooms, allowing students to have a more intuitive understanding of the learning content and process (Humble and Mozelius, 2022).

5.4.2. Joint virtual laboratory

In the future, generative AI can provide students with more diverse and realistic experimental experiences and opportunities through cloud computing technology and joint virtual laboratories. For example, biological, chemical, and physical experiments can be conducted in virtual laboratories, allowing students to explore and practice in a virtual environment.

5.4.3. Gamification of learning

Generative AI can provide students with entertaining and educational learning experiences through gamification design and machine learning algorithms. For example, learning games can

be designed in virtual environments, allowing students to learn and explore while playing, enhancing their learning interest and motivation (Lim et al., 2023).

Overall, generative AI will play an increasingly important role in future education, providing students and teachers with more intelligent and personalized learning and teaching experiences, and also bringing greater development and innovation to the education field.

6. Conclusion and limitations

The rise of generative AI has sparked panic due to sensationalist articles and swift bans by some educational institutions and organizations. However, the author believes that generative AI should be viewed as a transformative resource that educators and students can utilize in teaching and learning. Increasing awareness of these tools, using them together in the classroom, and guiding students to discuss their pros and cons are beneficial to deeper integration of AI and education. Generative AI tools such as Bard, Chat GPT, and DALL-E are opening up new fields that will impact how humans learn, interact, and collaborate with each other (Lim et al., 2022). This requires joint efforts from society to address the issues that arise from the use of generative AI in education and to reconstruct existing practices. Only then can we fully leverage the application advantages of generative AI in education to provide students with better, more efficient, and personalized learning experiences.

However, this study also has some limitations. Firstly, it may only cover current generative AI technologies and application cases, without involving possible new technologies and application scenarios in the future. Secondly, the proposed countermeasures may have implementation difficulties and require further exploration. In addition, the technological prospects presented in the study may be based only on current technology and application scenarios, without considering potential new problems and challenges in the future. Finally, the study may not fully consider the social and cultural factors that affect the use of generative AI in education, such as differences in learning needs and habits among students from different regions and cultural backgrounds.

Author contributions

HY wrote the first draft of the manuscript. Both authors revised the manuscript and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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