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Deep Learning in Education: A Systematic Literature Review on Its Applications and Challenges

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Abstract

This research aims to provide a systematic review of the application of deep learning technology in education and the challenges faced in its implementation. With the increasing adoption of artificial intelligence (AI) technology in education, especially in personalized learning, this research is important to understand the potential and barriers that affect the successful implementation of this technology. The main objective of this study is to identify the application of deep learning in education, evaluate the challenges faced, and assess its impact on the quality of learning in the formal and non-formal sectors.The method used is a systematic literature review by following the PRISMA 2020 guidelines. Relevant articles were selected from various academic databases published between 2020 and 2026. After screening, 13 articles that met the inclusion criteria were analyzed using narrative synthesis and thematic analysis approaches. The results show that deep learning can improve learning personalization, provide faster feedback, and increase student engagement. However, the main challenges faced are the limitations of technology infrastructure, unrepresentative data quality, and the difficulty of educators in integrating this technology. Issues related to data privacy and technology access gaps are also significant obstacles. This study recommends the need for policies that support more equitable access to technology, educator training, and increased transparency in the use of deep learning models.

Keywords : deep learning, education, applications, challenges

Introduction

Deep learning (DL) technology, which is one of the branches of artificial intelligence (AI), is increasingly being applied in various sectors, especially in the field of education. The application of deep learning in education has the potential to improve the learning experience by making it more personalized, adaptive, and responsive to student needs. This technology allows for in-depth analysis of student performance data, so that learning materials can be tailored to each student's abilities, creating a more efficient and relevant learning experience (M. Elbashbishy, 2024; Pașca-Tușa, 2021; Shibberu, n.d.; Vasile, 2024; W. Wang et al., 2025)

For example, in medical education, deep learning has been used to analyze student performance data and provide very specific feedback according to their learning needs (Bertl, Price, & Draheim, 2026). In addition, deep learning models such as Convolutional Neural Networks (CNN) and Bi-Directional Long Short-Term Memory (Bi-LSTM) are also used to detect students' emotions, allowing educators to tailor teaching methods based on students' emotional states, thus creating more effective and enjoyable learning (Chutia & Baruah, 2024).

Further application of deep learning is in the development of adaptive learning systems and intelligent tutoring that uses big data to dynamically adjust learning materials according to student progress (Greeni et al., 2024; Tato & Nkambou, 2023). This not only improves student engagement but also their learning outcomes, as evidenced in studies by (Farhood, Joudah, Beheshti, & Muller, 2024) and (Yu et al., 2026).

The adoption of deep learning technology in education has great urgency, especially amid the need to create a learning system that is more responsive and adaptive to rapid changes in the digital world (Nofamataro Zebua, 2025; Prashant Chonkar et al., 2019). According to available data, about 60% of educational institutions around the world have leveraged AI technology to support distance learning and material personalization (Jing et al., 2023). In light of the COVID-19 pandemic, AI-based learning technologies are becoming increasingly important, and the demand for deep learning integration in education continues to increase (Aslani & Jacob, 2023; Li & Liu, 2023; P, P, & A, 2020).

The application of this technology can overcome major challenges in education, such as inequality of access and quality of learning materials. However, while this technology promises many benefits, its implementation

also faces a number of challenges, such as the limitations of technology infrastructure, the quality of data that is less representative, and the inability of many educators to integrate this technology effectively. This adds urgency to focus more on research that identifies and addresses these barriers.

Currently, various deep learning models have been used to improve the quality of education, ranging from adaptive learning systems to automatic evaluation technology. Models such as Long Short-Term Memory (LSTM), Bidirectional Encoder Representations from Transformers (BERT), and deep reinforcement learning (DRL) are increasingly being used to create more personalized and responsive learning experiences. Innovations in this area, such as multimodal learning that combines text, images, and sound, further enrich the student learning experience (Gholami, Fateh, & Fateh, 2026). Research by (Bai & Stede, 2023) shows that automated evaluations using deep learning allow for faster and more accurate feedback compared to traditional methods.

However, while this technology has shown great potential, challenges related to data privacy, model transparency, and technology access gaps remain significant barriers to the implementation of deep learning in education. Although there have been studies showing the benefits of deep learning in education, most studies still focus on the application of theory or small experiments, with little attention to practical implementation on a large scale. Further, there is a lack of research on how educators can effectively integrate these technologies in their curriculum and how students from diverse backgrounds react to the use of deep learning in education. Data-related challenges, such as bias in datasets and privacy issues, have also not been widely discussed in the existing literature.

This research aims to identify and address the challenges associated with the application of deep learning in education. While this technology has enormous potential to improve the quality of education, especially in terms of personalization and adaptation of learning materials, many obstacles must be overcome to ensure that it can be implemented effectively and inclusively. Therefore, it is important to better understand these challenges and how they can be addressed through appropriate policies, training for educators, and the development of more transparent and accessible technologies.

Application of AI Technology in Education: About 60% of educational institutions in the world have leveraged AI to support adaptive learning and material personalization. Research Growth on Deep Learning: Research related to the use of deep learning in education has increased rapidly in the last five years, with the number of publications increasing by 25% per year since 2020 (P. Wang, 2023). Application of Deep Learning in Medical Education: About 40% of medical faculties in the world have started adopting AI-based technologies for medical image analysis and evaluation of students' practical skills.

Given these shortcomings, a systematic literature review focused on the application and challenges of deep learning in education. This review aims to answer four key questions: (RQ1) How is the application of deep learning technology in the field of education? (RQ2) What are the challenges faced in the implementation of deep learning in the education sector? (RQ3) How effective is deep learning in improving the quality of learning and teaching in formal and non-formal education? (RQ4) How has research on the use of deep learning in education progressed in recent years? By synthesizing the existing evidence, this study aims to examine the application of deep learning in various aspects of education; identify the challenges faced in the implementation of deep learning in education; evaluate the impact and effectiveness of deep learning in education; review the development of research related to deep learning in the education sector.

Methods

This study adopts a qualitative research approach with a systematic literature review to examine the applications and challenges of the use of deep learning in education. Following the guidelines of PRISMA 2020, the main objective of this study is to assess how deep learning and artificial intelligence (AI) affect educational practices, identify key trends in their application, and analyze the challenges faced in integrating these technologies in the educational environment. The article selection process was carried out by searching for peer-reviewed articles in academic databases published between 2020 and 2026 in English, with a special focus on articles that are openly accessible and related to deep learning and education.

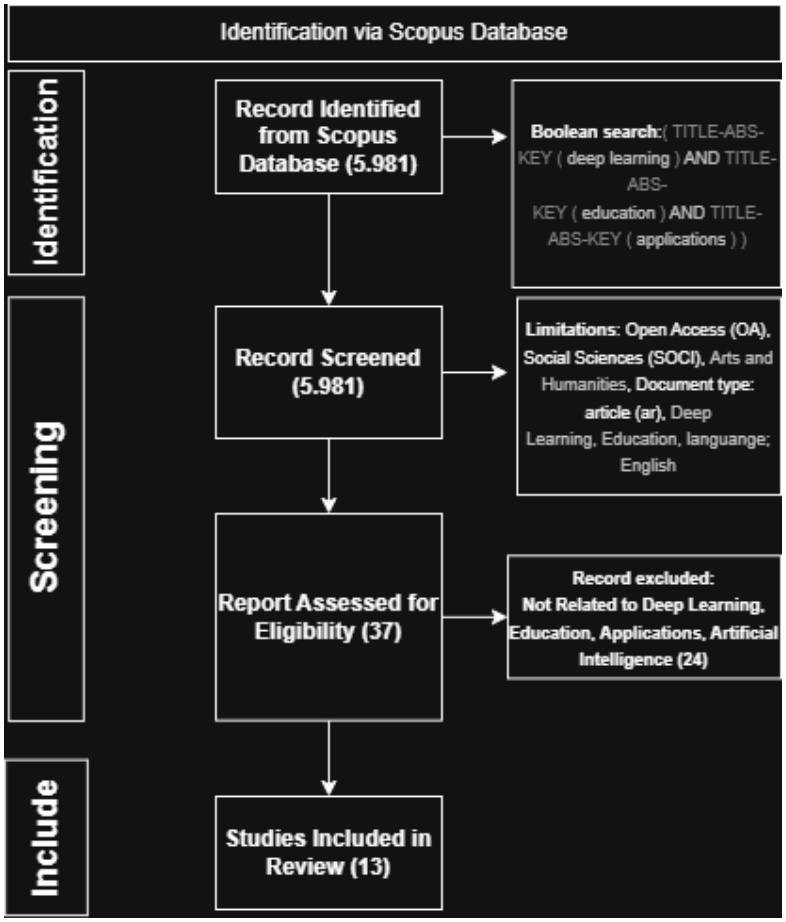
In the early stages, searches are conducted using search strings that include the main keywords "Deep Learning," "Education," "Applications," and "Artificial Intelligence," with a publication year limit between 2020

and 2026. Articles found must be available in open access and published in scientific journals indexed in recognized databases. This process resulted in **5,981 articles** relevant to the topic of deep learning and AI in education. After that, the articles found are filtered based on the inclusion criteria that have been set. The inclusion criteria include articles that focus on the applications of deep learning in education, published between 2020 to 2026, in English, and available in open access (OA). Articles relevant to the topic and type of research (only empirical research articles, not reviews or theories) are selected. After screening based on inclusion criteria, the number of eligible articles was reduced to **37 articles**.

The next step is a further screening process to ensure the suitability of the article with the research topic. Articles relevant to the title and focus of the discussion of this research were re-screened based on the suitability of the title and the relevance of the content of the article. Of the remaining 37 articles, only **13 truly** fit the goals and focus of this study. The article selection process follows the **guidelines of PRISMA 2020** (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The PRISMA flowchart is used to systematically and transparently document each step of article selection. This flowchart illustrates the process from article identification, initial screening, feasibility assessment, to final selection resulting in **13 articles** selected for further analysis.

The quality assessment of the selected article will be carried out using an assessment tool such as **JBI Critical Appraisal Tools** or **CASP**. Each article will be evaluated based on its methodological strength, reporting clarity, and relevance to the research objectives. Studies with a strong methodological design and clear reporting will be prioritized. Once the article is selected, the data will be extracted using a standard template that includes information such as author, year of publication, country of origin of the research, deep learning techniques used, challenges faced, applications in education, and results achieved. The collected data will then be analyzed using narrative synthesis and thematic analysis to explore the applications of deep learning in education, the existing challenges, and the future trends and direction of this technology in the education sector.

Using this methodology, this study aims to provide an in-depth understanding of how deep learning and artificial intelligence affect and transform educational practices as well as the challenges faced in their adoption. The research also seeks to outline potential solutions to the challenges faced, providing insight into how these technologies can be effectively integrated across different levels of education. The findings of this literature review are expected to make a significant contribution to the development of theory and practice in the field of technology-based education.



Picture 1. Prisma Diagram

Results

1. How is deep learning technology applied in the field of education?

The application of deep learning in education has opened up great opportunities to improve the quality of learning with a more personalized and adaptive approach. With this technology, education has not only become more interactive, but also more in line with the needs of each student. Deep learning enables in-depth analysis of student performance data, provides automated feedback, and tailors learning materials based on individual abilities, creating a more relevant and efficient learning experience.

For example, in medical education, deep learning is applied to analyze student data and provide very specific feedback according to their learning needs (Bertl et al., 2026). In addition, deep learning models such as Convolutional Neural Networks (CNN) and Bi-Directional Long Short-Term Memory (Bi-LSTM) are also used to detect students' emotions. This technology allows educators to adjust teaching methods based on students' emotional states, so that learning can take place more effectively and enjoyably (Chutia & Baruah, 2024).

Further applications of deep learning are in the development of adaptive learning systems and intelligent tutoring. The system uses technology to analyze big data and dynamically tailor learning content according to student needs. With this technology, materials can be adjusted in real-time to each student's abilities and progress, which of course increases their engagement and learning outcomes. This is proven in various studies, which show that this adaptive learning system can significantly improve learning effectiveness (Farhood et al., 2024; Yu et al., 2026). In addition, automated evaluation through technologies such as Long Short-Term Memory (LSTM) and Bidirectional Encoder Representations from Transformers (BERT) allows for faster and more accurate feedback, helping students to quickly correct their mistakes (Bai & Stede, 2023).

One of the advantages of deep learning is the application of deep reinforcement learning (DRL), which allows for the adjustment of teaching strategies based on direct interaction with students. DRL assists educators in adapting their teaching methods to obtain more optimal results based on student responses in each learning session (Yang, Qin, Lei, & Liu, 2023). On the other hand, adaptive algorithms in deep learning allow for the creation of a more personalized learning experience, with the adjustment of materials and approaches that are more appropriate to learning progress and student needs (Nguyen, Nguyen, & Tran, 2023).

In addition, deep learning also plays a role in semantic segmentation techniques, which combine visual and textual data to provide a more holistic understanding of the material being taught. With this technology, students can access richer and more integrated information, deepening their understanding of the concepts being taught (Gholami et al., 2026). As a result, deep learning creates a smarter, more responsive, and more personalized education system, which drives improved quality of learning in the digital age (Reina-Parrado, Román-Graván, & Hervás-Gómez, 2025).

The development of the application of deep learning in education is accelerating, especially in improving personalized learning and automatic evaluation. This technology enables more efficient learning by providing personalized feedback according to students' abilities. For example, in adaptive learning, deep learning can analyze student data and provide recommendations for materials relevant to their level of understanding, ensuring that each student gets the right material for them (Jing et al., 2023). In the world of online education, this technology also improves students' interaction with learning materials, allowing for dynamic adjustment of materials based on their progress (P. Wang, 2023).

In the context of medical education, deep learning is used for the analysis of medical images and the evaluation of students' medical skills. This allows educators to provide more accurate and relevant feedback on skills that students need to improve, accelerating the process of practical learning in the medical field (Pucchio et al., 2022). Overall, deep learning not only helps create a more personalized and effective learning experience, but also encourages education systems that are more adaptive and responsive to students' needs, provide real-time feedback, and tailor materials to their learning abilities.

2. What are the challenges faced in the implementation of deep learning in the education sector?

The application of deep learning in education holds tremendous potential to transform the way we teach and learn, but it is also faced with a variety of technical, social, and ethical challenges that affect its effectiveness. The main challenges that often arise are ambiguity in the text and data limitations, which make interpretation by students and deep learning models complicated. The reliance on large, structured datasets, which are often unavailable, further exacerbates this problem (Bertl et al., 2026). In addition, deep learning requires large computing resources, which are not always accessible to many educational institutions, especially in developing countries (Yu et al., 2026). Under-representative and biased data quality in datasets add to the challenge, while educators' resistance to this technology often slows down its adoption (Chutia & Baruah, 2024; Farhood et al., 2024; Reina-Parrado et al., 2025). Furthermore, the digital divide between students who have access to technology and those who cannot exacerbate inequities in education (Reina-Parrado et al., 2025). To overcome all of this, policies are needed that support equitable access to technology, educator training, and improved data quality used in deep learning models.

Despite its challenges, deep learning in education offers great opportunities for learning development. However, the challenges that arise, such as the complexity of integrating multi-modal data (such as text and visuals), increase computational costs and complicate model design (Gholami et al., 2026). In addition, issues related to data privacy and accessibility are also in the spotlight, with growing concerns about the protection of students' personal information used to train deep learning models (Nguyen et al., 2023). Limited technological infrastructure, such as fast internet access and adequate hardware, also hamper the adoption of deep learning, particularly in developing countries, where the need for model training often cannot be met (Yang et al., 2023). Plus, deep learning models that are often considered "black-box" make it difficult for educators and students to understand how these technologies make decisions, which can reduce their trust in them (Bai & Stede, 2023). For this reason, solutions that improve transparency and accessibility, as well as adequate training for educators are needed to ensure they can integrate these technologies more effectively in the learning process (Yang et al., 2023).

In addition, other significant challenges include limited technological infrastructure, inadequate data quality, and limited technical skills among educators. In many institutions, especially in developing countries, limited

resources hinder the ability to use deep learning effectively (Jing et al., 2023; P. Wang, 2023). The quality and quantity of data needed to train deep learning models are often lacking, and issues related to student data privacy remain a major concern (Pucchio et al., 2022; P. Wang, 2023). Many educators do not yet have the technical skills to effectively implement this technology in teaching, so adequate training is essential so that they can make the most of the potential of deep learning (Jing et al., 2023; P. Wang, 2023). Additionally, knowledge gaps among students who do not have a technical background in mathematics or computer science are often a barrier to understanding and using deep learning effectively (Pucchio et al., 2022). In some fields, such as medical education, the application of AI is often not prioritized due to the density of the curriculum, which causes this technology to be less introduced to students (Pucchio et al., 2022). Therefore, to overcome these challenges, it is critical to develop solutions that can improve data accessibility, provide training for educators, and update educational curricula to integrate deep learning more effectively.

With the right solutions, deep learning can have a tremendous impact in education. To that end, it is imperative to continue to address these challenges in a more adaptive and inclusive way, ensuring that these technologies can be put to good use by all parties involved.

3. How effective is deep learning in improving the quality of learning and teaching in formal and non-formal education?

The application of deep learning in education, both formal and informal, has been proven to have a significant impact on improving the quality of learning through personalization, adaptation, and real-time feedback. In formal education, this technology allows for the adjustment of teaching materials according to the needs of students. AI-based learning systems, such as Intelligent Tutoring Systems (ITS), can adapt material to students' level of understanding, creating a more personalized and immersive learning experience. These adjustments play an important role in improving student engagement as well as their learning outcomes (Bertl et al., 2026; Yu et al., 2026). Deep learning models such as Graph-based Neural Networks (GBNN) can also be used to predict student learning outcomes, provide more targeted interventions and support higher academic achievement (Farhood et al., 2024).

In addition, in non-formal education, this technology shows tremendous potential, especially in e-learning and online courses. Deep learning not only tailors the content to the student's learning style, but it also provides automated feedback that helps students understand the material better. The system can even detect students' emotions and adjust teaching materials to enhance the learning experience (Chutia & Baruah, 2024; Reina-Parrado et al., 2025; Yang et al., 2023; Yu et al., 2026). Deep learning in e-learning platforms allows for a more flexible and adaptive learning experience, significantly improving engagement and retention of subject matter. The use of this technology also further enriches the interaction between students and the subject matter, providing real-time support through features such as AI-based chatbots (Nguyen et al., 2023).

The application of deep reinforcement learning (DRL) in educational games is one example of how this technology can significantly increase student engagement. Research shows that students who use DRL policies in educational games score higher compared to students who use conventional systems (Yang et al., 2023). This highlights how profound the impact can be when deep learning-based learning technology is used to support a more interactive and enjoyable educational process.

However, while this technology offers a variety of advantages, the main challenge in its implementation is the need for big data as well as computing resources that are not always accessible to all educational institutions. In addition, the resistance of educators and students to new technologies is also a significant obstacle in the implementation of deep learning in the world of education (Bai & Stede, 2023). The gap in access to technology between more advanced and underprivileged educational institutions also exacerbates inequalities in the application of this technology.

Despite these challenges, the potential for deep learning to create a more effective and responsive learning environment to students' needs is enormous. This technology has proven its ability to improve the quality of education both in the classroom and in distance learning. With the various adaptive and personalization capabilities it offers, deep learning has the capacity to significantly change the face of education, making it more inclusive, effective, and affordable at various levels of education. Therefore, although the challenges faced are quite large, the potential offered by this technology makes it feasible to continue to be developed and implemented in various education sectors, both formal and non-formal.

Deep learning in education not only offers better solutions for academic achievement, but it also opens up opportunities for more flexible, adaptive, and personalized learning (Jing et al., 2023; Pucchio et al., 2022; P. Wang, 2023). By continuing to address data access and quality challenges, this technology will further make a major contribution to improving the quality of learning around the world.

4. How has research on the use of deep learning in education progressed in recent years?

The development of research on the use of deep learning in education has made significant progress in recent years, with the widespread adoption of AI technology. The convergence between Natural Language Processing (NLP) and logic-based systems, as described by (Bertl et al., 2026), has paved the way for the automation of relevant learning materials, allowing for materials that are more tailored to students' needs. Meanwhile, (Yu et al., 2026) Highlights the use of transformer models in handling complex student-teacher interaction data, which further aids in personalizing learning and improving the overall learning experience. However, despite the increasing adoption of AI in STEM education, challenges related to the complexity of technology and teacher training are still obstacles that need to be overcome (Reina-Parrado et al., 2025).

One of the major innovations in this study is the shift towards a more adaptive deep learning model. (Farhood et al., 2024) observed the emergence of deep learning models such as GBNN which have better ability to predict learning outcomes, and can adapt to various student conditions. In addition, (Chutia & Baruah, 2024) found that multimodal learning, which combines text, audio, and visuals, provides a more comprehensive understanding of students' emotional states, paving the way for a more holistic and empathetic learning experience. This approach not only provides deeper insights, but also allows for more personalized learning customization.

(Gholami et al., 2026) further explains that techniques such as Swin Transformer, which combines visual and textual data, have resulted in increasingly adaptive multimodal learning models. This allows for improved predictive ability and more precise personalization of learning. In addition, (Nguyen et al., 2023) describe a major shift from rule-based systems to more complex deep learning models, which can handle big data, such as student performance and learning patterns. With the application of NLP and voice recognition, interactions in learning are increasingly intuitive and natural, reducing barriers between students and technology.

Other studies have also noted advances in automated assessments using deep learning, as revealed by (Bai & Stede, 2023). Algorithms such as BERT and LSTM are now being used to produce more accurate and multitasking evaluations, changing the way we assess students' abilities in a more in-depth and comprehensive way. Meanwhile, in the context of broader developments, (Yang et al., 2023) shows that there are three main phases in the application of deep learning in education: starting from basic applications to the implementation of AI curriculum which has been increasingly structured since 2021, with the integration of technology increasingly widespread at various levels of education.

In addition, (Jing et al., 2023) added that deep learning plays a big role in educational data analysis and the design of more adaptive learning paths. Neural networks and reinforcement learning algorithms are now being used to predict student performance and design learning experiences that are more optimal and tailored to individual needs. (P. Wang, 2023) notes that the shift in focus from assessment automation is now more lean towards personalizing the student experience, which allows for more flexible learning and responsiveness to each student's development.

In the medical education sector, this development is attracting more and more attention. (Pucchio et al., 2022) highlight the growing demand for AI-based curriculum in medicine, where college students want more AI-based medical simulations and the use of medical image analysis in their learning. All of these developments confirm that deep learning is increasingly integrated into various aspects of education, both in the classroom and in practical applications, such as in medical education.

Thus, the use of deep learning in education not only increases the efficiency and effectiveness of learning, but also opens up new opportunities to create a more personalized, adaptive, and tailored learning experience to students' individual needs, while facing existing challenges.

Main Information About Data

Title	Authors	Year	Journal	Country	Author Affiliation
Transforming legal texts into computational logic: Enhancing next generation public sector automation through explainable AI decision support	Markus Bertl, Simon Price, Dirk Draheim	2025	International Journal of Cognitive Computing in Engineering	USA, UK, Austria, Estonia	Unisys (USA), University of Economics and Business (Austria), University of Bristol (UK), Tallinn University of Technology (Estonia)
Research on cooperative relationship prediction based on transformer dynamic graph modeling and comparative learning	Wei Yu, Ao Sun, Hongyu Wang, Dandan Chen, Long Zhang, Yanxia Zhao	2025	International Journal of Cognitive Computing in Engineering	China	Zhejiang Yuexiu University, Shaoxing Key Laboratory, Zhejiang University of Science and Technology, Tianjin University
PRISMA Review on Machine Learning in Education: Societal Challenges and Opportunities in Shaping Tomorrow's Citizens	Manuel Reina-Parrado, Pedro Román-Graván, Carlos Hervás-Gómez	2025	European Public & Social Innovation Review	Spain	University of Seville
Evaluating and Enhancing Artificial Intelligence Models for Predicting Student Learning Outcomes	Helia Farhood, Ibrahim Joudah, Amin Beheshti, Samuel Muller	2024	Informatics	Australia	Macquarie University
A review on emotion detection by using deep learning techniques	Tulika Chutia, Nomi Baruah	2024	Artificial Intelligence Review	India	Dibrugarh University
Text-Enhanced Semantic Segmentation via Contrastive Language-Image Pretraining Guided Multi-Modal Feature Fusion with Feature Refinement Approach	M. Gholami, M. Fateh, A. Fateh	2026	International Journal of Engineering, Transactions C: Aspects	Iran	Shahrood University of Technology, Iran University of Science and Technology
A Survey of Current Machine Learning Approaches to Student Free-Text Evaluation for Intelligent Tutoring	Xiaoyu Bai, Manfred Stede	2022	International Journal of Artificial Intelligence in Education (2023)	Germany	Xiaoyu Bai: Applied Computational Linguistics, University of Potsdam, Germany Manfred Stede: Applied Computational Linguistics, University of Potsdam, Germany

Artificial Intelligent-based Teaching and Learning Approaches: A Comprehensive Review	Thuong T. K. Nguyen, Minh T. Nguyen, Hoang T. Tran	2023	International Journal of Evaluation and Research in Education	Vietnam	Faculty of International Training, Thai Nguyen University of Technology, International Training and Cooperation Center
Reinforcement Learning in Education: A Literature Review	Business Fahad Mon, Asma Wasfi, Mohammad Hayajneh, Ahmad Slim, Najah Abu Ali	2023	Informatics	United Arab Emirates, USA	UAE University, The University of Arizona
Effects of Different Educational Interaction Modes on Students' Independent Online Learning Ability	Wang, P.	2023	International Journal of Emerging Technologies in Learning	China	Chongqing Business Vocational College
Exploration of Exposure to Artificial Intelligence in Undergraduate Medical Education: A Canadian Study	Aidan Pucchio, Raahulan Rathagirishnan, Natasha Caton, Peter J. Gariscsak, Joshua Del Papa, Jacqueline Justino Nabhen, Vicky Vo, Wonjae Lee, Fabio Y. Moraes	2022	BMC Medical Education	Canada	Various Canadian Medical Schools, Queen's University
Research Status and Challenges on the Sustainable Development of Artificial Intelligence Courses	Ying Yang, Jinruo Qin, Jing Lei, Yanping Liu	2023	Sustainability	China	Shaanxi University of Science and Technology (Ying Yang, Jinruo Qin, Yanping Liu), Shaanxi University of Technology (Jing Lei)
Research Landscape of Adaptive Learning in Education: A Bibliometric Study on Research Publications from 2000 to 2022	Yuhui Jing, Leying Zhao, Keke Zhu, Haoming Wang, Chengliang Wang, Qi Xia	2023	Sustainability	China	Zhejiang University of Technology (Yuhui Jing, Leying Zhao, Haoming Wang, Chengliang Wang), Chinese University of Hong Kong (Qi Xia), Zhejiang University of Technology (Keke Zhu)

Table 1. Main Information About Data

Based on the attached data, it can be seen that technological developments in education are increasingly significant, with the use of artificial intelligence (AI) and machine learning techniques becoming more widespread. A number of AI-related publications in education emerged in 2023 and 2025, reflecting the growing interest in the application of technology to improve learning experiences and educational outcomes.

One of the prominent topics in this study is the use of AI models to predict student learning outcomes, with various approaches used, such as transformer dynamic graph modeling to predict cooperative relationships in learning, as well as deep learning approaches to detect emotions in educational contexts. These studies show that digital technologies, such as AI-based learning and adaptive learning models, are not only used to support academic achievement, but also to enhance the emotional and interactive aspects of education, which can support the development of students' social and emotional skills.

Countries such as China, the USA, and Spain have made great contributions to research related to the application of technology in education. For example, in China, research on AI-based learning focuses on the development of sustainable courses in AI for education, while in the USA and Canada, technology is used to explore and enhance educational interaction capabilities in medical contexts. These studies lead not only to the application of digital tools in the classroom, but also to the integration of technology in broader professional fields, such as medicine and information technology.

Globally, the study shows a strong trend in the application of technology to create more interactive, personalized, and real-time feedback-based learning experiences. The application of this technology shows great potential in improving student engagement and learning outcomes, as well as preparing them for future challenges in an increasingly technology-based world. Countries with large contributions such as China, the USA, and Spain show that innovation in AI-based education will continue to grow and have a significant impact on the global education system.

Thus, it can be concluded that the application of AI in education has great potential to change the way we learn and teach, increase efficiency, and create more relevant and personalized learning experiences according to individual needs.

Discussion

The application of deep learning in education marks an important shift towards personalized and adaptive learning experiences. Deep learning technologies, particularly models such as Convolutional Artificial Neural Networks (CNNs) and Bi-Directional Short-Term Memory (Bi-LSTM), have improved the ability to analyze large data sets, provide tailored feedback, and tailor educational content to the needs of individual learners (Bertl et al., 2026). These models also allow for the detection of emotional cues from learners, allowing educators to tailor their teaching strategies to learners' emotional states, thus creating a more engaging and supportive learning environment (Chutia & Baruah, 2024).

One of the most significant advances is the development of adaptive learning systems, which dynamically modify learning content based on students' progress and needs. This system uses deep learning to assess student performance on an ongoing basis, making direct adjustments to educational materials, thus ensuring that each student receives the most appropriate resources (Farhood et al., 2024; Yu et al., 2026). The role of these systems is increasingly important, as it can not only increase engagement but also improve learning outcomes through personalized experiences that adapt over time.

Furthermore, the introduction of deep reinforcement learning (DRL) in the educational environment further increases the adaptability of the learning system. DRL-based systems offer direct customization of teaching methods based on student responses during interactive learning sessions, helping educators refine their teaching techniques for optimal outcomes (Yang et al., 2023). The system offers a personalized learning path, focusing on each student's strengths and weaknesses, thereby enhancing their overall educational experience (Nguyen et al., 2023).

The contribution of deep learning goes beyond personalization and ventures into the realm of multimodal learning, where data from various modalities such as text, audio, and images are integrated to create a more comprehensive understanding of educational content. This approach allows students to interact with richer and more contextual information, thus further deepening their understanding of the material (Gholami et al., 2026). As a result, students are not just passive recipients of information, but active participants in an integrated learning process that combines various forms of data for a holistic learning experience (Reina-Parrado et al., 2025).

However, the implementation of deep learning in education is not without challenges. The most pressing issues include the need for large, high-quality data sets and computing resources needed to train deep learning models. This requirement is often a barrier for educational institutions, especially in developing countries where access to these resources is limited (Yu et al., 2026). Further, the quality and representation of data remains crucial, as biased or incomplete data sets can lead to uneven outcomes, which exacerbate educational inequality (Bertl et al., 2026).

Another significant challenge is resistance to the adoption of new technologies within the framework of education. Many educators may not have the technical skills necessary to effectively integrate deep learning into their teaching methods. This resistance is exacerbated by the rapid development of technology, so that many educators find it difficult to keep up with developments (Chutia & Baruah, 2024; Farhood et al., 2024). Therefore, comprehensive training and a more inclusive approach to technology integration are essential to overcome these barriers (P. Wang, 2023)

Furthermore, deep learning models are often described as "black boxes", whose decision-making process is not transparent. This lack of transparency can undermine trust in technology, making it difficult for educators and students to understand how decisions are made by these systems (Bai & Stede, 2023). To address this problem, greater efforts should be made to design deep learning models that can be interpreted and explained, which provide insight into how they work and decision-making (Pucchio et al., 2022; Yang et al., 2023).

Despite these challenges, deep learning has the potential to revolutionize education by making it more personalized, responsive, and data-driven. The key to maximizing its potential lies in overcoming barriers to resource access, data quality, and educator readiness. In the coming years, collaboration between researchers and educators will be crucial in finding solutions that not only address these challenges, but also encourage the continuous integration of deep learning into education in different regions and contexts (Jing et al., 2023; P. Wang, 2023).

Deep learning presents a great opportunity to advance educational practices, but to realize its full potential, a concerted effort is needed to address the technical, social, and ethical challenges that accompany its implementation. Through proper training, better infrastructure, and ongoing research into more transparent and accessible AI models, deep learning can transform education into a more inclusive and effective process that benefits all learners, regardless of their backgrounds or available resources.

Conclusion

The conclusion of this study shows that the application of deep learning technology in education offers great potential to improve the quality of learning with a more personalized, adaptive, and responsive approach to student needs. This technology allows for in-depth analysis of student performance data, provides automated feedback, and tailors learning materials based on individual abilities. The application of deep learning models such as Convolutional Neural Networks (CNN) and Bi-Directional Long Short-Term Memory (Bi-LSTM) has been shown to increase learning effectiveness, including in the fields of medical education and student emotional recognition.

However, the main challenges faced in the implementation of this technology include limited infrastructure, inadequate data quality, and resistance from educators who do not have the technical skills to integrate this technology in learning. In addition, issues related to data privacy and access gaps between educational institutions also exacerbate inequalities in the application of this technology. For this reason, this study recommends the need for policies that support equitable access to technology, adequate training for educators, and technology development that is more transparent and accessible to all parties.

In the context of future research, more studies are needed to address these barriers, especially in terms of developing deep learning models that are more efficient, easy to implement, and can guarantee the privacy of student data. Further research on how deep learning can be integrated with existing curricula as well as how educators and students from diverse backgrounds can benefit from this technology will be crucial. With these steps, deep learning technology can transform education to be more inclusive, effective, and adaptive in the future.

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