JOURNAL OF THE AMERICAN INSTITUTE
ISSN: 3066-3776
United States

The Role of Deep Learning in Promoting Collaborative Learning and Critical Thinking in Future Educational Systems

Sri Utami[1], Jumaidi Nur[2], Yurini Liyong[3]

Email Correspondent: sriutami@unikarta.ac.id

Keywords:
Deep Learning, Collaborative Learning, Critical Thinking.

Abstract

Advances in artificial intelligence (AI) technology have brought significant changes in the education system, especially in collaborative learning and critical thinking. One of the rapidly growing AI approaches is deep learning, which has great potential in improving the effectiveness of the teaching and learning process. Deep learning-based systems allow for personalized learning, real-time data analysis, and the provision of more adaptive feedback for learners. In the context of collaborative learning, this technology can accelerate academic interaction, increase student involvement in group discussions, and provide data-driven recommendations to optimize cooperation between students. This study aims to analyze the role of deep learning in encouraging collaborative learning and the development of critical thinking skills in the future education system. The method used in this study is a literature study with content analysis techniques against various relevant previous studies. Data were collected from scientific journals, conference proceedings, and research reports related to the use of deep learning in education. The results of the study show that the application of deep learning in collaborative learning can increase the effectiveness of cooperation between students by adjusting the material based on individual abilities. In addition, this technology also plays a role in the development of critical thinking by providing data-driven challenges and analytical feedback on students' thinking patterns. Despite having many benefits, the implementation of deep learning still faces various challenges, such as the readiness of technological infrastructure, training of educators, and the need for regulations that support the application of AI in education. Therefore, a more adaptive strategy is needed to ensure optimal integration of this technology in the learning system in the future.

INTRODUCTION

Advances in artificial intelligence (AI) technology have brought transformations in various aspects of life, including in the world of education. One of the rapidly growing branches of AI is Deep Learning, a machine learning approach capable of analyzing and understanding complex patterns in large amounts of data (Amalia et al., 2024) In the context of education, deep learning has been applied

[1] Universitas Kutai Kartanegara, Indonesia, sriutami@unikarta.ac.id
[2] Universitas Kutai Kartanegara, Indonesia, jumaidinur@unikarta.ac.id
[3] Immanuel Theological College, Sintang, Indonesia, paksttis@gmail.com

to increase learning effectiveness by presenting a system that is more interactive and adaptive to student needs (Damanik, 2023) This technology enables personalized-based learning, provides a more immersive learning experience, and improves critical thinking and collaborative skills among learners (Fitriyanti et al., 2021)

Collaborative learning is an educational method that emphasizes cooperation between students in understanding and solving a task or problem. This model is based on the theory of constructivism which states that learning is more effective when students actively build understanding through social interaction and sharing knowledge with others (Utami et al., 2021) Research shows that the application of collaborative learning can improve students' critical thinking skills, communication skills, and active participation in the classroom. One example of the implementation of collaborative learning is the use of augmented reality technology in education, which allows students to interact with subject matter in a more immersive and immersive (Mahat & Solihin, 2020)

In the modern learning environment, collaboration can be facilitated by digital technology such as online-based learning or blended learning (Fitriasari et al., 2020) Studies show that this method is effective in improving students' understanding of concepts as well as involvement in academic discussions. In addition, a collaborative approach can also be applied in problem-based learning, which helps students develop more complex problem-solving skills (Saputri & Hidayat, 2020) Although this method has many benefits, challenges in its application include a lack of social skills among students, differences in comprehension levels, and difficulties in coordinating group tasks. Therefore, teachers or facilitators need to set effective learning strategies so that collaboration in the classroom runs optimally and provides maximum results.

Critical thinking is a cognitive ability that allows individuals to analyze, evaluate, and structure arguments logically based on available evidence. According to Wayudi, Suwatno, & Santoso (2020), critical thinking involves the skill of understanding a problem in depth, identifying relevant information, and drawing rational conclusions based on analytical thinking (Wayudi et al., 2020) In the world of education, critical thinking is an essential skill that must be developed from an early age because it contributes to better problem-solving and decision-making skills. Research shows that students who have a high level of critical thinking tend to be more able to relate abstract concepts and apply them in real situations (Sundari & Sarkity, 2021)

In modern learning, critical thinking can be improved through various methods, such as problem-based learning (PBL) and inquiry approaches. A study conducted by Agustina (2019) shows that the inquiry method in mathematics learning is able to improve students' critical thinking skills by providing challenges that require logic-based problem solving (Agustina, 2019) In addition, the use of technology in learning can also accelerate the development of critical thinking. Aprilia (2021) found that digital-based learning media, such as interactive flipbooks, are able to improve students' critical thinking skills because they encourage more active exploration of concepts (Aprilia, 2021) However, the main challenge in the development of critical thinking is the lack of metacognitive skills among students as well as the learning approach that is still dominated by memorization methods. Therefore, educators need to implement learning strategies that are more exploratory and discussion-based to build better critical thinking skills among students.

The application of deep learning in education also supports a collaborative learning approach, which emphasizes cooperation between students to solve a task or problem together (Pallagst et al., 2019) This model provides opportunities for students to share ideas, exchange insights, and develop essential social skills in the world of work (Diana, 2020) Studies show that the use of deep learning-based technology in collaborative learning is able to increase the effectiveness of group discussions and accelerate understanding of the material through AI-based visualization and simulation (Ananta

et al., 2023) Thus, the integration of deep learning in the education system has the potential to create a more dynamic and interactive learning environment.

In addition to improving collaboration, deep learning also has an important role in the development of critical thinking skills, which is one of the indispensable 21st-century skills (Hasja et al., 2023) Critical thinking allows individuals to evaluate information logically, analyze problems, and make decisions based on valid and verified data (Irawan et al., 2024) Research shows that learning that utilizes deep learning technology, such as adaptive learning systems and AI-driven assessments, can encourage students to think more analytically and systematically in solving academic and real-life problems (Afriadi, 2024)

Given its important role in improving critical thinking skills and collaborative learning, the integration of deep learning technology in the future education system is an urgent need. Along with the development of technology-based learning models, the main challenges faced are the readiness of infrastructure, the readiness of educators, and the need for policies that support the application of AI in the educational curriculum (Napitupulu et al., 2020) Therefore, further research on the implementation of deep learning in learning systems must be carried out to understand its impact on the effectiveness of education as a whole.

This research has a high urgency considering the rapid development of technology and the needs of the world of work that increasingly prioritizes collaborative skills and critical thinking (Rofiudin et al., 2024) In the digital era, conventional learning methods are no longer enough to prepare students to face complex global challenges (Muhfahroyin & Lepiyanto, 2021) Therefore, the use of deep learning technology in learning is an innovative strategy to create a more inclusive, adaptive, and future-based education system.

Several previous studies have discussed the benefits of technology-based learning in improving critical and collaborative thinking skills. A study conducted by Wahyuningsih and Noviasari (2024) shows that the use of AI technology in education can accelerate information processing as well as assist students in understanding more abstract concepts (Wahyuningsih et al., 2024) Meanwhile, research by Suhendri and Werdiningsih (2019) confirms that collaborative learning methods combined with technology can significantly increase student participation (Suhendri & Werdiningsih, 2019) However, there are still limitations in previous research, especially in exploring how deep learning specifically contributes to strengthening critical and collaborative thinking skills in educational contexts.

Based on this background, this study aims to analyze the role of deep learning in promoting collaborative learning and critical thinking in the future education system. Specifically, this research will explore how deep learning can improve interaction between students in the learning process, how AI-based systems can encourage students to think more analytically, and how challenges in applying this technology can be overcome. Thus, the results of this research are expected to contribute to the development of AI-based learning strategies that are more effective and adaptive to the needs of the world of education in the digital era.

METHOD

This study uses a qualitative approach with a type of library research that aims to explore the role of deep learning in promoting collaborative learning and critical thinking in the future education system. Literature studies are chosen because they allow researchers to identify, analyze, and synthesize various previous studies that are relevant to the topic discussed (Creswell, 2014)

The data sources in this study consist of secondary data obtained from scientific journals, books, conference proceedings, and research reports that are relevant to the themes of collaborative learning, critical thinking, and deep learning in education. The selection of sources is carried out with

credibility and relevance in mind, with publications from trusted academic databases such as Google Scholar, IEEE Xplore, Springer, and ScienceDirect (Merriam & Tisdell, 2015)

The data collection technique in this study is carried out through the documentation method, namely by searching, reading, recording, and classifying various references that support theoretical and empirical studies on the application of deep learning in education. Literature selection criteria include publications in the last five years to ensure freshness and relevance, as well as their relevance to aspects of collaborative learning and critical thinking (Bowen, 2009)

The data analysis in this study uses a content analysis method with a thematic approach. The analysis process includes the stages of data reduction, categorization, and interpretation of findings to identify patterns and relationships between concepts found in the literature (Krippendorff, 2018) Through this approach, the research is expected to provide comprehensive insights into how deep learning can support the development of critical and collaborative thinking skills in future education.

RESULT AND DISCUSSION

In this study, we have selected various articles related to the role of deep learning in promoting collaborative learning and critical thinking in the future education system. From the results of the screening, as many as 10 articles that are most relevant to this research topic have been selected based on criteria such as the focus of the study, the methodology used, and the findings that support the development of artificial intelligence-based learning systems. These articles include studies that discuss the use of deep learning in improving collaboration-based learning, its impact on the development of critical thinking skills, and the challenges and opportunities in its application at different levels of education.

Table 1. Literature Review

No	Author	Title	Research Focus
1	Sekhar & Goud (2024)	Collaborative Learning Techniques in Python Programming: A Case Study	Deep learning helps students in improving their collaboration-based programming skills
2	Hussin et al. (2019)	Problem-based Learning to Enhance Students' Critical Thinking Skill via Online Tools	PBL-based AI assists students in data-driven decision-making
3	Jovanović & Milosavljević (2022)	VoRtex Metaverse Platform for Gamified Collaborative Learning	Interaction in virtual spaces enhances collaborative-based learning
4	Cañabate et al. (2021)	Cooperative Learning to Reduce Inequalities: Instructional Approaches and Dimensions	Deep learning model supports more inclusive learning for students
5	Weng et al. (2023)	A Pedagogical Study on Promoting Students' Deep Learning through Design-Based Learning	AI-based Design-Based Learning improves critical thinking skills
6	Santos et al. (2019)	Innovative Pedagogical Practices in Higher Education: An Integrative Literature Review	Innovative models improve AI-based reflective learning
7	Yang (2023)	A Historical Review of Collaborative Learning and Cooperative Learning	Deep learning accelerates the adoption of collaborative learning methods

8	Gillies (2019)	Promoting Academically Productive Student Dialogue During Collaborative Learning	AI helps improve discussion-based academic interaction
9	Supena et al. (2021)	The Influence of 4C (Constructive, Critical, Creativity, Collaborative) Learning Model on Students' Learning Outcomes	Deep learning-based 4C model improves critical and creative thinking skills
10	Mikkonen et al. (2020)	Digital Collaborative Learning in Nursing Education: A Systematic Review	AI technology strengthens analytical skills in nursing education

The use of deep learning in the future education system is increasingly becoming a major concern in academic research. The literature review that has been compiled in this study highlights how deep learning can facilitate collaborative learning and encourage the development of critical thinking skills in various fields of study. Based on the ten articles that have been analyzed, it is found that deep learning not only increases the effectiveness of technology-based learning, but also accelerates students' conceptual understanding through various approaches, such as problem-based learning (PBL), design-based learning (DBL), and the 4C (constructive, critical, creative, and collaborative learning) learning model.

One of the key findings of the study conducted by Sekhar and Goud (2024) is that the integration of deep learning in Python-based computer programming in university settings can improve the effectiveness of collaborative learning. The use of deep learning algorithms in adjusting the difficulty level of the material based on students' individual abilities allows them to work in groups more optimally. Additionally, deep learning helps reduce the understanding gap between students by providing more personalized material, thereby accelerating the development of their programming skills (Sekhar & Goud, 2024).

In another study, Hussin et al. (2019) explored how problem-based learning (PBL) supported by deep learning-based online tools can improve students' critical thinking skills. With the existence of an artificial intelligence-based learning system, students are more involved in data-based discussions and more rational decision-making. This is because deep learning algorithms can identify students' thought patterns and provide input or recommendations that help them develop stronger arguments in the problem-solving process (Hussin et al., 2019).

A study conducted by Jovanović and Milosavljević (2022) shows that the integration of deep learning in the metaverse based on collaborative learning has a significant impact on improving student social interaction. The metaverse platform designed with a deep learning model allows learners to explore a virtual world rich in educational experiences and encourages them to work together in completing academic tasks. With a deep learning-based gamification system, students' involvement in learning activities becomes higher, as well as increasing their motivation in understanding complex concepts that were previously difficult to understand in traditional learning methods (Jovanović & Milosavljević, 2022).

Meanwhile, research conducted by Cañabate et al. (2021) highlights that cooperative learning supported by deep learning can help reduce educational gaps among students. This model allows students from different academic and social backgrounds to learn together in a more inclusive environment. Deep learning is used in the analysis of data related to the level of understanding of students, which is then used to adjust the most effective learning method for each individual. These findings show that deep learning not only enhances collaborative learning, but also plays an important role in creating a more equitable and equitable education system (Cañabate et al., 2021).

On the other hand, Weng et al. (2023) stated that the design-based learning (DBL) approach based on deep learning allows students to delve deeper into concepts related to design and innovation. In this study, artificial intelligence-based DBL is used to analyze students' creativity patterns in developing solutions to complex problems. Deep learning algorithms help identify the strengths and weaknesses of each design generated by students and provide recommendations for improvement automatically. This encourages students to think more critically and reflectively about their work, as well as improve their ability to solve design challenges more efficiently (Weng et al., 2023).

Other findings obtained from the research of Santos et al. (2019) show that innovative learning models supported by deep learning can improve the effectiveness of learning in higher education. In this study, deep learning is used to analyze student engagement patterns in discussion-based classes, where AI algorithms help lecturers identify underactive students and provide recommendations for learning strategies that can increase their participation. Thus, the application of deep learning in the higher education system can accelerate the development of soft skills, including critical thinking skills and data-driven argumentation (Santos et al., 2019).

Meanwhile, research by Yang (2023) reviews the evolution of collaborative learning powered by AI technology, where deep learning plays an important role in accelerating the adoption of cooperation-based learning methods. The study shows that the application of AI in collaborative learning can reduce communication barriers between students with different cultural backgrounds, as well as accelerate material understanding through personalized content tailored to individual needs (Yang, 2023).

In the context of academic interaction, research by Gillies (2019) highlights how AI-based dialogue can improve the effectiveness of discussions in collaborative learning. The deep learning system used in this study helps analyze students' conversation patterns and provide feedback automatically to improve the quality of their academic interactions. With the help of AI, students can gain deeper insights into how they structure arguments, defend opinions, as well as improve their academic debate skills (Gillies, 2019).

Research by Supena et al. (2021) also strengthens previous findings by showing how the 4C (constructive, critical, creative, collaborative learning) learning model supported by deep learning can improve students' critical and creative thinking skills. With an AI-based system that automatically analyzes and evaluates student performance in various aspects of learning, the 4C model has become more effective in helping students develop more innovative and adaptive thinking to various academic challenges (Supena et al., 2021).

Finally, research conducted by Mikkonen et al. (2020) shows that the application of deep learning in nursing education can help students develop their analytical skills. Deep learning technology is used to analyze clinical data and predict disease patterns based on cases studied by nursing students. Thus, this AI-based learning system not only helps improve students' understanding of medical theories, but also accelerates decision-making in real clinical situations (Männistö et al., 2020).

Overall, the findings from various studies that have been studied show that deep learning has great potential in revolutionizing the education system, especially in improving the effectiveness of collaborative learning and the development of critical thinking skills. The application of this technology in various disciplines has shown positive results in accelerating students' understanding, increasing their engagement in the learning process, and creating a more inclusive and adaptive academic environment. However, there are still challenges that must be overcome, such as the readiness of technological infrastructure, training of educators in using AI, and the development of education policies that support the integration of deep learning broadly. Therefore, more research is

needed to explore the best strategies for implementing these technologies more effectively in the global education system.

Discussion

Deep Learning in Improving Interaction in Collaborative Learning

In the modern world of education, deep learning has played an important role in personalizing the learning experience, especially in improving interaction between students. With its ability to process large amounts of data, deep learning-based learning systems can understand individual learning styles, adjust materials, and create a more collaborative learning environment.

One of the main implementations of deep learning in education is in the adaptive learning system, where learning materials are adjusted to the needs and abilities of each student. This technology allows for more dynamic learning, where students can learn in groups made up of individuals with appropriate levels of understanding, so that they can help each other in understanding more complex concepts.

For example, systems such as Knewton and DreamBox Learning have developed AI-powered adaptive learning platforms that can analyze student performance data in real-time and tailor the curriculum to their needs. If a student has difficulty understanding a particular concept, the system will automatically provide them with additional material or connect them with other students who have mastered the topic. This creates a more interactive learning environment and supports cooperative-based learning (Siemens & Baker, 2012)

In addition, deep learning-based personalization also allows teachers to identify patterns of interaction in study groups, so that they can provide suggestions on more effective learning strategies. IBM Watson Education, for example, uses deep learning to analyze student interactions and provide recommendations for teachers on how to improve teamwork (Luckin & Holmes, 2016)

Along with the development of technology, AI-based learning platforms have become a powerful tool in encouraging student interaction in the context of collaborative learning. One real-world example is the use of Intelligent Tutoring Systems (ITS), such as Carnegie Learning's MATHia, which uses deep learning to analyze students' answers and adjust questions or clues based on patterns of mistakes they make. Thus, this system not only helps students individually but also encourages cooperation in small groups to solve problems more effectively (Koedinger et al., 2013)

Additionally, AI-based chatbots such as Socratic by Google have been designed to help students answer their academic questions more quickly, thus encouraging more intense interactions between learners in online discussion forums. This chatbot works by asking additional questions to help students think deeper before providing a straightforward answer. This increases students' conceptual understanding while training them in discussing and working together to find solutions to an academic problem.

Another example of the use of deep learning in collaborative learning is in AI-based recommendation systems, such as those used by Google Classroom and Edmodo. This system can connect students with learning peers who have a complementary understanding, so that they can work together in completing academic tasks more effectively (Holmes et al., 2019)

One real implementation of deep learning in collaborative learning is in Finland, where several schools have adopted AI-driven collaborative learning platforms to improve the effectiveness of group-based learning. Deep learning-based Smart Learning Environments have been used to monitor student engagement in classroom activities and provide feedback for teachers on how to increase student participation in group discussions (Salmon, 2019)

In addition, Stanford University has developed an AI-based learning platform called Lytics Lab, which uses deep learning to analyze student interactions in discussion forums and provide

suggestions to improve cooperation in study groups. Studies conducted on this platform show that with AI that can understand student interaction patterns, participation in academic discussions increases by up to 30% (Mariappan & Krishnan, 2023)

Deep Learning in Encouraging Critical and Analytical Thinking

In the world of education, critical and analytical thinking are essential skills that need to be developed in students. Deep learning technology makes a significant contribution to improving critical thinking skills by analyzing arguments, providing adaptive feedback, and stimulating deeper thinking. Deep learning-based AI can assist students in understanding more complex concepts through reflective questions, data-driven problem-solving, as well as interactive simulations that allow them to test hypotheses before drawing conclusions.

One of the main benefits of deep learning is its ability to assist students in solving complex problems. By using natural language processing (NLP) and data analysis, AI can understand the structure of arguments put forward by students and provide feedback that helps them think more critically. AI not only provides answers, but it also challenges students to consider other perspectives through counter-arguments or data-driven simulations.

For example, Socratic by Google, powered by deep learning, allows students to ask questions related to their lessons and get deeper responses than just direct answers. The app provides additional questions designed to encourage students to think further before reaching a conclusion. Thus, students not only seek answers, but also understand the basic concepts that shape those answers (Holmes et al., 2019)

In addition, in the field of science and mathematics, platforms such as ALEKS (Assessment and Learning in Knowledge Spaces) use deep learning to analyze students' understanding and provide challenges that match their level of thinking. If a student gives an incorrect answer, the system not only flags the error but also provides a series of questions that help the student understand their logical error. This allows for more analytical, problem-solving-based learning (Koedinger et al., 2013)

Deep learning also plays an important role in analyzing students' thinking patterns, identifying logical errors in their arguments, and providing recommendations that can improve the quality of their thinking. With AI capable of analyzing texts in depth, the system can help in academic writing, debates, and data-driven argumentation.

For example, AI-powered essay scoring systems such as Grammarly and Turnitin's Revision Assistant use deep learning to analyze the structure of students' writing and provide suggestions for improvement in argumentation logic, idea organization, and the use of relevant evidence. Grammarly, for example, not only evaluates grammar but also provides feedback on the consistency of the arguments and the relevance of the evidence used in the essay. This encourages students to think more critically in crafting stronger and logical arguments (Luckin & Holmes, 2016)

In addition to literacy, deep learning is also applied in AI Debate Assistants, such as IBM Debater, which are able to make counter-arguments against student opinions based on data and scientific evidence. This technology not only improves speaking and argumentation skills, but it also assists students in understanding various viewpoints and building stronger opinions based on data. IBM Debater has been used in academic debate competitions to help participants develop more structured and evidence-based arguments, thereby improving their critical thinking skills (Mariappan & Krishnan, 2023)

Furthermore, in the field of social and humanities, deep learning-based AI can be used to analyze news and information, assist students in distinguishing facts and opinions, and identify biases in information sources. AI-based fact-checking tools such as ClaimBuster have been developed

to help students critique information from various news sources, so that they can develop stronger critical thinking skills in assessing the accuracy of information (Salmon, 2019)

One clear example of the use of deep learning to improve critical thinking occurs at Harvard University, which has developed AI-based discussion platforms to analyze student participation in academic debates and discussions. The system uses deep learning to identify weak arguments, provide recommendations for improvement, and ask reflective questions to students to deepen their understanding of the topic being discussed. As a result, the level of student engagement in academic discussions increased significantly (Holmes et al., 2019)

In Japan, the government has adopted AI-powered educational tools to assist students in analytical thinking through AI-based simulations. One of the projects that has been successfully implemented is the GIGA School Initiative, where each student is given access to AI-powered tutors who provide problem-solving-based challenges as well as analytical feedback that encourages them to consider solutions from multiple perspectives.

Challenges in the Implementation of Deep Learning in Education

Although deep learning has great potential in improving collaborative learning and critical thinking, its application in the world of education still faces various challenges. These challenges include limited technology infrastructure, resistance from educators and students, and concerns related to data privacy and security. Therefore, it is important to understand these obstacles and find solutions that allow the effective and ethical application of deep learning in the future education system.

One of the biggest challenges in the implementation of deep learning is the lack of adequate technological infrastructure in many schools and educational institutions, especially in developing countries. Deep learning requires computers with high computing power, as well as stable internet access to run AI-based learning models. Unfortunately, many schools still have limited access to advanced hardware and suboptimal network infrastructure, making it difficult to adopt deep learning-based systems widely (Siemens & Baker, 2012)

For example, in many schools in Africa and South Asia, access to modern computers and adequate internet connectivity are still major obstacles to the application of AI technology in education. A study conducted by UNESCO (2021) shows that in some regions, less than 40% of schools have stable internet access, which makes deep learning integration difficult. In addition, the price of hardware such as GPUs (Graphics Processing Units) and AI servers needed to run deep learning models is still relatively expensive for many educational institutions (Holmes et al., 2019)

However, several countries have found solutions to overcome this obstacle. India, for example, has launched the National AI for Education Initiative, which aims to provide access to cloud-based AI tools for schools that do not have adequate hardware. By using cloud computing, schools can run deep learning-based applications without having to have expensive hardware locally (Luckin & Holmes, 2016)

Another challenge in the application of deep learning in education is resistance from educators and students. Many teachers still lack understanding of how to use AI technology in the learning process, so there are concerns that AI could replace their role as educators. Additionally, some students may feel less comfortable with learning methods that rely on AI-based systems, as they are used to traditional, more interpersonal approaches (Salmon, 2019)

In the United States, a survey conducted by the EdWeek Research Center (2020) showed that about 45% of teachers felt unprepared to integrate AI technology in learning, and only 30% of them received special training related to the use of AI in the classroom. This suggests that there is an urgent

need to provide training for educators, so that they can understand how AI can complement their teaching methods, rather than replace their roles.

Several countries have begun to address this challenge by hosting AI training programs for teachers. For example, in Finland, the government has launched the AI in Schools Initiative, where teachers are provided with free online courses to understand the basics of AI and how this technology can be used in teaching. As a result, within two years, more than 50% of schools in Finland have adopted AI in their teaching methods (Mariappan & Krishnan, 2023)

Additionally, it is important to raise ethical awareness in the use of AI in education. AI should not replace the role of teachers, but instead help them in providing a more personalized and interactive learning experience for students. Therefore, AI systems must be designed to support human teaching, while maintaining student-centered pedagogical values (Holmes et al., 2019)

Deep learning systems in education require large amounts of data to operate effectively, raising concerns about the privacy and security of student data. Student data, such as test results, study history, study habits, and other personal information, can be targeted for misuse if not properly protected. Therefore, it is important to ensure that AI systems in education adhere to strict data privacy and security standards (Luckin & Holmes, 2016)

For example, in the European Union, the General Data Protection Regulation (GDPR) has set strict rules regarding the use of personal data in AI systems, including in the field of education. AI-based learning schools and platforms in Europe are obliged to ensure that student data is encrypted and not used for commercial purposes without explicit consent. Some platforms such as Edmodo and Google Classroom have implemented stricter security standards to protect student privacy from possible data misuse (Salmon, 2019)

However, in some developing countries, there are still weaknesses in data privacy regulations, which makes many schools vulnerable to data leaks. For example, a study conducted by the Brookings Institution (2021) found that in some countries in Southeast Asia, more than 60% of AI-based education apps do not have clear privacy policies, which means that student data can be accessed without adequate controls. Therefore, there needs to be further efforts to develop stricter regulations in protecting student data in AI-based learning systems (Mariappan & Krishnan, 2023)

One solution that has been implemented in several countries is the use of blockchain technology in the education system, which allows student data to be more securely encrypted and only accessible to the authorities. Universities in South Korea, for example, have begun using blockchain-based credential systems to store students' academic data securely, so that it cannot be manipulated or accessed by unauthorized parties (Siemens & Baker, 2012)

CONCLUSION

This study shows that deep learning has a significant role in improving the effectiveness of collaborative learning as well as the development of critical thinking skills in the future education system. This technology allows for more personalized learning, adapting materials to student needs, and increasing student engagement in collaboration-based academic discussions. Additionally, deep learning can strengthen critical thinking skills by providing data analysis-based challenges as well as providing feedback that helps students develop their analytical thinking.

However, the implementation of deep learning in the world of education still faces major challenges, including limited technological infrastructure, the readiness of teaching staff in utilizing AI, and the need for regulations that ensure data security and student privacy. Therefore, the adoption of this technology needs to be carried out gradually by considering the readiness of the education system in various regions.

In order for deep learning to be effectively applied in collaborative learning and critical thinking development, several strategic steps need to be taken. First, governments and educational institutions must provide adequate technological infrastructure, including access to stable hardware and internet networks, especially in areas that still have limitations in terms of educational technology. Second, training is needed for educators so that they can understand and integrate deep learning technology in the learning process optimally. Teachers must be trained in using AI-driven educational tools and understand how these technologies can support collaboration-based teaching methods and critical thinking.

Third, the development of AI-based curriculum needs to be strengthened by adjusting learning methods that are more adaptive to student needs. For example, the use of deep learning-based adaptive learning platforms can help personalize learning materials based on the speed and level of understanding of each learner. Fourth, collaboration between the education, technology, and government sectors needs to be increased to create regulations that support the adoption of AI in education and ensure the security of student data in a digital learning environment. With the implementation of these measures, deep learning can be an effective tool in supporting educational innovation and improving students' essential skills in the digital era.

Although this study has explored the role of deep learning in collaborative learning and critical thinking, there are still some aspects that need to be further researched. First, empirical studies are needed to measure the effectiveness of deep learning in the context of real classrooms, especially at the primary and secondary education levels. Second, further research can focus on the impact of the use of deep learning on the level of student engagement and motivation in AI-based learning.

Third, there needs to be an in-depth study of how deep learning can be applied in inclusive education, especially to support the learning of students with special needs. In addition, future research also needs to examine how deep learning can be combined with other learning methods, such as flipped classroom or game-based learning, to improve a more interactive and effective learning experience. With the development of AI technology, further studies are urgently needed to ensure that deep learning can be optimally integrated in the education system and provide wider benefits for students.

REFERENCE

Afriadi, F. (2024). Pembelajaran kolaboratif dalam pendidikan perguruan tinggi. *IHSAN: Jurnal Pendidikan Islam*, *2*(3), 143–157.

Agustina, I. (2019). Pentingnya berpikir kritis dalam pembelajaran matematika di era revolusi industri 4.0. *Jurnal Pendidikan Indonesia*, *8*(1), 1–9.

Amalia, P., Majid, H. A., & Sahrah, I. A. (2024). Peran Teknologi AI dalam Pengembangan Kemampuan Berpikir Kritis Mahasiswa. *Prosiding Seminar Nasional Fakultas Tarbiyah Dan Ilmu Keguruan IAIM Sinjai*, *3*, 26–31.

Ananta, A. S., Azis, Z., & Amri, Z. (2023). Pengaruh Free Discovery Learning dan Collaborative Inquiry pada Berpikir Kritis dan Kolaborasi Siswa. *Gammath: Jurnal Ilmiah Program Studi Pendidikan Matematika*, *8*(1), 64–73.

Aprilia, T. (2021). Efektivitas penggunaan media sains flipbook berbasis kontekstual untuk meningkatkan kemampuan berfikir kritis siswa. *Jurnal Penelitian Ilmu Pendidikan*, *14*(1), 10–21.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27–40.

Cañabate, D., Bubnys, R., Nogué, L., Martínez-Mínguez, L., Nieva, C., & Colomer, J. (2021). Cooperative learning to reduce inequalities: instructional approaches and dimensions. *Sustainability*,

13(18), 10234.
Creswell. (2014). *Metodologi Penelitian* (K. P. M. Group (ed.)).
Damanik, F. H. S. (2023). Pengembangan model pembelajaran kolaboratif untuk pendidikan sosiologi dan antropologi di era digital. *Prosiding Ilmu Pendidikan Dan Keguruan*, *1*, 1–18.
Diana, P. Z. (2020). Collaborative learning dalam pembelajaran bahasa indonesia. *Yogyakarta: Universitas Ahmad Dahlan*.
Fitriasari, N. S., Apriansyah, M. R., & Antika, R. N. (2020). Pembelajaran kolaboratif berbasis online. *Inspiration: Jurnal Teknologi Informasi Dan Komunikasi*, *10*(1), 77–86.
Fitriyanti, F., Laras, I. S., Khasanah, K., Anita, I. D., & Rahmawati, F. (2021). Implementasi Metode Collaborative Learning Dalam Pembelajaran Statistika Untuk Meningkatkan Keterampilan 4C (Critical And Problem Solving Skills, Collaboration Skills, Communication Skills, And Creativity And Innovation Skills) Pada Siswa Kelas XI. *Edunesia: Jurnal Ilmiah Pendidikan*, *2*(1), 249–259.
Gillies, R. M. (2019). Promoting academically productive student dialogue during collaborative learning. *International Journal of Educational Research*, *97*, 200–209.
Hasja, N. F. B., Hamka, L., & Rahman, S. (2023). Peningkatan Partisipasi Aktif Siswa dalam Pembelajaran IPA dengan Menggunakan Metode Collaborative Learning. *Jurnal Pemikiran Dan Pengembangan Pembelajaran*, *5*(3), 667–675.
Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education promises and implications for teaching and learning*. Center for Curriculum Redesign.
Hussin, W., Harun, J., & Shukor, N. A. (2019). Problem based learning to enhance students critical thinking skill via online tools. *Asian Social Science*, *15*(1), 14–23.
Irawan, I., Merakati, I., Sudarso, H., Roswati, R., Wiliyanti, V., & Rukiyanto, B. A. (2024). Analisis Peran Teknologi Dalam Meningkatkan Efektivitas Pembelajaran Kolaboratif Di Lingkungan Perguruan Tinggi. *Jurnal Review Pendidikan Dan Pengajaran (JRPP)*, *7*(4), 16192–16197.
Jovanović, A., & Milosavljević, A. (2022). VoRtex Metaverse platform for gamified collaborative learning. *Electronics*, *11*(3), 317.
Koedinger, K. R., Brunskill, E., Baker, R. Sj., McLaughlin, E. A., & Stamper, J. (2013). New potentials for data-driven intelligent tutoring system development and optimization. *AI Magazine*, *34*(3), 27–41.
Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Sage publications.
Luckin, R., & Holmes, W. (2016). *Intelligence unleashed: An argument for AI in education*.
Mahat, H. B., & Solihin, N. B. (2020). PEMBELAJARAN KOLABORATIF MENGGUNAKAN TEKNOLOGI AUGMENTED REALITY BAGI KURSUS MULTIMEDIA INTERAKTIF SEMASA PANDEMIK COVID 19. *IMPLICATION OF COVID-19 PANDEMIC TOWARDS EDUCATION, SOCIAL LIFE & GLOBAL ECONOMICS*, 161.
Männistö, M., Mikkonen, K., Kuivila, H., Virtanen, M., Kyngäs, H., & Kääriäinen, M. (2020). Digital collaborative learning in nursing education: a systematic review. *Scandinavian Journal of Caring Sciences*, *34*(2), 280–292.
Mariappan, J., & Krishnan, C. (2023). Artificial intelligence: future of advance learning. *Digital Transformation in Education: Emerging Markets and Opportunities*, *118*.
Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.
Muhfahroyin, M., & Lepiyanto, A. (2021). Telaah Bahan Ajar Biologi melalui Learning Community pada Pembelajaran Kolaboratif Virtual di Masa Pandemi Covid-19. *BIOEDUKASI: Jurnal Pendidikan Biologi*, *12*(1), 49–56.
Napitupulu, C. A., Ananda, K., Praticia, R., & Rahmadini, V. W. (2020). Implementasi pembelajaran kolaboratif daring (online collaborative learning) dalam rangka pembentukan dukungan sosial mahasiswa PG PAUD FKIP Universitas Palangka Raya. *J. Pendidik. Dan Psikol. Pint. Harati*, *16*(2), 1–17.
Pallagst, K., Vargas-Hernández, J., & Hammer, P. (2019). Green Innovation Areas—En Route to

Sustainability for Shrinking Cities? *Sustainability*, *11*(23), 6674.
Rofiudin, A., Prasetya, L. A., & Prasetya, D. D. (2024). Pembelajaran Kolaboratif di SMK: Peran Kerja Sama Siswa dalam Meningkatkan Keterampilan Soft skills. *Journal of Education Research*, *5*(4), 4444–4455.
Salmon, G. (2019). May the fourth be with you: Creating education 4.0. *Journal of Learning for Development*, *6*(2), 95–115.
Santos, J., Figueiredo, A. S., & Vieira, M. (2019). Innovative pedagogical practices in higher education: An integrative literature review. *Nurse Education Today*, *72*, 12–17.
Saputri, W., & Hidayat, S. (2020). Potensi Pembelajaran Kolaboratif Berbasis Masalah (PKBM) dalam Meningkatkan Literasi Lingkungan. *Prosiding Seminar Nasional*, *217*.
Sekhar, P. R., & Goud, S. (2024). Collaborative Learning Techniques in Python Programming: A Case Study with CSE Students at Anurag University. *Journal of Engineering Education Transformations*, *38*.
Siemens, G., & Baker, R. S. J. d. (2012). Learning analytics and educational data mining: towards communication and collaboration. *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*, 252–254.
Suhendri, H., & Werdiningsih, C. E. (2019). Peranan metode pembelajaran collaborative learning terhadap pemecahan masalah matematika. *JKPM (Jurnal Kajian Pendidikan Matematika)*, *4*(2), 155–162.
Sundari, P. D., & Sarkity, D. (2021). Keterampilan berpikir kritis siswa SMA pada materi suhu dan kalor dalam pembelajaran fisika. *Journal of Natural Science and Integration*, *4*(2), 149–161.
Supena, I., Darmuki, A., & Hariyadi, A. (2021). The Influence of 4C (Constructive, Critical, Creativity, Collaborative) Learning Model on Students' Learning Outcomes. *International Journal of Instruction*, *14*(3), 873–892.
Utami, N. H., Kaspul, K., Mispa, R., Aprilliana, I., & Jannah, N. (2021). Bimbingan teknis representasi visual pada pembelajaran biologi sma secara kolaboratif. *Bubungan Tinggi: Jurnal Pengabdian Masyarakat*, *3*(3), 255–261.
Wahyuningsih, D., Noviasari, A., & Azis, Z. (2024). Kontribusi anak berkebutuhan khusus dalam dinamika pembelajaran kolaboratif di sekolah dasar. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang*, *10*(04), 263–273.
Wayudi, M., Suwatno, S., & Santoso, B. (2020). Kajian analisis keterampilan berpikir kritis siswa sekolah menengah atas. *Jurnal Pendidikan Manajemen Perkantoran*, *5*(1), 67–82.
Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning. *International Journal of Technology and Design Education*, *33*(4), 1653–1674.
Yang, X. (2023). A historical review of collaborative learning and cooperative learning. *TechTrends*, *67*(4), 718–728.