

The Transformation of AI-Based Learning in Strengthening Students' Critical Thinking Skills in the Digital Era

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Abstract: The advancement of digital technology, particularly Artificial Intelligence (AI), has significantly influenced the field of education. The emergence of AI has enabled learning processes to become more modern, effective, and responsive to students' individual needs. The integration of AI in education supports students in becoming more independent, active, and engaged learners. This study aims to examine the role of AI-based learning in enhancing students' critical thinking skills in the digital era. The research employs a literature review method by collecting and analyzing various sources, including scholarly journals, books, and previous studies related to AI and critical thinking. The findings indicate that the implementation of AI in learning can assist students in understanding information, analyzing problems, and formulating solutions and decisions in a more logical manner. Furthermore, AI technology contributes to creating a more flexible and engaging learning environment. However, the effective use of AI still requires teacher guidance and adequate digital literacy to ensure that the technology is utilized appropriately within educational contexts. Therefore, AI-based learning represents an important innovation in fostering students who are critical, creative, and capable of adapting to the demands of a rapidly evolving world.

Keywords: Artificial Intelligence, AI-based Learning, Critical Thinking Skills, Digital Education, Digital Literacy.

1. INTRODUCTION

The development of digital technology in the twenty-first century has brought significant changes to the field of education. One of the most influential technological advancements today is Artificial Intelligence (AI). AI refers to technologies designed to simulate human cognitive abilities, including thinking, data analysis, problem-solving, and decision-making processes. In education, AI has been increasingly utilized in various forms, such as adaptive learning applications, educational chatbots, virtual tutors, automated assessment systems, and digital learning platforms capable of personalizing instruction according to students' needs. The integration of AI has made learning processes more flexible, interactive, and accessible anytime and anywhere.

These developments indicate that education is undergoing a rapid digital transformation. According to the Society 5.0 concept introduced by the Government of Japan in 2019, digital technologies and artificial intelligence should be utilized to enhance human well-being, including within the educational sector. This concept places humans at the center of technological development, emphasizing that AI should support students in learning more effectively and creatively. In the context of modern education, technology is no longer merely a supporting tool but has become an integral component of the learning process.

The application of AI in education is also consistent with the constructivist theory proposed by Jean Piaget. This theory suggests that learners construct knowledge through experience and active interaction with their learning environment. AI can facilitate this process by providing personalized and adaptive learning experiences tailored to students' individual abilities. Furthermore, Lev Vygotsky's social constructivist theory highlights the importance of social interaction in learning. The

use of AI in virtual discussions, collaborative learning environments, and digital platforms can enhance students' cognitive development through interaction with teachers and peers.

In the digital era, critical thinking has become one of the essential competencies that students must possess. This skill is increasingly important because students are exposed to vast amounts of information that are rapidly disseminated and often complex in nature. According to Robert Ennis (2015), critical thinking is the ability to think logically and reflectively in order to make sound decisions based on information analysis. Similarly, Peter Facione (2020) defines critical thinking as encompassing the skills of interpretation, analysis, evaluation, inference, and explanation when addressing a problem. Through critical thinking, students are not merely passive recipients of information; rather, they are capable of evaluating the validity of information and solving problems rationally.

The utilization of AI in education is further supported by the theory of connectivism developed by George Siemens and Stephen Downes. Connectivism posits that learning in the digital age occurs through networks of information and technology. Knowledge is acquired not only from teachers but also from interconnected digital sources. In this context, AI enables students to access information quickly and supports independent learning processes.

In addition, humanistic learning theory, as developed by Abraham Maslow and Carl Rogers, emphasizes that education should help learners achieve their fullest potential. The integration of AI into educational settings can provide learning experiences that align more closely with students' interests and needs, thereby enhancing learning motivation. However, humanistic theory also stresses that technology cannot fully

replace the role of teachers, as education fundamentally requires human values, empathy, and social interaction.

Numerous previous studies have demonstrated the positive impact of AI on students' critical thinking skills. A report by UNESCO (2023) found that AI can create more personalized and effective learning experiences by analyzing students' learning needs. The study further noted that AI technologies help students gain a deeper understanding of subject matter through interactive digital learning environments.

Similarly, research conducted by OECD (2024) revealed that the integration of AI in education can enhance students' problem-solving abilities, creativity, and critical thinking skills. AI supports the development of analytical competencies through simulations, automated assessments, and broader access to information. Furthermore, research by Wayne Holmes et al. (2024) highlighted the substantial potential of AI in fostering twenty-first-century skills, particularly critical thinking, communication, collaboration, and digital literacy.

Another study by Luckin (2023) argued that AI facilitates adaptive learning by adjusting instructional content to students' individual competency levels, thereby improving learning effectiveness. Meanwhile, Zawacki-Richter (2022) found that the implementation of AI in higher education increased student engagement and strengthened critical analytical skills. More recently, Hwang and Tu (2025) demonstrated that AI-based learning environments can significantly improve students' abilities to evaluate information and solve problems systematically.

In Indonesia, the adoption of AI in education has gradually expanded through digital learning platforms and technology-enhanced teaching practices. Research by Suyanto (2024) indicated that AI-assisted learning encourages students to participate more actively in discussions and seek solutions to learning challenges. Likewise, Nurhayati (2025) found that AI-based learning can improve both learning motivation and critical thinking skills among secondary school students.

Despite these benefits, the use of AI in education also presents several challenges. Some studies suggest that excessive reliance on AI may lead to technological dependency and reduced social interaction among students. Additionally, inadequate digital literacy and insufficient supervision may result in the misuse of AI technologies within educational contexts. Therefore, teachers continue to play a crucial role as facilitators and mentors who guide students in using technology responsibly and ethically.

Based on the foregoing discussion, it can be understood that AI-driven learning transformation has a substantial influence on strengthening students' critical thinking skills in the digital era. The integration of AI into education not only contributes to making learning more modern and effective but also supports the development of essential twenty-first-century competencies required to address global challenges. Therefore, this study is important for examining more comprehensively the role of AI in enhancing students' critical

thinking abilities as well as the challenges associated with its implementation in contemporary educational settings.

2. RESEARCH METHODOLOGY

This study employed a qualitative research method with a library research approach. This method was chosen because the study focuses on examining theories, concepts, and previous research findings related to Artificial Intelligence (AI)-based learning and students' critical thinking skills in the digital era. According to Sugiyono (2022), qualitative research is a method used to gain an in-depth understanding of social phenomena through descriptive data. Similarly, Moleong (2021) states that qualitative research aims to understand a phenomenon based on data and information obtained from various sources.

The library research approach was utilized to collect data from various written sources, including books, scientific journals, articles, and previous studies relevant to the research topic. Zed (2018) defines library research as a research method conducted through the collection and analysis of literature related to the research problem. In this study, data sources were obtained from national and international journals, educational books, and recent research reports concerning the application of AI in education.

Data collection was carried out through reading, note-taking, and gathering information related to the transformation of AI-based learning and the development of students' critical thinking skills. This study also incorporated references from UNESCO (2023) and OECD (2024), which discuss the advancement of AI in education and its impact on twenty-first-century skills.

The collected data were subsequently analyzed using content analysis techniques. According to Krippendorff (2019), content analysis is a research technique employed to systematically and comprehensively examine the content of information. The analysis process involved selecting data relevant to the research topic, interpreting the content, comparing findings from previous studies, and drawing conclusions based on the analyzed data.

3. RESULTS AND DISCUSSION

3.1 The Transformation of AI-Based Learning in the Digital Era

The rapid development of digital technology has brought significant changes to modern educational systems. One of the most prominent technological innovations today is Artificial Intelligence (AI). AI refers to technology designed to emulate human capabilities in thinking, analyzing data, solving problems, and making decisions automatically. In the field of education, AI has been implemented in various forms, including educational chatbots, virtual tutors, adaptive learning systems, digital learning applications, and automated assessment systems. The integration of AI has made learning processes more flexible, interactive, effective, and responsive to students' needs in the digital age.

The transformation of AI-based learning demonstrates that education has entered an era of digitalization that demands the integration of technology into teaching and learning processes. According to the Society 5.0 theory introduced by the Japanese government in 2019, technological advancements should be utilized to enhance human quality of life, including in the educational sector. The concept of Society 5.0 places human beings at the center of technological development; therefore, the application of AI in education is expected to help students learn more effectively, creatively, and innovatively. In this context, AI functions not merely as a learning tool but also as an essential component of the broader transformation of modern education.

Furthermore, the theory of Connectivism proposed by George Siemens (2005) and Stephen Downes explains that learning in the digital era occurs through interconnected information networks facilitated by technology. Knowledge is no longer acquired solely from teachers but also from diverse digital sources that are widely accessible. AI supports this theory by enabling students to access information, learning materials, educational videos, and practice exercises through AI-driven digital systems quickly and efficiently.

The implementation of AI in education is also aligned with Jean Piaget's Constructivist Theory, which argues that learners construct knowledge through experience and active interaction with their learning environment. In AI-based learning environments, students are provided opportunities to explore learning materials, engage in digital simulations, and solve problems independently, thereby becoming more actively involved in the learning process. This perspective is further reinforced by Lev Vygotsky's Social Constructivist Theory, which emphasizes the importance of social interaction in learning. AI facilitates virtual discussions, collaborative learning environments, and digital communication platforms that support students' learning experiences.

According to Burrhus Frederic Skinner's Behaviorist Theory (1953), learning occurs through stimulus-response mechanisms strengthened by reinforcement. In AI-based learning systems, adaptive technologies can provide immediate feedback to students, enabling them to recognize mistakes and improve their understanding more rapidly. This demonstrates how AI can enhance learning effectiveness through automated responses and continuous feedback on students' learning activities.

In addition, the Humanistic Theory developed by Abraham Maslow and Carl Rogers emphasizes that education should foster the optimal development of learners' potential. AI supports this perspective through personalized learning approaches that adapt to students' individual needs, abilities, and interests. Through more personalized learning experiences, students can become more confident, motivated, and actively engaged in the learning process. Nevertheless, humanistic theory also highlights that technology cannot fully replace the role of teachers, as education fundamentally requires human values, empathy, and social interaction.

Research conducted by UNESCO (2023) indicates that the use of AI in education can improve learning quality through adaptive and personalized learning systems. AI enables students to understand learning materials according to their individual abilities, thereby making the learning process more effective and efficient. Similarly, research by the OECD (2024) demonstrates that the integration of AI in education can enhance twenty-first-century skills, including creativity, problem-solving, communication, collaboration, and critical thinking.

Research conducted by Wayne Holmes and colleagues (2024) further explains that AI possesses significant potential to support educational transformation by creating more interactive learning experiences tailored to students' needs. Likewise, Luckin (2023) found that AI can facilitate independent learning through adaptive and data-driven educational systems. Furthermore, Zawacki-Richter (2022) concluded that AI can increase student engagement in learning and assist teachers in managing educational processes more effectively.

In Indonesia, the transformation of AI-based learning has increasingly developed through the adoption of digital learning platforms and modern educational technologies. Research by Suyanto (2024) found that the use of AI in learning encourages students to become more active in seeking information and solving learning-related problems. In addition, Nurhayati (2025) reported that AI-based learning can enhance students' learning motivation because the learning process becomes more engaging, accessible, and easier to understand.

3.2 Enhancing Students' Critical Thinking Skills through AI-Based Learning

Critical thinking is one of the essential skills that students must possess in the digital era. The rapid flow of information requires students to be capable of selecting, understanding, and evaluating information logically and rationally. According to Robert Ennis (2015), critical thinking is reflective and reasonable thinking focused on deciding what to believe or do. Similarly, Peter Facione (2020) explains that critical thinking encompasses the abilities of interpretation, analysis, evaluation, inference, explanation, and self-regulation in understanding and addressing problems.

AI-based learning supports the development of students' critical thinking skills because students are not merely passive recipients of information; rather, they are encouraged to search for, comprehend, and evaluate information independently. The integration of AI into education promotes greater student engagement through digital discussions, simulations, problem-solving activities, and the exploration of learning materials.

According to David Kolb's Experiential Learning Theory (1984), learning becomes more effective when students gain direct experience during the learning process. AI supports this theory through virtual simulations, project-based learning, and interactive learning environments that provide students with authentic learning experiences. These experiences enable

students to understand concepts more effectively and enhance their critical thinking abilities.

Furthermore, John Dewey's Inquiry Learning Theory emphasizes that learning should encourage students to actively seek answers to problems. AI facilitates inquiry-based learning by allowing students to explore diverse digital information sources and identify solutions to the challenges they encounter. Through this process, students' critical thinking skills are strengthened as they regularly engage in the analysis and evaluation of information.

Similarly, Jerome Bruner's Cognitive Development Theory suggests that effective learning should enable students to discover concepts through active thinking processes. In AI-supported learning environments, students are provided with opportunities for exploratory and self-directed learning, which contribute to the development of their analytical and reasoning abilities.

Research conducted by Hwang and Tu (2025) demonstrates that AI-based learning significantly improves students' abilities to evaluate information and solve problems systematically. Their study further indicates that AI enhances students' logical reasoning skills through simulation-based learning and digital data analysis.

Likewise, Luckin (2023) found that AI helps students achieve a deeper understanding of learning materials by providing personalized learning experiences tailored to individual needs and abilities. In addition, research by Wayne Holmes et al. (2024) reveals that the use of AI can enhance students' critical thinking, creativity, and digital literacy skills, which are recognized as essential competencies for the twenty-first century.

Another study by Zawacki-Richter (2022) explains that AI increases student engagement in learning activities, encouraging students to participate more actively in discussions, analysis, and problem-solving tasks. Therefore, the integration of AI in education has a positive impact on the development of students' critical thinking skills and contributes to the cultivation of higher-order thinking competencies required in contemporary learning environments.

3.3 Challenges and Negative Impacts of AI Utilization in Education

Critical thinking skills are among the essential competencies that students must possess in the digital era. The rapid flow of information requires students to be capable of selecting, understanding, and evaluating information in a logical and rational manner. According to Robert Ennis (2015), critical thinking is the ability to engage in reflective and reasonable thinking in order to make appropriate decisions. Similarly, Peter Facione (2020) argues that critical thinking encompasses the abilities of interpretation, analysis, evaluation, inference, explanation, and self-regulation when addressing and understanding problems.

AI-based learning supports the development of students' critical thinking skills because students are not merely passive recipients of information; rather, they are encouraged to independently seek, comprehend, and evaluate information. The integration of artificial intelligence into educational settings promotes active learning through digital discussions, simulations, problem-solving activities, and the exploration of learning materials.

According to David Kolb's Experiential Learning Theory (1984), learning becomes more effective when students gain direct experience during the learning process. Artificial intelligence supports this theory through virtual simulations, project-based learning, and interactive learning environments that provide students with authentic learning experiences. These experiences enable students to understand concepts more effectively and foster the development of critical thinking skills.

Furthermore, John Dewey's Inquiry Learning Theory emphasizes that the learning process should encourage students to actively seek answers to problems. AI facilitates inquiry-based learning by allowing students to explore diverse digital resources and identify solutions to challenges they encounter. Through this process, students' critical thinking skills are enhanced as they become accustomed to analyzing and evaluating information critically.

In addition, Jerome Bruner's Cognitive Development Theory suggests that effective learning should help students discover concepts through active thinking processes. In AI-based learning environments, students are provided with opportunities for exploratory and independent learning, thereby strengthening their analytical and reasoning abilities.

Research conducted by Hwang and Tu (2025) demonstrates that AI-based learning significantly improves students' abilities to evaluate information and solve problems systematically. The study further indicates that AI enhances students' logical reasoning skills through simulation-based learning and digital data analysis.

Similarly, Luckin (2023) found that AI helps students achieve a deeper understanding of learning materials through personalized learning experiences tailored to individual abilities. Moreover, a study by Wayne Holmes et al. (2024) revealed that the use of AI can enhance students' critical thinking, creativity, and digital literacy, all of which are considered essential competencies for the twenty-first century.

Another study by Zawacki-Richter (2022) explains that AI increases student engagement in learning activities, encouraging them to participate more actively in discussions, analysis, and problem-solving tasks. Therefore, the integration of artificial intelligence in education has a positive impact on the development of students' critical thinking skills.

4. CONCLUSION

The transformation of learning through Artificial Intelligence (AI) has brought significant changes to education

in the digital era. The integration of AI into educational practices has enabled learning processes to become more interactive, flexible, adaptive, and student-centered. AI technologies facilitate students' access to information through various digital media, including virtual tutors, educational chatbots, adaptive learning applications, and online learning platforms.

Based on theoretical studies and previous research findings, AI-based learning has a positive impact on strengthening students' critical thinking skills. AI encourages learners to engage more actively in analyzing information, solving problems, evaluating data, and making logical and systematic decisions. This is consistent with the educational theories of Jean Piaget's constructivism, George Siemens' connectivism, David Kolb's experiential learning, and John Dewey's inquiry-based learning, all of which emphasize the importance of active learning, experiential engagement, interaction, and information exploration in developing students' cognitive abilities.

Recent studies conducted by the UNESCO (2023), the OECD (2024), and research by Wayne Holmes and colleagues (2024) further demonstrate that the use of AI in education can enhance essential twenty-first-century competencies, including critical thinking, problem-solving, creativity, communication, and digital literacy.

Nevertheless, the implementation of AI in education also presents several challenges, such as technological dependency, limited digital literacy, inadequate infrastructure, and the potential misuse of technology. Therefore, the role of teachers remains indispensable as facilitators and mentors who can ensure that AI is utilized wisely, ethically, and in ways that uphold the humanistic values of education.

In conclusion, AI-based learning represents an effective educational innovation for strengthening students' critical thinking skills in the digital age. The appropriate and purposeful use of AI is expected to contribute to the development of a generation that is critical, creative, adaptive, and well-prepared to face the challenges posed by future technological advancements.

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