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Developing 21st-Century Skills in Elementary School Students Through Artificial Intelligence

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Abstract
This research aims to analyze the effectiveness of using Artificial Intelligence (AI) in developing 21st-century skills in elementary school students. This research methodology is literature research, which involves collecting articles from Google Scholar in 2024 using keywords AI, learning effectiveness, and 21st-century skills. Thirty-eight articles were determined using a simple random sample technique. The article is then analyzed with the help of the application of Voyant tools and interpreted to obtain an in-depth meaning. The research results show that using AI is effective for elementary school students to develop 21st-century skills, including critical thinking skills, creativity, communication, and collaboration skills. Research findings show that AI has a significant impact on human life. The positive impact of using AI is efficiency, while the adverse effect is the anxiety that arises (AI Anxiety) and dependence on technology. This research implies that AI must be appropriate and careful without relying entirely on technology.

Keywords: *21st-century skills, critical thinking, creativity, artificial intelligence, collaboration*

Introduction

The use of technology has become an inherent part of everyday life. The digital era has changed our way of life and perspective, including education. Technological developments have created artificial intelligence, or artificial intelligence (AI). Artificial Intelligence has become one of the fastest-growing technologies in recent years. In the era of information technology development, there is a merger between human skills and new technology, which is known as artificial intelligence (AI).

The widespread use of AI in various sectors, including education, is feared to impact writing skills, student creativity, and critical thinking skills; it is also essential to explore the challenges faced in integrating AI into the education curriculum. What are the concerns about the use of AI can reduce or improve students' writing skills? How to use AI safely and responsibly in the school environment.

Previous research conducted by (Warschauer & Healey, 1998) and (Aljuaid, 2024) showed that AI-based technology and applications can improve students' writing skills by providing instant feedback and helping to improve the structure and grammar of writing. Research shows that technology, including AI, can support students' creativity by providing inspiration and tools for innovative projects and improving critical thinking skills through complex problem-solving scenarios (Facione, 2011). However, teachers have barriers to technology integration, such as a lack of training and support, which emphasizes the need for ongoing professional development (Ertmer & Ottenbreit-Leftwich, 2010; Inan & Lowther, 2010). In addition, AI can create personalized learning experiences to improve student learning outcomes (Luckin et al., 2016; Pane et al., 2017), but ethical issues related to student data privacy and security must be considered (Pardo & Siemens, 2014; Prinsloo et al., 2021).

Artificial intelligence (AI) is a system that studies how to make computers think, learn, and act like humans (Marsella et al., 2023). It encompasses studying and developing theories, methods, technologies, and application systems to simulate, expand, and enhance human intelligence. As a comprehensive and interdisciplinary field, AI draws from various scientific domains, including computer science, physiology, philosophy, psychology, and mathematics. The benefits of artificial intelligence are significant, as they can transform multiple sectors, including education(Rahadiantino, 2022)

Education is a crucial foundation for developing individuals equipped to face future challenges. The quality of education is reflected in several aspects, including the learning process, media use, student participation, and the relevance of teaching materials. In this context, integrating artificial intelligence into educational design becomes essential to support and enhance the education system. By incorporating AI, students can more easily grasp complex lessons, and interactions between students and teachers can be significantly improved.

The involvement of AI in education facilitates understanding and encourages active participation among students. Through innovative design concepts and targeted learning training, AI can motivate students and teachers to engage more fully in learning. Ultimately, this integration aims to enhance educational outcomes by leveraging appropriate technology, ensuring students are better prepared for future demands.

In primary and secondary education, schools serve as centers of learning and teaching where students are required to engage in independent learning by actively participating in the learning process (Scharle & Szabo, 2000). This involvement fosters a sense of ownership and responsibility, which is essential for developing effective learning habits. One of the main challenges teachers face is how to help students take responsibility for their learning process. An independent learner must increase awareness, change their attitude, and transfer their role (Scharle & Szabo, 2000).

Elementary school is the right place to start introducing AI concepts to students, as this period is crucial for forming critical and adaptive thinking patterns (Abar et al., 2021). Understanding elementary school students' responses to AI is essential because their early developmental stage often influences their perceptions of technology (Yuliani, 2024). The development of information and communication technology is one of the causes of changes in the new paradigm of 21st-century education. In the context of the use of information and communication technology in education, it has been proven to increasingly narrow and merge "space and time," which have been the determining aspects of the speed and success of mastering knowledge (Kurniawan, 2019) AI, with all its advances, is the answer to digital era learning as well as challenges in the industrial era 5.0

The skills essential for 21st-century learning often called the 4C abilities—critical thinking and problem-solving, collaboration, communication, creativity, and innovation—are increasingly important in today's educational landscape(Jasmine & Supriatna, 2022). In this context, artificial intelligence (AI) offers various conveniences to enhance the learning experience, such as virtual mentors, voice assistants, innovative content, smart classrooms, automatic assessments, and personalized learning pathways. One notable example of AI is ChatGPT, an AI-based chatbot capable of generating text in various formats, including formal, informal, and creative writing. While AI presents significant opportunities for improving educational outcomes, it also poses challenges. For instance, although ChatGPT can process information efficiently, its use may inadvertently reduce the originality of students' work, leading to concerns about creativity (Pertiwi et al., 2023).

Moreover, while integrating AI into learning can enhance time efficiency, energy conservation, and ease of task completion, it can also contribute to adverse outcomes such as laziness, anxiety (often referred to as AI anxiety), and dependency on

technology. This research aims to explore the role of artificial intelligence in developing 21st-century skills among elementary school students, emphasizing the need for a balanced approach that harnesses the benefits of AI while mitigating its potential drawbacks.

Method

This research employs a qualitative approach through a literature study. A systematic search for international and national literature was conducted using Google Scholar, which was selected for its extensive database and user-friendly interface. Initially, 11,200 articles published between 2019 and 2024 were identified using the keyword "utilization of artificial intelligence in elementary schools." This broad search was refined with the additional keyword "21st-century skills development," resulting in 2,090 articles. A further filtering using the keyword "in science subjects" yielded 572 articles.

A simple random sampling technique was applied to select relevant articles for analysis. This method allows for result projection but presents challenges such as difficulty constructing a sampling frame, potential high costs, lower precision, and a lack of guaranteed representativeness. From the 572 articles, 38 were included based on their relevance to the research topic. Articles were excluded if they did not directly address the effectiveness of AI in developing 21st-century skills, lacked empirical data, or were not published in peer-reviewed journals.

Data analysis was conducted using Voyant Tools software, which facilitated the extraction of key insights from user feedback and informed recommendations for further development. The selected articles were categorized into two main topics aligned with the research objectives: (1) articles addressing the effectiveness of AI in the development of 21st-century skills (20 articles) and (2) articles focusing on the most relevant 21st-century skills enhanced by AI. The research objectives then interpreted the findings. The literature review included international and national articles, ensuring a comprehensive understanding of the topic.

Result and Discuss

The research results show that of the 38 articles entered the Voyant tools, the results in Figures 1 and 2 were obtained.

Figure 1 Results of Voyant tools analysis of 20 articles related to the effectiveness of AI in learning

Figure 2: Results of Voyant tools analysis of 18 articles related to 21st-century skills using AI

Based on Figure 1, it can be interpreted that the words learning, education, technology, and effective are the dominant words. The skills essential for 21st-century

learning, often referred to as the 4C skills—critical thinking and problem-solving, collaboration, communication, and creativity and innovation—are increasingly important in today's educational landscape (Cardona, Miguel A Rodriguez & Kristina, 2024; Nabilah & Nana, 2020). In this context, artificial intelligence (AI) offers various conveniences that can enhance the learning experience, such as virtual mentors, voice assistants, innovative content, smart classrooms, automatic assessments, and personalized learning pathways (Fitri & Dilia, 2024; Pertiwi et al., 2023). One notable example of AI is ChatGPT, an AI-based chatbot capable of generating text in various formats, including formal, informal, and creative writing. While AI presents significant opportunities for improving educational outcomes, it also poses challenges. For instance, although ChatGPT can process information efficiently, its use may inadvertently reduce the originality of students' work, leading to concerns about creativity (Firdaus & Firman, 2023).

Moreover, while the integration of AI in learning can enhance time efficiency, energy conservation, and ease of task completion, it can also contribute to adverse outcomes such as laziness, anxiety (often referred to as AI anxiety), and dependency on technology (Fostering 21st Century Skills: AI Integration for Education, 2025). This research aims to explore the role of artificial intelligence in developing 21st-century skills among elementary school students, emphasizing the need for a balanced approach that harnesses the benefits of AI while mitigating its potential drawbacks.

However, the use of AI for learning cannot be wholly relied on. The role of the teacher as an educator needs to be presented in the classroom as a learning facilitator, and it needs to include empathy, feelings, physical interactions, and other things that AI cannot do. AI provides efficiency in data management, personalization of learning, feedback, and increased learning effectiveness (Riyandi, Salim, and Qomario, 2024).

The role of AI technology in developing 21st Century Skills

Technology and education go hand in hand. Critical thinking ability is one of the 21st-century skills that students need to solve real-life problems. Developing critical thinking skills can be done through learning media, namely digital media (Alif Agung Wicaksono, Lola Depra, Silva Maharani, Syahrial, 2022).

An overview of the 21st-century learning framework is presented in Figure 3 below.

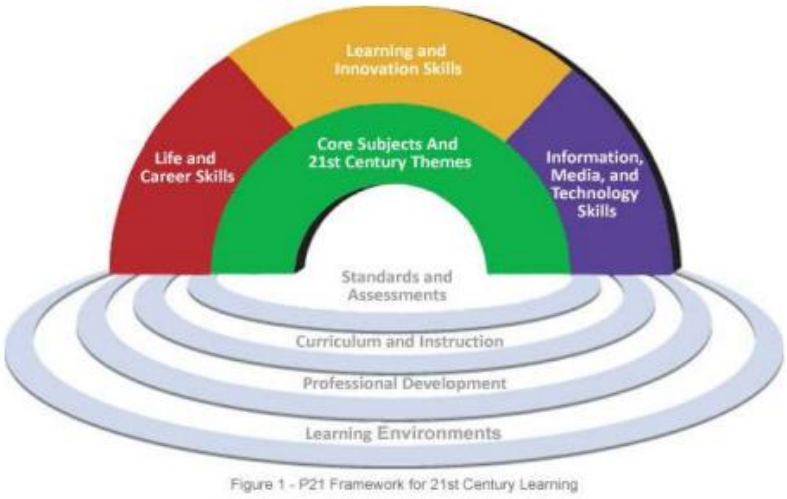

Figure 3: 21st-century Learning Framework
Source: Fahruzy, in (Sinaga, 2023).

AI data analysis provides deep insights into students' progress, needs, and learning patterns. This allows teachers and other users to make quick and accurate decisions, identify areas that need attention, and adjust learning strategies according to student needs (Aristanto et al., 2023). AI applications such as Canva for Education, AI for Presentation, Bing for Write and Image, and Open AI for Creative Ideas enable the personalization of learning. They are one of the main strengths of AI.

The research results show several examples of forms of artificial intelligence used in learning by students and teachers.

Table 1 AI used by teacher and student

No	AI name	Description	Kind of 21st-century skills
1	Automatic assessment	It helps teachers to create questions or quizzes with automatic grading. Students can also immediately find out their scores after answering all the quizzes.	Think critically
2	Quizlet	Create quizzes and flashcards	Think critically
3	Tutor AI	Students can use AI tutors in real time when they need help understanding or answering lesson material.	Think critically
4	Canva, crello dan pwton	Create dynamic graphic designs, animations, and interactive presentations,	Collaboration and creativity
5	Elsa Speak	Sharpen your English skills	Communication

AI can provide learning content relevant to the user's needs through the information conveyed. AI technology can adjust the difficulty level, strategy model, learning method, and material delivery style and create an attractive learning atmosphere for students (Kisno et al., 2022). This personalized learning increases motivation, accelerates learning progress, and helps achieve the best results. Feedback in every learning activity, both digital and non-digital, is critical. AI can provide detailed and relevant feedback, offering explanations, suggestions for improvement, related material, and additional assignments according to student needs (Kisno et al., 2022).

Using AI technology in learning activities increases effectiveness, creativity, and innovation capabilities in digital learning as part of digital transformation (Luckin et al., 2016). AI offers a broader variety of feedback, including audio, visual, or interactive explanations, helping students with different learning styles understand the material and respond better to feedback. Despite increasing automation, the teacher's role remains essential in providing effective feedback and guidance. AI supports users in achieving learning goals.

Artificial Intelligence (AI) is making significant strides in elementary education by enhancing personalized learning experiences and supporting educators' teaching practices. AI tools, such as adaptive learning systems, can tailor educational content to meet the diverse needs of young learners, thereby improving engagement and learning outcomes (National Science Foundation, 2025). Additionally, AI applications in early childhood education, including intelligent tutoring systems, are being integrated into curricula to foster critical thinking and problem-solving skills (Wang et al., 2024)

However, implementing AI in elementary education also presents challenges, such as the need for ethical considerations and the involvement of educators in developing these technologies (Balta, 2024). Studies indicate that while AI has the potential to enhance learning quality through innovative methods like augmented reality and virtual learning environments, ongoing research is necessary to fully understand its impact and optimize its integration into various subjects (Casal-Otero et al., 2023). Overall, the future of AI in elementary education holds promise for transforming teaching and learning experiences.

Artificial Intelligence (AI) is increasingly transforming the educational landscape by personalizing learning experiences, enhancing instructional quality, and

streamlining administrative tasks. AI-driven tools, such as adaptive learning platforms, allow for tailored educational content that meets individual student needs, thereby improving engagement and learning outcomes (National Science Foundation, 2025). Furthermore, AI applications in writing assistance have been shown to elevate the quality of student work, particularly in language learning contexts, by helping students refine their arguments and improve coherence (Wang et al., 2024).

In addition to personalized learning, AI plays a significant role in supporting educators. Teachers are utilizing AI to modify assessments and enhance their instructional strategies, which can lead to more effective teaching practices (Partono et al., 2021). However, integrating AI into education is not without challenges; it requires careful consideration of ethical implications and the involvement of stakeholders in the development of AI tools to ensure they meet the needs of both students and educators (Casal-Otero et al., 2023). Overall, the potential of AI in education is vast, promising to revolutionize how learning and teaching occur in the modern classroom.

Conclusion

The conclusion of this research indicates that the use of Artificial Intelligence (AI) significantly impacts the development of 21st-century skills among elementary school students, including critical thinking, creativity, communication, and collaboration. The research findings suggest that AI not only enhances efficiency in the learning process but also has the potential to enrich students' learning experiences by providing tools and resources that support exploration and innovation.

However, alongside these benefits, some challenges must be addressed, such as the emergence of AI-related anxiety (AI Anxiety) and dependence on technology. This anxiety can hinder students' ability to think independently and develop essential interpersonal skills. Therefore, it is crucial to implement AI wisely and rationally, emphasizing the development of human skills that technology cannot replace.

The implications of this research highlight the need for a careful approach to integrating AI into education. AI should support, rather than replace, traditional learning processes while encouraging students to remain active and critical thinkers. In this way, education that leverages AI can produce a generation skilled in technology capable of adapting and innovating in the face of future challenges.

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