The Intersection of AI and Science Education in Indonesia: A Path Forward

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Keywords	Abstract	History
	ChatGPT's launch by the end of 2022 caused significant global disruption, particularly in education. ChatGPT acts as a computer capable of answering inquiries in multiple languages. The introduction of ChatGPT highlights the inevitable evolution of AI technology. Artificial intelligence (AI) is a rapidly emerging technical phenomenon and leading technology capable of functioning similarly to human intelligence. The study reviewed the literature semi-systematically. This approach searched for and overviewed the research area and the progress made. The first phase of this research was to formulate the research questions. The keywords were AI and science education. It was found that there are four categories for AI in educational institutions: University/ School Policies, Curriculum and Course Development, Pedagogical Innovations, and Professional Development with distance learning. The development of AI technology is inevitable in education. AI technology is not a threat if it can be integrated properly. This technology also applies to science education in Indonesia. Science education in Indonesia is often highlighted based on PISA results that do not meet global standards, so the existence of AI tools is an innovation in learning.	

INTRODUCTION

ChatGPT's launch by the end of 2022 caused significant global disruption. ChatGPT acts as a computer capable of answering inquiries in multiple languages. The introduction of ChatGPT highlights the inevitable evolution of AI technology. ChatGPT is a product of artificial intelligence. Artificial intelligence (AI) is a rapidly emerging technical phenomenon and leading technology (Sarker, 2022), capable of functioning similarly to human intelligence (Huang et al., 2021). According to Hassani et al. (2020), this technology is depicted as an automated, intelligent, and smart system that can eventually replace humans for intelligent jobs (Sarker, 2021).

People worldwide are surprised by ChatGPT's artificial intelligence capabilities to answer questions, write essays, and finally even compose a song that has always required inspiration and creativity in its creation. In a sense, a little thinking is solved with AI technology. As a result, AI has transformed society, the economy, governance, and the most effective method of teaching and learning in education (West &Allen, 2018; Syahrizal et al., 2024). AI technology involves many tools with different focuses. The first tool is machine learning. Machine learning focuses on the development of algorithms to analyze data, identify patterns that can be learned from and making predictions or decisions based on data without being explicitly programmed, and provide suggestions like a human being rather than a machine with one-way communication (Xu et al., 2021). So, the success of machine learning solutions depends on the data quality (Sarker, 2021b).

The second tool is deep learning (DL). This tools works like the human brain (Alzubaidi et al., 2021). Deep learning methods require a vast quantity of data to function properly, and they rely on GPU power for efficient processing. Deep learning models may predict, categorize, and produce insights from complicated datasets using a training and optimization process.

In conclusion, the relations among AI, machine learning, and deep learning are shown in Figure 1.
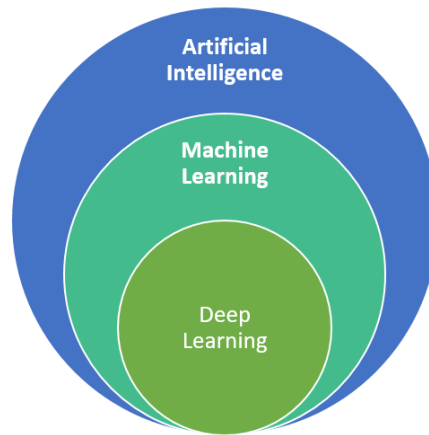

Figure 1. Relations Among AI, Machine Learning and Deep Learning
(Source: Iesc, 2018)

The figure shows that AI is built into human behavior and intelligence into machine or computer systems, while machine learning is automating analytical model building to learn from data or experience. Continuing to deep learning is computation through multi-layer neural networks and processing. Deep learning works like the human brain. It uses neural networks to automatically learn and extract features from data (Alzubaidi et al., 2021). Deep learning methods require a vast quantity of data to function properly, and they rely on GPU power for efficient processing. Deep learning models may predict, categorize, and produce insights from complicated datasets using a training and optimization process. Some studies have claimed the invention of AI technology has a transformational potential across the work fields, likewise in the industry. AI has influenced the learning, analyzing, and interpreting of data science for business management (Mundhe et al., 2023). AI can help the management in making decisions, predict the marketplace and get the idea of innovation of the product. AI technology is being developed with the primary goal of improving human life in a variety of areas (Mohsienuddin Mohammad, 2023). There are common AI impacts in all sectors. The positive impacts can make the work faster, more efficient, and more accessible in remote areas.

The negative impact of AI is job losses because the machines can replace most human jobs, including cashiers. Some stores use robots or machines for payment in the store. The other impacts are a lack of human social relationships and interaction, and the most crucial is cyber security. In education, the worst AI impact will decrease in constructing knowledge, critical thinking, problem-solving, and creativity skills (Heeg & Avraamidou, 2023). The advancement of AI technology is unstoppable, including in Indonesia. To cope with the impact of AI, of them is through

education. Education in Indonesia must be prepared to face the disruption by AI in all subjects, especially science. The main reason why science subjects need to be designed carefully as a result of AI development is because the nature of science is to improve students' thinking skills due to the presence of inquiry as the spirit of learning science. But if science is not designed to adapt to AI, then science lessons are no longer to solve problems. So, the worst of Indonesia will have a scarce number of scientists.

As the results of PISA 2022, the science competencies of Indonesian students were at level 1a or the lowest, below the global average (OECD, 2023); at the same time, AI technology was accessible in Indonesia. The Indonesian system should be aware of this and transform education quickly to minimize the disruptive impact of AI technology. Teaching and learning science should change from transferring knowledge to finding the knowledge by adapting to AI technology in science education. To summarize, this research reviewed the studies of AI in science education, especially in Indonesia. The review focuses on the readiness for science education on AI technology and its impact on critical thinking. Much research has been conducted in terms of AI to increase critical thinking, but not specifically in science education (Darwin et al., 2023). The research questions of this review are: *How can AI be effectively integrated into the current science education curriculum in Indonesian schools?*

This research on the integration of AI into science education in Indonesia is very important for several reasons. First, it modernizes education and keeping up with changes in the global use of AI technology. Second, results turned in by Indonesia's students in international tests, like the PISA examination, are unsatisfactory; therefore, it is incumbent to implement innovative approaches to

education. AI, in many ways, can fill this gap: first, through the enhancement of critical thinking skills, and second, with personalized learning to make learners more fitted to the challenges of the 21st century. In light of this research, literacy in AI has been put at center stage as having the capacity to change pedagogical practice and make education relevant to the digital age.

RESEARCH METHOD

The study reviewed the literature semi-systematically (Snyder, 2019). This approach searched for and overviewed the research area and the progress made. The first phase of this research is to formulate the research questions. After formulating the questions, the next phase of this study was to search for keywords in Google Scholar published from 2014 until 2024. The keywords are AI and science education. The findings were based on the citation rank, with 58 articles. Then, 58 articles were selected into 30 articles with more than one citation.

The next step is to review 19 articles with themes that can answer the research questions, which are reviewed by the research results of each of these articles. The research steps are described in Figure 2.
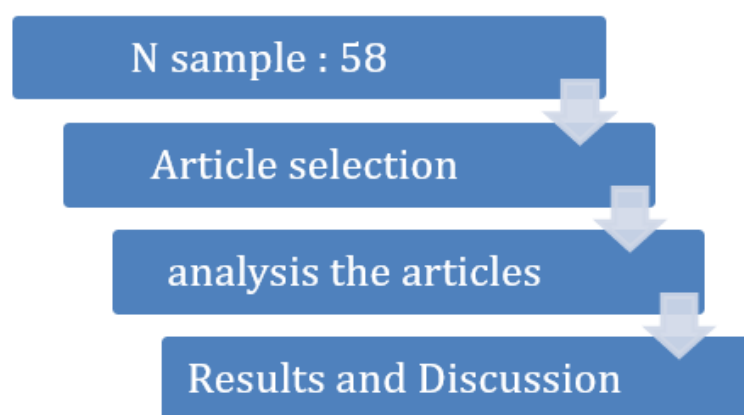

Figure 2. Steps in the study

RESULT AND DISCUSSION

Graph 1 depicts 29 articles cited more than once in publications on AI and science over the ten years since 2014. The graph shows an increasing trend in AI and science education research. This graph illustrates the drastic increase in research in AI and science education. This surge in research activity has been significantly influenced by the release of ChatGPT by Open AI in 2022 (Lo, 2023; Subiyantoro et al., 2023).
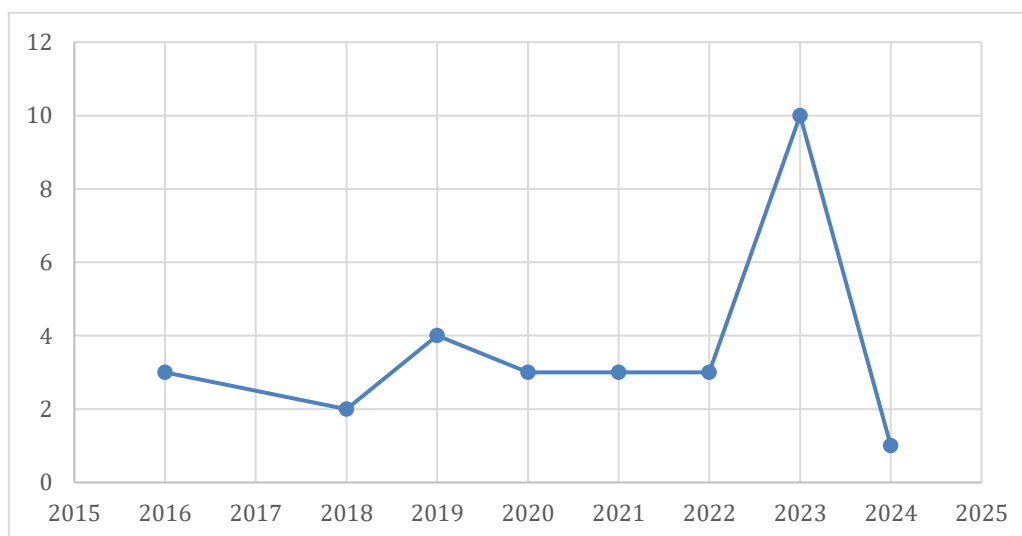
Graph 1. *Trend publication in AI integrated into science education*

However, only three articles are available when this title is combined with the keyword Indonesia. Likewise, when the word critical thinking is added, the article is not available. So, 17 articles were reviewed, with the results shown in Table 1.

Table 1. Research Finding Articles

Journal Title	Finding
The Adaptation Of Artificial Intelligence (Ai) In Social Science Education: Opportunities And Threats (Darajati et al., 2023)	Universities need to enforce policies on the use of AI, including ethics, to maintain the university's integrity.
Fostering AI Literacy In Elementary Science, Technology, Engineering, Art, And Mathematics (Steam) Education In The Age Of Generative AI (Relmasira et al., 2023)	AI is inevitable. It needs to be integrated into school learning in the form of AI literacy. Transformation learning involving AI will prepare children in the future who cannot avoid the development of AI while still relying on learning theory.
Epistemology of artificial intelligence (AI) and the importance of ethics in interdisciplinary education (Michael reskiantio pabubung, 2021)	AI has an impact like the two sides of a coin, with both positive and negative impacts. AI currently needs to be aligned with the existing curriculum in vocational schools the graduates directly enter the industrial world, which is closely related to AI technology.
Community college information technology education: curriculum mapping, a learning science framework, and AI learning technologies (Mclaren et al., 2023)	Developing a new approach by first mapping the curriculum and then creating knowledge, the learning and instruction framework (CLI) integrates learning technology development and focuses on AI technology.
AI education matters: a first introduction to modeling and learning using the data science workflow (Neumann, 2019)	AI and ML courses should be taught at the beginning with an emphasis on mathematical skills, so it is necessary to present the principles of data modeling and reasoning through the data science pathway.
AI risks prevention and critical thinking education: the perspective of open science-based sustainable development (Zinchenko et.al, 2022)	Robotics integration has become a necessity to be integrated into modern schools. Humans must learn to communicate with robots and begin to see open science as sustainable.
Future trends of science and education: the use of AI in the new world (Baharum, 2023)	This study investigates the use of an AI tool, ChatGPT, to promote professional development among early-career instructors. It investigates the efficacy of adult learning theory, technological pedagogical content knowledge, sociocultural theory, and the theory of planned behavior in professional development. The study provides a complete theoretical framework for understanding ChatGPT's role in autonomous learning, pedagogy-technology intersection, social interaction, and influencing AI usage.
Real-world deployment and evaluation of Kwame for science, an AI teaching assistant for science education in West Africa (Boateng et.al, 2023)	Kwame for Science has the potential to deliver scalable, cost-effective, quality distance education to millions of people.
Interrogating AI-driven professional development in higher education: a quad-theoretical analysis (Baskara, 2022)	The study examines the effectiveness of ChatGPT, an AI tool, in fostering professional growth among early-career lecturers, using adult learning theory, technological pedagogical content knowledge, sociocultural theory, and theory of planned behavior.
What should medical students know about artificial intelligence in medicine? (Park et.al., 2019)	AI technology will have a progressive impact on medicine when it is properly integrated in medical courses. Medical students must be able to distinguish information obtained by AI from theoretical studies in medicine.
Analysis of the utilization of artificial intelligence technology in Learning in Indonesia (Ramdania, 2023)	Teachers have a positive belief in the development of AI. However, there is a need for structured training to improve digital literacy and AI skills among educators and students so that they are ready to become global citizens.

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Teaching artificial intelligence for non-computer science students in undergraduate education: a competency framework and an AI course (doctoral consortium) (Tenorio. K, 2023)	AI is very effective for solving tasks in various fields; therefore, non-computer science students need to be prepared to master AI literacy in their future work.
What type of leaf is it? Ai in primary social and Science Education (Napierala et.al, 2022)	The elementary school curriculum in Germany has been integrated with digital technology to support this, and teaching materials integrated with AI technology were created.
Virtual labs, online exams, and now Ai? Professional learning strategies to navigate emergent challenges in science education (Wang. J.T, 2023)	Teaching innovation with the technological revolution in the classroom through virtual labs and AI chatbots has had a positive impact on the development of classroom learning.
Increasing reading and creative thinking skills to face the threat of AI in the modern digital era (Firmansyah, 2023)	The development of AI technology is not a threat to humans, AI will not reach the level of consciousness like humans. Therefore, AI can be used to personalize learning through critical reading and learning.
Utilization of GPT-4 to improve education quality through personalized learning for Generation Z in Indonesia (Firdaus et al., 2023)	Learning for Generation Z today must involve AI technologies such as Duolingo Max and Khanmigo, while there are limitations in arithmetic calculations and bias in models. However, this is quite effective in addressing the needs of Generation Z in Indonesia.
Implementation of a competency enhancement program for science teachers assisted by artificial intelligence in designing hots-based integrated science learning (Gunawan et al., 2021)	The implementation of the competency improvement program assisted by AI can help science teachers will have an impact on the content of science and the context of science learning. And, this is quite interesting for the trainees.

Discussion

This increasing trend of research in AI is also happening in Indonesia. At the beginning of 2024, 273 teachers in elementary, junior high, and high school were trained directly by Harvard University lecturers in the form of the CS50x Indonesia-Harvard University program (*Kemendikbudristek RI*, 2024). This program is intended for computer teachers and all fields to improve teacher computing in Indonesia. Although research in AI is increasing, according to The Global Index AI (2023), Indonesia is still ranked 46th out of 60 countries in terms of research on AI, including infrastructure development to facilitate the development of AI technology. Meanwhile, two countries from the Asian continent rank second and third, namely China and Singapore, presented in Table 2.

Table 2. Comparison of Global AI Index Rankings among China, Singapore, and Indonesia
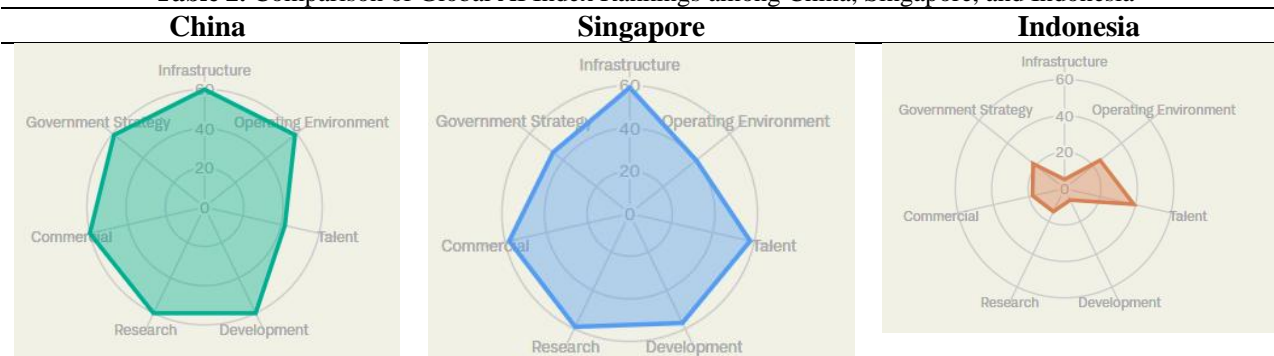
(Source : The Global AI Index - Tortoise, 2023)

Table 2 shows the research contrasts the Global AI Index Rankings for China, Singapore, and Indonesia. The result indicates that in terms of AI, research and infrastructure development in Indonesia is far behind other countries. This is an important point: it illustrates how far behind Indonesia really is in terms of integrating AI into education. The table suggests that, with countries like China and Singapore surging in AI capability, Indonesia has some distance to cover in stepping up the pace of AI research and its applications,

especially in the educational sector. If supported by more detailed insights from this table, it would further add to the understanding of the present situation of Indonesia and the ways to be taken towards betterment in its standing of AI integration. Looking at the comparison, Indonesia is still far behind in AI technology, especially in research. It states that with the rise of AI training in education in Indonesia, there is certainly an imbalance if this training is not based on the results of research on the needs of education in Indonesia in utilizing AI technology.

The results of the literature study on the implementation of AI suggest that it still needs to be researched, especially to overcome the negative impact of AI in education. One example is that students tend to think less when they can find answers through ChatGPT (Lo, 2023). Indonesia, with minimal research results in the field of AI, of course, must improve and have a special strategy in education to be ready to face this rapid world change, not least in science education.

Based on the student's performance in science competencies in 2022 (OECD, 2023), Indonesian students can apply essential content and procedural skills to recognize and explain simple scientific phenomena. Using guidance, individuals can conduct structured scientific inquiries using only two variables. They can recognize simple causal or correlational links and interpret them. AI technology is undoubtedly challenging if not addressed with deep thinking based on field conditions and research results, especially in Indonesian Education.

The results of the review of articles containing research on the use of AI technology in education are not many articles that specifically research the experimental implementation of AI in science teaching. The average research conducted is qualitative research and also a literature review. From the reviewed literature, there is only one piece of literature that has implemented science learning with AI integration in an elementary school in Germany (Napierala et.al., 2022). The results of this article review can be categorized as presented in Table 2. Based on the results of the article review, it was found that there are four categories for AI to be implemented in educational institutions, as shown in Figure 3.
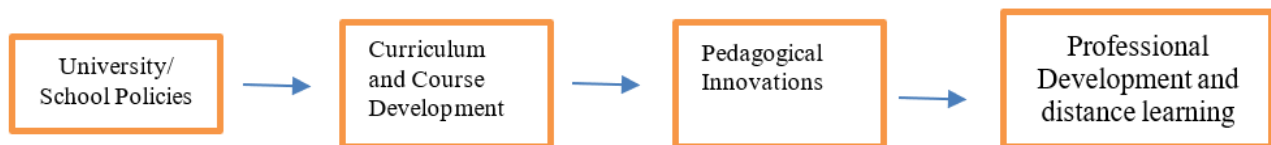

Figure 3. Four Categories for Implementing AI in Educational Institutions

The first stage in implementing AI technology is to develop a policy on using AI in institutions, especially schools. The policy developed with the ethical use of AI in academia. Students must be able to be responsible and maintain integrity when using AI (Sheikh et al., n.d.). Collaboration with stakeholders, teachers, and researchers is essential in developing this policy. By prioritizing ethics and incorporating them into the development and use of AI chatbots, we can create a more inclusive, trustworthy, and beneficial environment for all stakeholders.

Currently, the IB curriculum organizers have issued a policy on AI use policy in the academic integrity policy document (IB, 2019). It said that IB does not prohibit AI technology as it is an opportunity for educational innovation. One of the policies made, for example, is that when students write an essay, they must include citations from AI tools, and this is a bibliography, including AI-generated text time.

The second step is to dissect the current national curriculum, the independent curriculum used in Indonesia. Curriculum experts and education practitioners need to do curriculum mapping and create knowledge; the learning and instruction framework (CLI) integrates learning technology development and focuses on AI technology (Peter E. Childs, 2015). Especially in science education, the nature of science education must still be prioritized. The scientific process (Darmaji et al., 2019) remains the spirit of science learning so that concepts remain embedded in students. AI is integrated into learning, such as using Khanmigo to explain scientific phenomena. In addition, designing AI that is integrated into the national curriculum must also examine the teaching materials, assessments, and AI tools that will be used. So, it will accelerate the adaptation process for teachers. Due to the different conditions in each region in Indonesia regarding internet facilities, it is also necessary to design AI that can be used in remote places that lack internet facilities.

The third step is that once the curriculum is standardized with AI integration, teachers must be able to teach it in the classroom. Classroom learning must transform (Majeed, 2023); it is no longer traditional learning where teachers teach and explain in front of the class. Teachers' pedagogy needs to be transformed by AI technology (Jiménez

et.al., 2024). Pedagogy innovation (Firdaus et al., 2023) is personalized learning, where content is tailored to individual student needs. Thus, it can detect students' learning difficulties in a personalized manner. Therefore, teachers must be literate and utilize AI technology in designing learning. The similarities between AI and science in developing accurate learning include content mastery and curriculum adaptation (Park et al., 2023). Teachers can develop AI literacy by integrating STEM approaches into teaching and learning. Lin et.al., (2002) proposed the scientific structure of the creativity model in teacher pedagogy is essential, which includes the creative process, individual characteristics, and the resulting products. They suggested prioritizing creativity in education to meet the challenges of the 21st century. Active learning strategies that focus on interaction, inquiry, problem-solving, and interdisciplinarity can promote autonomy, responsibility, and creative thinking skills.

After designing the policy curriculum that integrates AI technology and developing teacher pedagogy, the fourth step is teacher training or professionalism development of the teacher to implement this in schools, which is unique for science teachers. The professional development of science teachers can be improved through various methods such as training, workshops, and webinars. However, these activities are temporary and need to be more sustainable. Literature studies show that teacher professionalism programs can be sustainable if they involve stakeholders (Silvhiany, 2022).

Research conducted using coaching methods also indicates that teachers need individually facilitated, improving collaboration skills, initiative, and confidence (Nugent et al., 2023; Hamann et al., 2021). Professional development of science teachers is very important because science learning in schools has not been implemented by nature of science education. The limitations of chemical equipment and materials in the laboratory, the lack of teacher readiness to carry out practicum, and the absence of assistants in practicum preparation are the main obstacles (Dewi et al., 2021). Balanced science learning, involving testing and application of theory, is expected to encourage positive attitudes among students and contribute to an overall teaching approach (Lestari et al., 2023). Therefore, involving AI technology will have a positive and meaningful impact on teacher professional development programs.

CONCLUSION

In conclusion, the study reveals a significant increase in research on AI integration in education. However, there is still a lack of research, especially focusing on AI implementation in science education. Indonesia, while making progress in AI training in education, is still behind in AI technology research compared to other countries. The development of AI technology is inevitable in education. The use of technology has two sides, but AI technology is not a threat if it can be integrated properly. This technology also applies to science education in Indonesia. Although research and development related to AI technology are still lacking, Indonesia cannot take too long to address this. Science education in Indonesia is often highlighted based on PISA results that do not meet global standards. So, the existence of AI tools is an innovation in learning, serving as both a media and pedagogical advancement.

The integration of AI technology in science education in Indonesia can follow four steps, namely formulating policies, developing a science curriculum integrated with AI technology, developing pedagogical guidelines for science teachers to be able to teach effective science with AI technology, and finally, a continuous and sustainable training program so that the expected results, namely the science competence of Indonesian students, can compete globally.

However, several limitations have to be addressed. First of all, this study is mostly based on the literature review; hence, it relies on existing studies rather than the collection of primary data. This could further limit the ability for in-depth analysis and the provision of new empirical evidence. Since AI integration in Indonesian schools related to science education is relatively new, a limited number of studies relating to this context have been found. This places a limit on the generalizability of the findings. Another limitation is that the trends of AI taken from the global platform are directly applied to the Indonesian situation, giving less emphasis to the educational and infrastructural issues at the local level. Last but not least, the ethical issues of AI in education are not deeply discussed, and this should be where probably future research could be directed.

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