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The Use of AI in Elementary School Learning: A Systematic Literature Review

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Abstract

This study systematically reviews the implementation of Artificial Intelligence (AI) in elementary education, focusing on the role of AI in enhancing teaching effectiveness, personalized learning, and student engagement. The research synthesizes various studies from the past decade to identify key AI technologies, the challenges faced, and the requirements for successful adoption in primary schools. The findings reveal that AI technologies, such as biosensors, voice recognition systems, and AI-powered platforms, significantly contribute to creating adaptive learning environments and providing real-time feedback, thus supporting personalized and experiential learning. However, the study also highlights challenges such as inadequate infrastructure, teacher competence, and ethical concerns regarding data privacy and algorithmic bias. Addressing these challenges requires investment in infrastructure, ongoing teacher training, and clear ethical guidelines to ensure equitable access to AI-driven learning. The study concludes that while AI holds great potential to transform primary education, its successful implementation depends on overcoming these barriers and fostering a culture of innovation within schools. The results offer practical recommendations for educators, policymakers, and technology developers to optimize AI use in primary schools, ensuring that it becomes an inclusive tool for enhancing educational outcomes.

Keywords Artificial Intelligence; Learning; Primary School; Educational Technology

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1. INTRODUCTION

The development of artificial intelligence (AI) technology has brought great changes in various aspects of life, including the education sector. AI in education functions as a tool that allows for a more personalized and adaptive learning experience for students, especially in basic education (Alkan, 2024a; González-Calatayud et al., 2021a). This technology allows for the customization of learning materials based on individual needs, real-time monitoring of student progress, as well as the provision of instant feedback to educators to design more effective teaching strategies (Chen et al., 2020; Dogan et al., 2023). In addition, AI has also been applied in various learning methods, such as intelligent tutor systems and

AI-based learning platforms that can adjust the level of material difficulty to students' abilities (Fahimirad & Kotamjani, 2018; Lukianets & Lukianets, 2023). However, despite the significant benefits, the implementation of AI in primary education still faces various challenges, including infrastructure readiness, digital divides, ethical issues related to data privacy, and the potential for algorithmic bias in learning systems (Bai et al., 2023; Marengo et al., 2024).

The application of AI in basic education promises various benefits, such as increased teaching effectiveness, personalized learning, and student engagement. AI allows students to interact with materials tailored to their learning style as well as providing additional support for those who have difficulty understanding certain concepts (Arip Nurahman & Pandu Pribadi, 2022a; Suharyo et al., 2024a). This technology also supports experiential learning through interactive simulations and responsive digital learning environments (Baidoo-Anu & Owusu Anisah, 2023; Pont-Niclòs et al., 2024). However, the implementation of AI in elementary schools still faces obstacles, one of which is the low competence of teachers in utilizing this technology optimally. In addition, there are still few studies that explore how AI can be completely adapted to the characteristics of elementary school-age students who are still in the early stages of cognitive development (Li et al., 2024a). The lack of studies addressing the long-term impact of AI on primary education indicates the need for more research to understand its effectiveness and the challenges in its implementation.

Several learning theories can be used in education to understand how AI contributes to a more effective learning process. The constructivist theory emphasizes that students build their understanding through active interaction with the learning environment. AI can support this theory by providing exploratory and problem-solving-based learning experiences that are tailored to students' abilities (Harnawati & Hidayati, 2024; Yusuf et al., 2024). Problem-based learning (PBL) theory is also relevant in the application of AI, as it allows students to engage in solving real problems with the help of AI technology, such as simulation-based learning systems or interactive data analysis (Arip Nurahman & Pandu Pribadi, 2022a; Suharyo et al., 2024a). In addition, Adaptive Learning Theory is increasingly showing its relevance to AI, as this technology allows for the adjustment of learning methods based on individual student progress (Li et al., 2024a; Sun, 2020). By combining these theories, AI can provide a more inclusive learning experience, support the improvement of critical thinking skills, and provide real-time feedback to students and educators (Ratnadewi et al., 2023).

Although previous studies have discussed the application of AI in education, most research still focuses on secondary and higher education levels. Studies that specifically review the application of AI in elementary schools are still limited and tend to be fragmented, so they have not provided a comprehensive picture of the effectiveness of this technology for early childhood students (Schleiss et al., 2023; Seo et al., 2021). In addition, existing studies highlight more of the potential of AI in improving the quality of learning but have not yet explored in depth the challenges faced in its implementation, such as technical barriers, teacher competence, and the social and ethical implications of its use. Therefore, this study aims to fill this gap by conducting a systematic review of studies that have been carried out on the implementation of AI in learning in elementary schools.

This research will synthesize studies conducted in the past decade to identify AI usage patterns, the main benefits offered, and the challenges arising in its implementation in elementary schools. With a systematic approach, this research will provide a deeper understanding of how AI technology can support learning at the primary education level and how various parties, including teachers and policymakers, can optimize its use (Tolentino et al., 2024). In addition, this study will also explore how factors such as infrastructure readiness, teacher skills, and the role of education policies in determining the effectiveness of AI application in the context of basic education (Rejeki et al., 2024; Syarifuddin et al., 2024). The results of this study are expected to provide applicable recommendations for educators, educational technology developers, and policymakers in developing better strategies to integrate AI into elementary school learning systems.

By conducting a systematic review of various studies that have been conducted, this research will make a theoretical and practical contribution to understanding the trends and challenges of using AI in basic education. From a theoretical perspective, this research will enrich the academic literature on the role of AI in education by integrating constructivist theory, PBL, and adaptive learning to support more innovative and inclusive learning. From a practical perspective, the results of this study can be used as a guideline for policymakers to develop regulations related to the use of AI in basic education, as well as provide recommendations for educators in utilizing AI to improve the quality of learning. In addition, this study also highlights the importance of training and professional development for teachers so that they can effectively utilize AI technology in the learning process (Chemlal, 2023).

This study is expected to provide broader insights into how AI can be used optimally in basic education and how various existing challenges can be overcome through better implementation strategies. Thus, this research not only provides a mapping of the development of AI in primary education but also offers evidence-based solutions to improve the effectiveness and accessibility of this technology for all students. The results of this study are also expected to be the basis for developing education policies that are more adaptive to technological developments to ensure that the use of AI in basic education provides maximum benefits for student development and the overall quality of learning.

2. METHODS

This study uses the Systematic Literature Review (SLR) method with a descriptive qualitative approach to analyze the role of Artificial Intelligence (AI) technology in basic education. SLR is carried out by following the stages of identification, selection, data extraction, and synthesis from literature obtained from reputable databases such as Scopus. This study aims to provide a systematic understanding of the application of AI in learning as well as support data-driven decision-making in the field of education (Ahmad et al., 2024). This review process is illustrated in Figure 1.

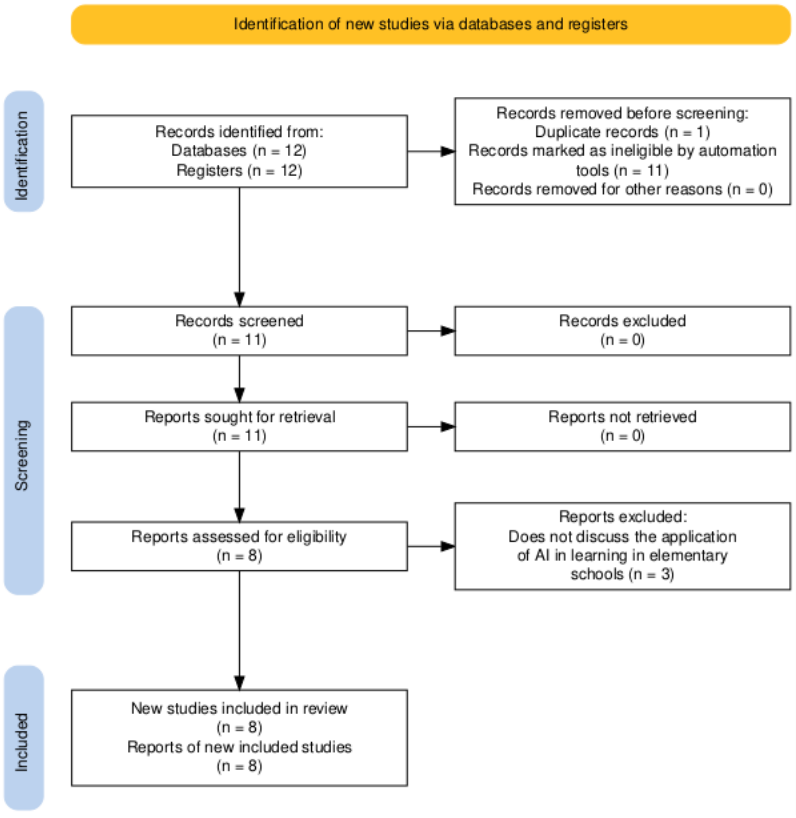


Figure 1. PRISMA Flow Diagram

The first step in this process is to formulate research questions that are relevant to the topic of AI utilization in elementary schools. The next step is to develop a three-stage search strategy: determining specific search keywords, selecting appropriate literature databases, and systematically executing search procedures. The third stage establishes study selection criteria, including inclusion and exclusion, to screen relevant literature. Once the primary literature has been identified, the fourth step involves assessing the quality of the selected study using a variety of quality assessment questions. The next step is data extraction to answer the research questions that have been formulated. The final step, data synthesis, aims to integrate evidence from key studies to produce findings that support the application of AI in improving learning in primary schools.

Research Question

The first step in any systematic literature review (SLR) is formulating a research question (Mohamed Shaffril et al., 2021). Based on the research gaps discussed in Part 1, this SLR uses the central question as a guide: "How can the use of Artificial Intelligence (AI) technology improve learning in elementary schools?" This question becomes the primary framework that connects all research questions (see Table 1).

Table 1. Research Questions

ID	Research Questions	Rationality/Justification
RQ1	What are the leading AI technologies applied in learning in elementary schools?	Identifying key AI technologies is essential to understand their role in learning. Different technologies have specific functions in improving various aspects of learning.
RQ2	In what ways does this AI technology enhance the educational experience in primary schools?	This inquiry examines the potential of AI to enhance education by highlighting actual applications and their advantages in primary school settings.
RQ3	What are the specific challenges and needs in applying AI technology in elementary schools?	This question examines the specific benefits and challenges faced by the application of AI. The primary school context requires a unique approach to addressing complexity and collaborative needs.
RQ4	What are the technical requirements needed for adopting AI in elementary school learning?	Understanding the technical requirements is essential to ensure a successful AI implementation. This question identifies the infrastructure changes needed to support AI in learning.
RQ5	What are the non-technical requirements needed for adopting AI in elementary school learning?	Focus on non-technical needs such as teacher training and integration strategies to ensure AI can align with primary school learning structures.

This inquiry encompasses an examination of diverse AI technologies utilized in education (RQ1), their influence on the learning process in primary schools (RQ2), the obstacles to implementing AI within primary school settings (RQ3), and the prerequisites for successful adoption (RQ4 and RQ5). This method guarantees a thorough examination of the study subject. This research topic in the systematic literature review aims to investigate the function of AI technology in elementary school education by emphasizing critical aspects of its implementation. This inquiry framework offers a methodical and comprehensive methodology for evaluating the feasibility, effect, and constraints of using AI to enhance learning in primary schools. Table 1 delineates the specifics of the research inquiries and their rationales.

Search Strategy

Employing a systematic search technique is crucial for rapidly locating relevant material. This procedure encompasses many phases, such as identifying keywords and search strings, choosing

relevant literature databases, and establishing the methodology for article selection. The subsequent sections will delineate these actions.

a. Search String

Tests were performed to optimize the search string and ascertain pertinent articles to address the study issue. Search queries that include terminology associated with AI technology, education, and elementary education are used as follows: ("artificial intelligence OR "AI") AND ("education" OR "learning") AND ("primary schools" OR "elementary school" OR "grade school" OR "grammar school" OR "*Madrasah ibtidaiyah*" OR "MI") AND ("technology-enhanced learning"). The logical operator "OR" is used for terms such as "Artificial Intelligence," "education," and "primary schools" because all three are often used interchangeably in academic and industrial settings. This search string facilitates extensive study into the implementation of AI in several educational contexts.

This methodology broadly examines AI trends, technologies, and prerequisites, offering a comprehensive insight into its possibilities within the educational sector. Moreover, excluding certain terms such as "Elementary School" may hinder the acquisition of significant insights from research that, while not directly addressing elementary education, are pertinent to wider dialogues about the role of AI in education. The investigation in this research was conducted using the criteria of title, keywords, and abstract. Only papers published from 2014 to 2024 are included within the search criteria. The search is restricted to publications in English.

b. Literature Databases

The digital database is selected before the search to find all relevant publications related to the research subject and the relevant review questions. Data coverage and accuracy are key considerations in choosing a suitable database to support a comprehensive search strategy. For this systematic literature review, the databases used are Scopus and WoS. These two databases were chosen because they offer a wide coverage of high-quality publications in technology, education, and research relevant to utilizing Artificial Intelligence (AI) in learning in elementary schools. This combination of databases ensures the diversity and completeness of information to support in-depth literature analysis.

c. Defining Article Selection Approach

Keyword-based search techniques and tailored vocabulary are used to locate and retrieve relevant items from a designated database. The preliminary review yielded a more restricted assortment of papers. To facilitate the initial selection process, skyspace AI is used, which allows researchers to effectively assess and select relevant studies based on titles and abstracts. Only relevant articles will be reviewed and exported using this tool for further analysis. This methodology guarantees that the chosen literature aligns with the study goals and facilitates an extensive discourse on the use of AI technology in primary education.

Study Selection

In the main study selection stage, inclusion and exclusion criteria are applied to ensure that only relevant studies are included (Keung et al., 2020). Studies that met the inclusion criteria, namely discussing the application of AI in learning in primary schools and written in English, were included in the list of key studies. Instead, studies that do not meet these criteria, such as those that discuss the application of AI outside of the context of learning, are excluded. In the initial search phase, 12 studies were identified. After analyzing the title abstract, as many as 11 studies were selected for further review. Then, based on the inclusion and exclusion criteria, as many as eight studies were selected. This approach ensures that the selected literature contributes substantially to understanding AI technology's application in improving primary school learning.

Study Quality Assessment

One of the essential steps in implementing an SLR is to assess the quality of the study to be analyzed (Yang et al., 2021). The Quality Assessment (QA) approach in this literature study is based on five principal areas, each carrying equal significance. Every question has three response options: "yes" (score 1), "partially" (score 0.5), and "no" (score 0). The subject of the inquiry encompasses:

a. Well-defined research aims and inquiries (20%)

b. A clear articulation of scientific contribution (20%)

c. Elucidation of technical application or comprehensive AI function (20%)

d. Relevance: Case studies, practical applications, or implications (20%)

e. A definitive articulation of study findings (20%)

In the subsequent analysis phase, only relevant research with an average score over 70% was included, guaranteeing the results' validity. Studies deemed relevant must possess a score of seven or above on a scale of ten. Out of 12 articles, as many as 8 met the relevance criteria for further analysis. This process provides a strong foundation to support research on AI technology's application in primary school learning, ensuring that only high-quality literature is used in SLRs.

Data Extraction and Synthesis

The studies selected based on the Quality Assessment (QA) results are further analyzed to answer the five research questions formulated previously. At this stage, each research question is answered using data extraction cards for each selected article. Table 2 illustrates how the data were extracted to help answer the five research questions. This process is designed to relate the key findings of each article to the research question, resulting in a structured and comprehensive analysis. This approach ensures that studies that have met the relevance criteria can make a real contribution to the research objectives, particularly in the context of AI technology's application in primary school learning.

Table 2. Data Extraction Card

Field	Description
Database	The digital database where the study was taken (Scopus and WoS).
Year of Publication	Year of publication of the study.
Author's Name	Names of authors of relevant articles.
Source	The journal or conference proceedings in which the article was published.
Article Title	The title of the article summarizes the content and focus of the study.
AI Technology (RQ1)	The main AI technology is applied in learning in elementary schools.
Learning Process (RQ2)	How AI technology contributes to improving the learning process in elementary schools.
Challenges and Needs (RQ3)	Specific challenges and needs faced in applying AI technology in elementary schools.
Technical Requirements (RQ4)	Technical requirements required to adopt AI in learning in elementary schools.
Non-Technical Requirements (RQ5)	Non-technical needs, such as teacher training and AI integration strategies in learning structures in primary schools.

3. FINDINGS AND DISCUSSIONS

Implementation of AI Technology in Learning in Elementary Schools (RQ 1)

Implementing Artificial Intelligence (AI) technology in primary school education has demonstrated significant potential in enhancing student learning experiences by offering personalized and adaptive learning environments. AI is an intelligent system that can assess individual student needs, provide tailored learning materials, and monitor student performance to offer timely support (Alkan, 2024a; González-Calatayud et al., 2021a). Various AI technologies, such as voice recognition systems, chatbots, and biosensor data analysis, have been integrated into classrooms to facilitate effective teaching and learning.

One example is the use of wearable biosensors, as highlighted by (M. I. Ciolacu et al., 2019), which monitors students' health and learning behaviors in real-time. The collected data allows teachers to analyze student engagement, detect learning difficulties, and provide immediate interventions, increasing motivation and participation in learning activities. This aligns with the adaptive learning theory, where AI helps adjust instructional strategies based on student's cognitive and behavioral responses (Li et al., 2024a; Sun, 2020).

Additionally, AI contributes to early identification of students at risk of academic difficulties through predictive modeling (M. L. Ciolacu et al., 2020). By leveraging AI-powered diagnostics, educators can provide targeted interventions to improve student retention and reduce dropout rates. Furthermore, AI-driven personalized learning systems enable teachers to deliver instructional content tailored to students' abilities and learning paces, aligning with constructivist learning theory, which emphasizes student-centered and interactive learning (Harnawati & Hidayati, 2024; Yusuf et al., 2024).

However, the implementation of AI in elementary education also raises ethical concerns, particularly regarding data privacy and algorithmic bias (Bai et al., 2023; Marengo et al., 2024). Educational institutions must formulate explicit ethical standards to guarantee that AI serves all students fairly and does not exacerbate educational inequalities (Busch et al., 2023). Furthermore, teacher training and professional development are essential to maximize AI's potential, as many educators still require adequate knowledge and skills to integrate AI effectively into their teaching practices (Sadykova & Kayumova, 2024a).

In conclusion, AI technology is reshaping primary education by offering personalized learning, predictive analytics, and real-time student support. Schools must address ethical challenges, provide teacher training, and ensure equal access to AI-powered educational resources to harness its benefits fully. This will ensure that AI serves as an inclusive and transformative tool for improving learning outcomes in elementary schools.

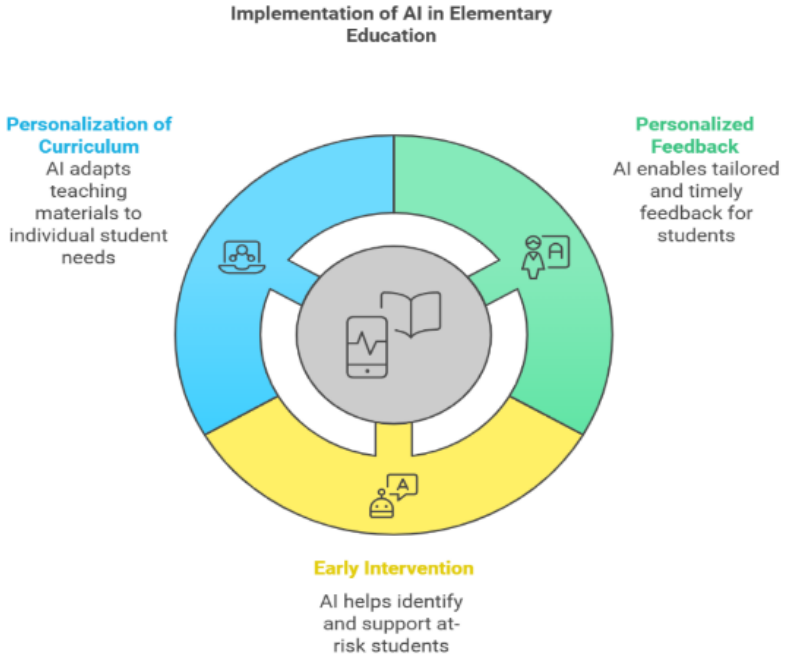


Figure 2. Implementation of AI in Elementary Education

The Contribution of AI Technology in Improving the Learning Process in Elementary Schools (RQ 2)

Integrating Artificial Intelligence (AI) technology in elementary school education has significantly enhanced teaching and learning by creating more adaptive and personalized learning experiences. AI plays a crucial role in assessing student needs, monitoring academic progress, and providing real-time feedback, which helps teachers develop more effective instructional strategies (Alkan, 2024a; González-Calatayud et al., 2021a).

One notable AI application is the use of wearable devices with biosensors, as discussed by (M. I. Ciolacu et al., 2019). These devices enable real-time data collection on student behavior and health, allowing teachers to identify students who need additional support and tailor interventions accordingly. This aligns with adaptive learning theory, which emphasizes personalized learning approaches based on individual student progress (Li et al., 2024a; Sun, 2020). Consequently, AI contributes to a more engaging and responsive learning environment, enhancing student motivation and participation in the classroom.

Furthermore, AI technology improves teaching effectiveness by supporting data-driven decision-making and personalized instruction. Research by (Earp et al., 2014) Highlights the impact of AI-powered game-based learning (GBL) on student engagement. Through interactive game design platforms, students apply academic concepts, collaborate with peers, and develop problem-solving skills, aligning with constructivist learning theory, which promotes active and experiential learning (Harnawati & Hidayati, 2024; Yusuf et al., 2024). The study found that students engaged in game-making activities demonstrated significant improvements in critical thinking and creativity, outperforming those in traditional learning environments.

Moreover, AI facilitates curriculum innovation and pedagogical transformation by enabling dynamic content adaptation based on real-time student performance (Fahimirad & Kotamjani, 2018; Lukianets & Lukianets, 2023). Institutions are increasingly leveraging AI to support online learning environments, optimize resource management, and enhance collaborative learning experiences (Chen et al., 2020; Dogan et al., 2023). However, ethical concerns regarding data privacy and algorithmic bias remain significant challenges (Bai et al., 2023; Marengo et al., 2024). Schools must establish clear ethical guidelines to ensure AI's fair and equitable implementation in education (Busch et al., 2023). In

conclusion, AI technology significantly contributes to personalized learning, enhanced student engagement, and improved instructional methods in elementary schools. However, teacher training, ethical considerations, and infrastructure readiness must be prioritized to ensure AI-driven education remains inclusive, effective, and sustainable to maximize its benefits.

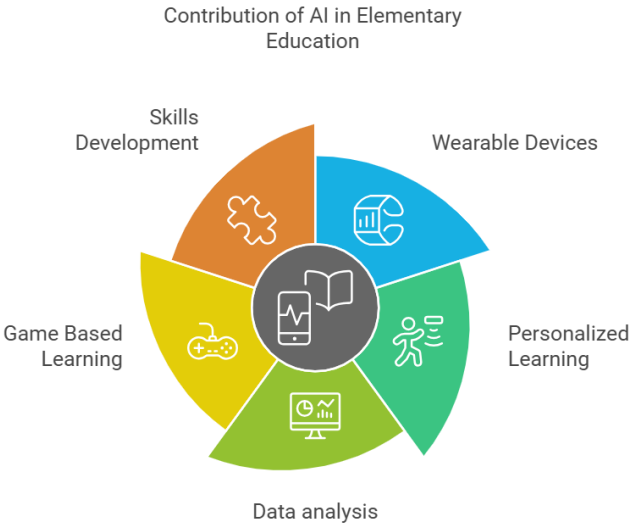


Figure 3. The Contribution of AI Technology in Elementary Education

Challenges and Needs in the Application of AI Technology in Elementary Schools (RQ 3)

Implementing Artificial Intelligence (AI) technology in elementary school education presents significant opportunities and challenges that must be addressed to ensure effective integration. While AI has the potential to enhance personalized learning, facilitate adaptive teaching methods, and optimize educational resources, several infrastructural, pedagogical, and ethical barriers hinder its widespread adoption.

a. Infrastructure Limitations

One of the primary challenges is the lack of adequate infrastructure, which includes hardware, stable internet connectivity, and efficient data management systems (M. I. Ciolacu et al., 2019). Emphasize that many elementary schools lack the necessary devices and technological support to implement AI-based learning tools effectively. Without adequate digital infrastructure, AI cannot function optimally to provide personalized learning experiences and real-time student assessment (Alkan, 2024b; González-Calatayud et al., 2021b). Addressing this challenge requires government and institutional support to invest in technological upgrades and ensure equitable access to AI-driven education.

b. Teacher Training and Professional Development

Beyond infrastructure, teacher preparedness is another critical factor influencing AI adoption in schools. It is common for educators to be unprepared to incorporate AI-based technologies into their lessons successfully (M. L. Ciolacu et al., 2020). Highlight that many educators struggle to adapt AI-powered instructional strategies, resulting in ineffective implementation and limited student engagement. Research also indicates that AI reshapes the traditional role of teachers, shifting their focus from content delivery to facilitating interactive and student-centered learning experiences (Li et al., 2024b). To bridge this gap, structured training programs and continuous professional development are essential to equip educators with the competencies required for AI-assisted instruction (Sadykova & Kayumova, 2024b).

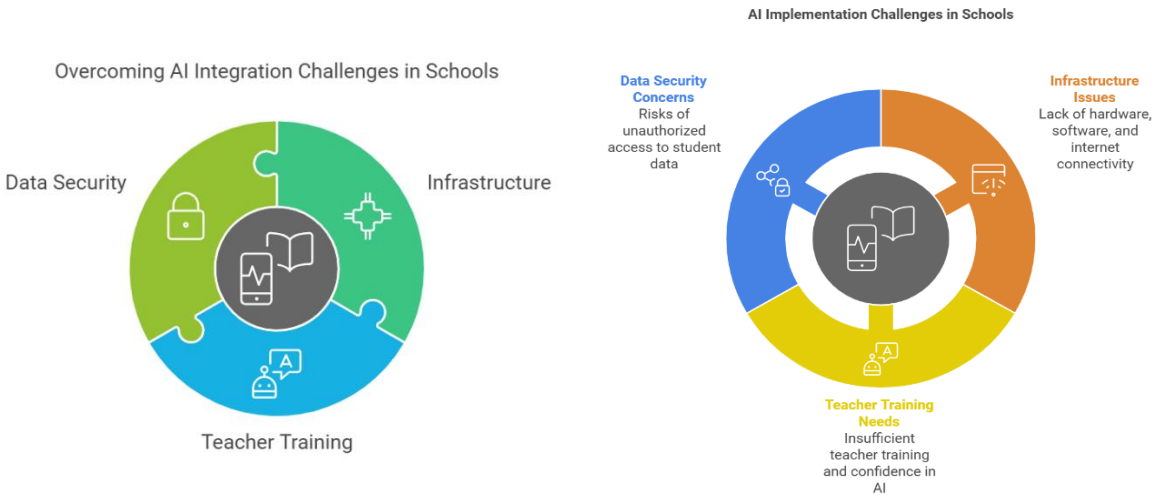
c. Data Security and Ethical Concerns

The increasing reliance on AI in education raises ethical challenges, particularly regarding data privacy and security. Many AI applications collect and analyze vast amounts of student data, raising concerns about unauthorized access, data misuse, and algorithmic bias (Bai, 2023; Marengo, 2024). Noster et al. (2022) highlight that schools often lack clear policies to regulate AI-driven data collection and student privacy protection. If not properly managed, AI risks exacerbating educational inequalities by disproportionately benefiting students with better technological access (Busch et al., 2023). To ensure responsible and inclusive use of AI in educational settings, it is necessary to build rigorous ethical principles and apply stringent data protection regulations.

d. The Need for Ethical AI Governance in Schools

AI governance in schools requires a multi-stakeholder approach involving educators, policymakers, parents, and technology developers. Research suggests that AI-powered education must align with pedagogical goals while prioritizing fairness and transparency. That AI does not replace but rather augments human educators in encouraging critical thinking and active learning among their students is an important part of this effort, as is the development of guidelines for the responsible use of AI in the classroom (Arip Nurahman & Pandu Pribadi, 2022b; Suharyo et al., 2024b). Furthermore, inclusive AI policies must be designed to provide equal learning opportunities for all students, regardless of their socioeconomic background or digital literacy level.

There is great promise in introducing AI into primary schools to improve individualized instruction and classroom management. Still, there are also major obstacles to overcome regarding infrastructure, teacher competence, and ethical considerations. Overcoming these barriers requires investment in digital infrastructure, continuous teacher training, and the development of clear data governance policies. If these challenges are adequately addressed, AI can be a transformative tool to improve elementary school student engagement, learning outcomes, and educational equity.



(a) (b)

Figure 4. Opportunities and Challenges of AI Integration in Elementary Education (a,b)

Technical Requirements for the Adoption of AI in Learning in Primary Schools (RQ 4)

Adopting artificial intelligence (AI) technology in learning in primary schools requires the fulfillment of several critical technical requirements to ensure effective and sustainable implementation. One of the key requirements is adequate technological infrastructure, including the hardware and software needed to support AI applications. The article by (M. L. Ciolacu et al., 2020) Explains that using devices such as Raspberry Pi and IoT sensors is essential for collecting and analyzing student data.

Schools cannot harness AI's potential to improve learning without the proper hardware.

In addition to hardware, stable and fast internet connectivity is also a crucial technical requirement. Many AI applications, especially cloud-based ones, require good internet access to function optimally. The article (M. I. Ciolacu et al., 2019) Highlights that without a reliable internet connection, data collected from wearable devices cannot be uploaded and analyzed in real-time, which reduces the effectiveness of using this technology in learning. Therefore, a robust network infrastructure is critical to supporting AI adoption in primary schools.

Additionally, an effective data management system is required to handle the data produced by AI technology. The student data collected must be appropriately managed to provide valuable insights for teachers and school managers. The article by (Noster et al., 2022) Shows that proper data analysis can help identify students' learning patterns and provide more personalized feedback. Therefore, schools need a system that can store, process, and analyze data safely and efficiently.

Finally, the importance of technical training for teaching staff and administration cannot be ignored. Teachers may find it challenging to make the most of this technology without understanding how AI technology works and how to integrate it into the curriculum. The article by (Earp et al., 2014) Proper training can help teachers develop the skills necessary to use AI technology. Thus, the technical requirements for the adoption of AI in learning in primary schools not only include infrastructure and hardware but also include ongoing training and professional development for educators.

Non-Technical Requirements for the Adoption of AI in Learning in Elementary Schools (RQ 5)

The deployment of artificial intelligence (AI) technology in learning in primary schools not only relies on technical needs but also requires the fulfillment of many non-technical conditions that are crucial to enable the effective integration of these technologies. One of the most crucial non-technical requirements is professional training and development for teachers. In the article, (M. L. Ciolacu et al., 2020) Teachers need adequate training to understand how AI technology works and integrate it into the existing curriculum. Teachers may feel unconfident in using this technology without proper training, hindering learning effectiveness.

In addition to teacher training, support from school management is also critical. The article (M. I. Ciolacu et al., 2019) Shows that the successful implementation of AI technology depends on school leaders' commitment and support. Proactive management in providing resources, both in the form of budgets and supportive policies, will create an environment conducive to adopting new technologies. This support also includes the development of clear policies regarding the use of AI technology, including aspects of student data privacy and security.

The involvement of parents and the community is also an essential factor in the adoption of AI technology in primary schools. The article by (Noster et al., 2022) Good communication between schools and parents can help increase understanding and acceptance of AI technology in learning. By involving parents in this process, schools can create greater trust and support for technology initiatives, improving the success of AI implementations in the classroom.

Finally, the importance of creating a culture of innovation in schools cannot be overlooked. The article by (Earp et al., 2014) emphasizes that to adopt new technologies such as AI, schools need to build a culture that supports continuous experimentation and learning. Schools can more easily integrate AI technology into the learning process by creating an environment encouraging teachers and students to try new approaches and share experiences. Therefore, the non-technical requirements for adopting AI in primary schools include teacher training, management support, parent involvement, and a culture of innovation that supports experimentation and learning.

This research offers a methodical way to comprehend the use of AI technology in elementary school curricula via its suggested literature synthesis framework. The framework makes it possible to

thoroughly examine AI integration in primary education by organizing the research around five critical dimensions: the recognition of AI technologies, their effects on learning, related difficulties and requirements, and technical and non-technical specifications. This method does more than just compile previous studies; it delves further into the variables that affect AI adoption in primary schools (Zawacki-Richter et al., 2019).

Identifying AI technologies applied in primary school education reveals various tools and applications designed to enhance learning experiences. AI-powered tools such as speech recognition systems, chatbots, and biosensors have been employed to personalize instruction, provide real-time feedback, and foster student engagement. As noted by (Alkan, 2024a; González-Calatayud et al., 2021a), AI plays a pivotal role in assessing students' needs and delivering tailored instructional materials. Studies by (T. K. F. Chiu et al., 2023), (Hooda et al., 2022), and (Bakti et al., 2023) Further reinforcing this notion, emphasizing how AI-driven data collection via wearables allows teachers to provide targeted and timely interventions. This aligns with the principles of Adaptive Learning Theory, which underscores the importance of instructional customization based on individual learning trajectories (Li et al., 2024a; Sun, 2020). Consequently, AI contributes to creating a more responsive and student-centered learning environment.

Beyond its role in student assessment, AI significantly enhances pedagogical strategies and instructional methodologies. AI-driven learning analytics enable teachers to identify students' strengths and weaknesses, allowing for early intervention and differentiated instruction. Research by Earp et al. (2014) indicates that AI-based game-based learning environments can improve students' critical thinking and problem-solving skills, reinforcing the relevance of Problem-Based Learning (PBL) in AI-integrated classrooms (Arip Nurahman & Pandu Pribadi, 2022a; Suharyo et al., 2024a). AI also facilitates constructivist learning environments by enabling interactive and exploratory learning experiences, wherein students actively construct knowledge through AI-generated simulations and adaptive content delivery (Harnawati & Hidayati, 2024; Yusuf et al., 2024). Thus, AI is an auxiliary tool and a catalyst for pedagogical innovation.

However, integrating AI into primary school education is not without challenges. One of the primary barriers to AI adoption is the lack of adequate infrastructure, including access to stable hardware and internet connectivity. As highlighted by (Chen et al., 2020), many elementary schools struggle with technological limitations that impede AI implementation. Additionally, the effectiveness of AI in education hinges on the preparedness of educators. Studies by (J. L. Chiu et al., 2020) and (Sadykova & Kayumova, 2024a) emphasize the necessity of professional development programs to equip teachers with the requisite knowledge and skills for integrating AI into the curriculum. Teachers may find it challenging to harness AI's potential effectively without adequate training. These challenges underscore the pressing need for investment in technological infrastructure and educator training programs.

From a technical perspective, effective AI integration requires robust data management systems to ensure efficient data processing and secure storage. As (Lim et al., 2021) Suggest AI-generated student data must be systematically analyzed to provide actionable insights that enhance teaching and learning outcomes. This aligns with (Viktorova & Mamchur, 2021) The cognitive learning framework emphasizes AI's role in information processing and knowledge organization. Moreover, technical literacy among educators and administrative staff is essential to optimize AI utilization, reinforcing the need for specialized training initiatives.

In addition to technical considerations, non-technical factors such as institutional leadership and parental involvement play a crucial role in AI adoption. The successful implementation of AI in education requires a strong commitment from school administrators, as emphasized by (Fullan et al., 2024; Ghamrawi et al., 2024). Furthermore, engaging parents in the AI integration process fosters greater acceptance and understanding of the technology's benefits, thereby facilitating smoother adoption

(Zhang et al., 2022). As research by (Busch et al., 2023) Highlights that ethical considerations—such as data privacy and algorithmic bias—must also be addressed to ensure equitable access to AI-driven educational resources. Without clear ethical guidelines, AI risks exacerbating existing educational inequalities (Bai et al., 2023; Marengo et al., 2024).

Finally, fostering a culture of innovation within schools is key to ensuring the long-term success of AI adoption. Schools must create environments encouraging experimentation and continuous learning, enabling teachers and students to explore AI's potential applications. This aligns with findings by (Earp et al., 2014), which stresses the importance of institutional support in cultivating an AI-driven learning culture. Integrating AI into primary education represents a paradigm shift that necessitates ongoing adaptation and professional development. By leveraging AI's capabilities while addressing its associated challenges, schools can create a more inclusive, adaptive, and responsive learning ecosystem that enhances educational outcomes for all students.

4. CONCLUSION

Students' educational experiences have been greatly enhanced by integrating artificial intelligence (AI) technology into primary school curricula. This study delves into how AI technologies like biosensors, voice recognition systems, and chatbots might enhance student engagement, motivation, and learning results. Further evidence that AI is both a tool and a driver of change in education comes from its role in developing more responsive and individualized learning experiences and enhancing critical thinking abilities via novel educational approaches, such as game-based learning.

However, the current problems and requirements must be met to integrate AI technology successfully. Issues with data security, insufficient infrastructure, and the necessity to educate teachers are all factors to consider. To foster an atmosphere favorable to adopting AI, the research stresses the need to satisfy technical and non-technical needs, such as having management backing and parental participation. Schools can maximize AI's potential, improve educational results for students, and design more effective learning experiences by tackling these difficulties and satisfying the standards.

REFERENCES

Ahmad, K., Iqbal, W., El-Hassan, A., Qadir, J., Benhaddou, D., Ayyash, M., & Al-Fuqaha, A. (2024). Data-Driven Artificial Intelligence in Education: A Comprehensive Review. *IEEE Transactions on Learning Technologies*, *17*, 12–31. https://doi.org/10.1109/TLT.2023.3314610

Alkan, A. (2024a). Artificial Intelligence: Its Role and Potential in Education. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi*, *13*(1), 483–497. https://doi.org/10.15869/itobiad.1331201

Alkan, A. (2024b). Artificial Intelligence: Its Role and Potential in Education. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi*, *13*(1), 483–497. https://doi.org/10.15869/itobiad.1331201

Arip Nurahman, & Pandu Pribadi. (2022a). Pemanfaatan Kecerdasan Buatan pada Media Pembelajaran Berbantuan Google Assistant. *Jurnal Genesis Indonesia*, *1*(01), 24–32. https://doi.org/10.56741/jgi.v1i01.17

Arip Nurahman, & Pandu Pribadi. (2022b). Pemanfaatan Kecerdasan Buatan pada Media Pembelajaran Berbantuan Google Assistant. *Jurnal Genesis Indonesia*, *1*(01), 24–32. https://doi.org/10.56741/jgi.v1i01.17

Bai, J. Y. H., Müskens, W., Zawacki-Richter, O., & Senyo Loglo, F. (2023). Prospects of artificial intelligence in education. *ASCILITE Publications*, 22–29. https://doi.org/10.14742/apubs.2023.534

Baidoo-Anu, D., & Owusu Anisah, L. (2023). Education in the Era of Generative Artificial Intelligence

(AI): Understanding the Potential Benefits of ChatGPT in Promoting Teaching and Learning. *Journal of AI*, *7*(1), 52–62. https://doi.org/10.61969/jai.1337500

Bakti, I. K., Zulkarnain, Yarun, A., Rusdi, Syaifudin, M., & Syafaq, H. (2023). The Role of Artificial Intelligence in Education: A Systematic Literature Review. *Jurnal Iqra' : Kajian Ilmu Pendidikan*, *8*(2), 182–197. https://doi.org/10.25217/ji.v8i2.3194

Busch, F., Adams, L. C., & Bressem, K. K. (2023). Biomedical Ethical Aspects Towards the Implementation of Artificial Intelligence in Medical Education. *Medical Science Educator*, *33*(4), 1007–1012. https://doi.org/10.1007/s40670-023-01815-x

Chemlal, Y. (2023). *Fostering sustainable Development Through Artificial Intelligence in Education (ESD): A Comprehensive Evaluation Framework and Key Criteria Analysis*. https://doi.org/10.21203/rs.3.rs-3372485/v1

Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. *IEEE Access*, *8*, 75264–75278. https://doi.org/10.1109/ACCESS.2020.2988510

Chiu, J. L., Fajardo, J. J., Lopez, P. N., Lourdes, J., & Miranda, F. (2020). The Effect of Employer Branding on Turnover Intention and Employee Satisfaction of the Utility Industry in the Philippines. *Management Review: An International Journal*, *15*(2), 1–153.

Chiu, T. K. F., Moorhouse, B. L., Chai, C. S., & Ismailov, M. (2023). Teacher support and student motivation to learn with Artificial Intelligence (AI) based chatbot. *Interactive Learning Environments*, 1–17. https://doi.org/10.1080/10494820.2023.2172044

Ciolacu, M. I., Binder, L., & Popp, H. (2019). Enabling IoT in Education 4.0 with BioSensors from Wearables and Artificial Intelligence. *SIITME 2019 - 2019 IEEE 25th International Symposium for Design and Technology in Electronic Packaging, Proceedings*, 17–24. https://doi.org/10.1109/SIITME47687.2019.8990763

Ciolacu, M. L., Tehrani, A. F., Svasta, P., Tache, I., & Stoichescu, D. (2020). Education 4.0: An Adaptive Framework with Artificial Intelligence, Raspberry Pi, and Wearables-Innovation for Creating Value. *2020 IEEE 26th International Symposium for Design and Technology in Electronic Packaging, SIITME 2020 - Conference Proceedings*, 298–303. https://doi.org/10.1109/SIITME50350.2020.9292148

Dogan, M. E., Goru Dogan, T., & Bozkurt, A. (2023). The Use of Artificial Intelligence (AI) in Online Learning and Distance Education Processes: A Systematic Review of Empirical Studies. *Applied Sciences (Switzerland)*, *13*(5), 3056. https://doi.org/10.3390/app13053056

Earp, J., Dagnino, F. M., & Ott, M. (2014). Learning through game making: An HCI perspective. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Bioinformatics)*, *8514 LNCS*(PART 2), 513–524. https://doi.org/10.1007/978-3-319-07440-5_47

Fahimirad, M., & Kotamjani, S. S. (2018). A Review on Application of Artificial Intelligence in Teaching and Learning in Educational Contexts. *International Journal of Learning and Development*, *8*(4), 106. https://doi.org/10.5296/ijld.v8i4.14057

Fullan, M., Azorín, C., Harris, A., & Jones, M. (2024). Artificial intelligence and school leadership: Challenges, opportunities, and implications. *School Leadership and Management*, *44*(4), 339–346. https://doi.org/10.1080/13632434.2023.2246856

Ghamrawi, N., Shal, T., & Ghamrawi, N. A. R. (2024). Exploring the impact of AI on teacher leadership: Regressing or expanding? *Education and Information Technologies*, *29*(7), 8415–8433. https://doi.org/10.1007/s10639-023-12174-w

González-Calatayud, V., Prendes-Espinosa, P., & Roig-Vila, R. (2021a). Artificial intelligence for student assessment: A systematic review. *Applied Sciences (Switzerland)*, *11*(12), 5467.

https://doi.org/10.3390/app11125467

González-Calatayud, V., Prendes-Espinosa, P., & Roig-Vila, R. (2021b). Artificial intelligence for student assessment: A systematic review. *Applied Sciences (Switzerland)*, *11*(12), 5467. https://doi.org/10.3390/app11125467

Harnawati, H., & Hidayati, U. (2024). Persepsi Mahasiswa Calon Guru Matematika terhadap Pemanfaatan Teknologi Kecerdasan Buatan dalam Konteks Pembelajaran. *JagoMIPA: Jurnal Pendidikan Matematika Dan IPA*, *4*(1), 50–59. https://doi.org/10.53299/jagomipa.v4i1.389

Hooda, M., Rana, C., Dahiya, O., Rizwan, A., & Hossain, M. S. (2022). Artificial Intelligence for Assessment and Feedback to Enhance Student Success in Higher Education. *Mathematical Problems in Engineering*, *2022*, 1–19. https://doi.org/10.1155/2022/5215722

Keung, E. Z., McElroy, L. M., Ladner, D. P., & Grubbs, E. G. (2020). *Defining the Study Cohort: Inclusion and Exclusion Criteria* (pp. 47–58). https://doi.org/10.1007/978-3-030-35488-6_5

Li, Q., Sorscher, B., & Sompolinsky, H. (2024a). Representations and generalization in artificial and brain neural networks. *Proceedings of the National Academy of Sciences of the United States of America*, *121*(27). https://doi.org/10.1073/pnas.2311805121

Li, Q., Sorscher, B., & Sompolinsky, H. (2024b). Representations and generalization in artificial and brain neural networks. *Proceedings of the National Academy of Sciences of the United States of America*, *121*(27). https://doi.org/10.1073/pnas.2311805121

Lim, L.-A., Dawson, S., Gašević, D., Joksimović, S., Pardo, A., Fudge, A., & Gentili, S. (2021). Students' perceptions of, and emotional responses to, personalized learning analytics-based feedback: An exploratory study of four courses. *Assessment & Evaluation in Higher Education*, *46*(3), 339–359. https://doi.org/10.1080/02602938.2020.1782831

Lukianets, H., & Lukianets, T. (2023). Promises and Perils of AI Use on the Tertiary Educational Level. *Grail of Science*, *25*, 306–311. https://doi.org/10.36074/grail-of-science.17.03.2023.053

Marengo, A., Pagano, A., Pange, J., & Soomro, K. A. (2024). The educational value of artificial intelligence in higher education: A 10-year systematic literature review. *Interactive Technology and Smart Education*, *21*(4), 625–644. https://doi.org/10.1108/ITSE-11-2023-0218

Mohamed Shaffril, H. A., Samsuddin, S. F., & Abu Samah, A. (2021). The ABC of systematic literature review: The basic methodological guidance for beginners. *Quality & Quantity*, *55*(4), 1319–1346. https://doi.org/10.1007/s11135-020-01059-6

Noster, N., Hershkovitz, A., Tabach, M., & Siller, H. S. (2022). Learners' Strategies in Interactive Sorting Tasks. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Bioinformatics)*, *13450 LNCS*, 285–298. https://doi.org/10.1007/978-3-031-16290-9_21

Pont-Niclòs, I., Echegoyen-Sanz, Y., Orozco-Gómez, P., & Martín-Expeleta, A. (2024). Creativity and artificial intelligence: A study with prospective teachers. *Digital Education Review*, *45*, 91–97. https://doi.org/10.1344/der.2024.45.91-97

Ratnadewi, R., Andrianto, H., Saragih, R. A., Prijono, A., Sunoto, T. D., Susanthi, Y., & Jarden, J. J. (2023). Pelatihan Kecerdasan Buatan bagi Siswa-siswi SMKN-4 Bandung. *AKM: Aksi Kepada Masyarakat*, *4*(1), 233–240. https://doi.org/10.36908/akm.v4i1.839

Rejeki, H. S., Purwanto, D., & Mentara, H. (2024). Pengembangan Model Pembelajaran Berbasis Permainan Untuk Meningkatkan Kebugaran Jasmani Siswa Sekolah Dasar. *Journal of SPORT (Sport, Physical Education, Organization, Recreation, and Training)*, *8*(2), 620–631. https://doi.org/10.37058/sport.v8i2.11007

Sadykova, G., & Kayumova, A. (2024a). Educators' Perception of Artificial Intelligence as Instructional

Tool. *TEM Journal*, *13*(4), 3194–3204. https://doi.org/10.18421/TEM134-54

Sadykova, G., & Kayumova, A. (2024b). Educators' Perception of Artificial Intelligence as Instructional Tool. *TEM Journal*, *13*(4), 3194–3204. https://doi.org/10.18421/TEM134-54

Schleiss, J., Laupichler, M. C., Raupach, T., & Stober, S. (2023). AI Course Design Planning Framework: Developing Domain-Specific AI Education Courses. *Education Sciences*, *13*(9), 954. https://doi.org/10.3390/educsci13090954

Seo, K., Tang, J., Roll, I., Fels, S., & Yoon, D. (2021). The impact of artificial intelligence on learner–instructor interaction in online learning. *International Journal of Educational Technology in Higher Education*, *18*(1). https://doi.org/10.1186/s41239-021-00292-9

Suharyo, S., Subyantoro, S., & Pristiwati, R. (2024a). Kecerdasan Buatan dalam Konteks Kurikulum Merdeka pada Jenjang Pendidikan Dasar dan Menengah: Membangun Keterampilan Menuju Indonesia Emas 2045. *Humanika*, *30*(2), 208–217. https://doi.org/10.14710/humanika.v30i2.60563

Suharyo, S., Subyantoro, S., & Pristiwati, R. (2024b). Kecerdasan Buatan dalam Konteks Kurikulum Merdeka pada Jenjang Pendidikan Dasar dan Menengah: Membangun Keterampilan Menuju Indonesia Emas 2045. *Humanika*, *30*(2), 208–217. https://doi.org/10.14710/humanika.v30i2.60563

Sun, Y. (2020). Analysis of Impulsive Buying Behavior in Live Broadcast Scenarios. *Education Reform and Development*. https://doi.org/10.26689/erd.v2i2.2135

Syarifuddin, S., Nufus, M. S., Sasoko, W. H., Zukhruf, A., Ramdan, F., Rosnani, R., & Kurnia, A. (2024). Analisis Tingkat Keterampilan Guru Sekolah Dasar di Kota Bima dalam Pengembangan Pembelajaran Berbasis Media Interaktif. *Jurnal Pendidikan Dan Pembelajaran Indonesia (JPPI)*, *4*(1), 35–48. https://doi.org/10.53299/jppi.v4i1.387

Tolentino, R., Baradaran, A., Gore, G., Pluye, P., & Abbasgholizadeh-Rahimi, S. (2024). Curriculum Frameworks and Educational Programs in AI for Medical Students, Residents, and Practicing Physicians: Scoping Review. *JMIR Medical Education*, *10*, e54793. https://doi.org/10.2196/54793

Viktorova, L., & Mamchur, K. (2021). The Use of Artificial Intelligence for Arabic Learning. *Priority Areas for Development of Scientific Research: Domestic and Foreign Experience*. https://doi.org/10.30525/978-9934-26-049-0-16

Yang, L., Zhang, H., Shen, H., Huang, X., Zhou, X., Rong, G., & Shao, D. (2021). Quality Assessment in Systematic Literature Reviews: A Software Engineering Perspective. *Information and Software Technology*, *130*, 106397. https://doi.org/10.1016/j.infsof.2020.106397

Yusuf, Azizah, N. L., Suci, T. P., & Walida, S. El. (2024). Implementasi Pembelajaran Berbasis Artificial Intelligence Melalui Media Canva Pada Calon Guru Matematika. *Jurnal Pengabdian Kepada Masyarakat Bersinergi Inovatif*, *1*(2), 101–108. https://doi.org/10.61674/jpkmbi.v1i2.154

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0

Zhang, Q., Lin, S., Liu, J., & Jin, Y. (2022). A game perspective on collaborative learning among students in higher education. *Cogent Education*, *9*(1), 2115617. https://doi.org/10.1080/2331186X.2022.2115617