

Implementation Patterns and Challenges of Generative AI in Elementary Education: A PRISMA-Based Review

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ABSTRACT

The rapid adoption of generative artificial intelligence (GenAI) in education offers new opportunities for teaching and learning; however, evidence regarding its implementation and associated challenges in elementary education remains fragmented. This study aimed to identify patterns of GenAI implementation and examine the challenges affecting its integration into elementary education. A systematic literature review was conducted following the PRISMA framework. Open-access, peer-reviewed empirical articles published in English between 2020 and 2025 were identified through ScienceDirect and restricted to Scopus-indexed journals (Q1–Q4). After identification, screening, and eligibility assessment, 15 articles were included. Data on study characteristics, implementation practices, and challenges were extracted and synthesized thematically. The findings indicate that GenAI and AI-supported technologies are implemented across several educational functions, including instructional planning, personalized learning, language learning, mathematics problem-solving, assessment and feedback, and the development of computational thinking and AI literacy. Across the reviewed studies, recurring challenges included limited teacher competency and AI literacy, inadequate infrastructure, varying institutional readiness, concerns regarding content accuracy and overreliance, data privacy and academic integrity risks, and insufficient policy and ethical guidance. These findings suggest that effective GenAI integration in elementary education depends not only on technological capabilities but also on pedagogical readiness, teacher professional development, adequate infrastructure, and institutional governance. Future research should employ rigorous empirical designs to evaluate the effectiveness and conditions of GenAI implementation across diverse elementary education contexts.

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1. INTRODUCTION

The development of technology and information has led to the advancement of artificial intelligence (AI), which has influenced various fields, including the education and learning sector (Fatmadiwi, Suryani, Hartoyo, & Erlina, 2025). AI is an area of computer science that tries to enable computers to do activities like humans, such as awareness, representation of knowledge, reasoning, figuring out solutions, and planning to deal with complicated and ambiguous situations in a purposeful, intelligent, and adaptable way (Pan & Zhang, 2021). One type of AI used in the world of learning and education is generative AI (GenAI) (Rizal, 2024). GenAI encompasses computer methods that may produce ostensibly novel and meaningful material, such as text, pictures, or audio, derived from training data (Feuerriegel, Hartmann, Janiesch, & Zschech, 2024).

GenAI is a tool used to demonstrate artificial intelligence that not only fulfills tasks assigned by humans but also exceeds the tasks given (Maphoto et al., 2024). GenAI can respond to questions or commands and generate information needed by learners, such as text, images, etc. Integrating GenAI into instructional design represents a significant evolution in pedagogical practice, but a comprehensive investigation of international policy frameworks is needed to guide its responsible and effective implementation (Nguyen, Duong, Nguyen, Lai, & Dang, 2025). This GenAI technology offers prospects for adapting instruction to meet the needs of individual learners, providing rapid feedback, and facilitating flexible learning pathways, thereby making it easier for teachers to optimize educational outcomes (AlAli & Wardat, 2024).

However, the implementation of GenAI also presents several challenges that require careful consideration. For example, ChatGPT is one type of GenAI that some instructors have welcomed because of its potential to improve students' learning experiences. Others have raised worries about its influence on educational integrity and plagiarism (Chen, Zhu, & Díaz del Castillo H., 2023). While posing threats, ChatGPT also presents opportunities that must be thoroughly assessed and addressed to ensure that its implementation conforms with ethical and pedagogical issues (Wu, 2023). Issues associated with the usage of ChatGPT include possible legal, moral, and ethical concerns posed by GenAI, such as infringement of copyright in AI-generated artworks, plagiarism and cheating in educational institutions, privacy and data security, and the harmful use of deepfakes (Nah, Zheng, Cai, Siau, & Chen, 2023). Another issue related to GenAI is that it is still difficult to identify whether the generated content is of high quality and trustworthy, as ChatGPT may provide answers or responses that seem plausible but are incorrect or illogical (Andriyani et al., 2024).

Therefore, it is important to conduct an in-depth study on the implementation of GenAI in learning and elementary education so that all stakeholders in elementary education have a foundation or guideline in integrating GenAI into learning in elementary schools. If GenAI is utilized wisely, it will assist in the process of responsible and integrity-based learning, while also preserving the essence of character education (Asisah, Raihani, & Haliq, 2025; Pratiwi & Yunus, 2024). Additionally, this research provides an overview of the utilization, impact, and challenges of GenAI in primary education.

Previous research on GenAI includes AI policies in higher education (Fatmadiwi et al., 2025). The study indicates that AI-based learning has both benefits and limitations. On the one hand, GenAI may be a tool to aid academics in information collection and learning efficiency. But improper usage may compromise academic integrity. Research on improving teacher competence through GenAI training (Pratikno & Kisworo, 2024). The research illustrates that the implementation of GenAI in the form of ChatGPT, Bard, and Perplexity can help teachers in improving the quality of teaching and learning. Additionally, in other countries, research has been conducted on GenAI, including the use of AI for university students to enhance motivation and learning (Mohamed, Shaaban, Bakry, Guillén-Gámez, & Strzelecki, 2025). The study revealed that AI-based learning tools can help improve motivation and learning. Furthermore, the integration of AI in learning improves self-efficacy, motivation, and digital literacy among adult learners (Lyu & Salam, 2025). The results of the study revealed that strategic integration of AI-based personalized learning can significantly improve self-efficacy, learning motivation, and digital literacy.

Previous research focused more on the use and impact of GenAI in higher education and among teachers. This study focuses on primary education, involving stakeholders in elementary schools. Additionally, research on GenAI in primary education is still emerging compared with higher education, including how to implement GenAI, as well as current concerns and challenges regarding education and learning at the primary level. Additionally, few studies have specifically examined GenAI in Indonesian primary education. Therefore, a comprehensive and systematic review of the implementation and challenges of GenAI in primary education is necessary. Furthermore, this research is interesting to examine because the implementation of GenAI in primary education poses challenges, particularly in aspects of elementary school child development, pedagogy, ethics, and infrastructure that differ in each elementary school.

The focus of this research is on elementary education. The purpose of this study is to identify the implementation of GenAI in elementary education and analyze the challenges of GenAI in learning and elementary education. The research question is how the implementation and challenges in using GenAI in primary education? The findings of this study can contribute to the field of education and learning, particularly in elementary schools, by providing recommendations to stakeholders on positive policies for integrating GenAI into learning to ensure that learning maintains its academic credibility and integrity. Additionally, it offers support for students and teachers by integrating GenAI, thereby making learning more effective and efficient.

2. METHODS

This study employs a Systematic Literature Review (SLR) research approach. The SLR will identify, evaluate, and understand the impact and limitations of differentiated learning in improving student learning outcomes. This SLR follows the Preferred Reporting Items for Systematic Reviews (PRISMA) standards (Cabrera, Cabrera, & Cabrera, 2023). A PRISMA-based systematic review is a systematic review of a clearly formulated research question that uses systematic and explicit methods to identify, select, and critically appraise relevant studies, as well as to collect and analyze data from those studies (Moher, Liberati, Tetzlaff, & Altman, 2010). PRISMA has a unique characteristic in that it not only influences how protocols are reported but also impacts how reviews are conducted, enabling a smoother transition to a fully reported systematic review (Moher et al., 2015).

To achieve rigorous and focused results, the review process is guided by clearly formulated research questions, which help maintain a focused scope and facilitate the identification of relevant data in the literature. The research questions for this study are as follows:

RQ1: How is generative AI implemented in elementary education?

RQ2: What are the challenges in implementing generative AI in elementary education?

The PRISMA protocol used in this systematic review consists of four stages: the identification stage, the screening stage, the eligibility assessment stage, and the data extraction stage. In the first stage, the identification phase, the process of selecting articles that meet the predetermined criteria involves the following steps: first, source selection; there are various databases available for systematic literature reviews, such as ScienceDirect. In this study, the articles used were obtained from Scopus-indexed articles, as Scopus provides more consistent results; it is one of the digital libraries that yields promising results based on titles, abstracts, or keywords, and offers more advanced search options (Baas, Schotten, Plume, Côté, & Karimi, 2020). Second, the researchers began the search by using the research questions to identify keywords relevant to the study. These keywords were then combined by adding quotation marks, wildcards, or curly braces to improve the quality of the results. Searching for articles using the predetermined keywords via the search engine yielded the following structure: "Generative AI" OR "GenAI"; "elementary education."

Second, the screening phase. Next came the process of screening titles and abstracts, and mapping articles based on their titles and abstracts. Titles were screened for relevance and alignment with the keywords used. Next, the abstracts of each article were screened and reviewed according to the

predetermined inclusion and exclusion criteria. The author established inclusion criteria to assess the relevance of the articles to the research objectives and to ensure a consistent evaluation. The results of the data search using these criteria were subsequently used by the author to review the articles. The inclusion criteria used by the author in selecting the literature included: published between 2020 and 2025, original research articles, with a complete structure, open access, and written in English. The publications were taken from ScienceDirect, indexed in Scopus in Q1-Q4. Furthermore, the selected articles covered the implementation of AI in primary education.

The inclusion criteria for this study were established based on theoretical and methodological considerations. First, the selected articles must focus on educational topics relevant to the study's objectives, namely the implementation and challenges of using GenAI in elementary education. Second, only articles published in peer-reviewed scientific journals were included to ensure the credibility and academic rigor of the reviewed studies. Third, the publication year is limited to a specific range to enhance the reproducibility of findings and avoid reliance on outdated theories or methodologies. Fourth, unpublished studies or those still in the registration phase are excluded to maintain data reliability. Fifth, only full-text, peer-reviewed articles are considered to ensure full access to the content necessary for in-depth analysis. Sixth, publications are limited to those written in English, as it is the dominant language in academic research and facilitates a broader understanding of scientific concepts. Finally, the scope of this study was narrowed by applying these criteria to ensure specificity and a focus on elementary education. Following the explanation of the inclusion criteria, the author outlines the exclusion criteria applied in this review. Exclusion criteria were used to screen the literature; these criteria included research findings that did not reflect empirical or original research results, were published before 2020, lacked a complete article structure (such as containing only an abstract), were not downloadable (not open access), or were not written in English.

Third, during the eligibility screening phase of this study, the full texts of articles that initially met the eligibility criteria were downloaded and reviewed in greater depth. At this stage, any articles that met the exclusion criteria were removed from the dataset. The remaining articles were required to demonstrate clear relevance to the research questions and provide data or insights that directly addressed the study's objectives.

Next, the data extraction phase was conducted. After confirming the eligibility of the articles based on the predefined inclusion and exclusion criteria, the researchers narrowed their focus to studies addressing the large-scale implementation and challenges of using GenAI in elementary education. From the period between 2020 and 2025, a total of 7,402 articles were initially identified. Subsequently, 5,285 articles were excluded because they were published before 2020 or after 2025. Then, an additional 285 articles—including conference proceedings, books, reviews, and theses—were excluded because they did not qualify as research articles. This left 1,832 research articles. Additionally, 3 articles were discarded because they were not written in English. Subsequently, 1,829 articles were further screened and filtered to exclude those that were inaccessible, those outside the subject areas of social sciences and computer science, as well as articles with incomplete structures or that did not comprehensively discuss the implementation and challenges of GenAI in elementary education (EE). In the end, only 15 articles met all the criteria and were deemed suitable for in-depth analysis. The complete selection process is illustrated in the PRISMA flowchart shown in Figure 1.

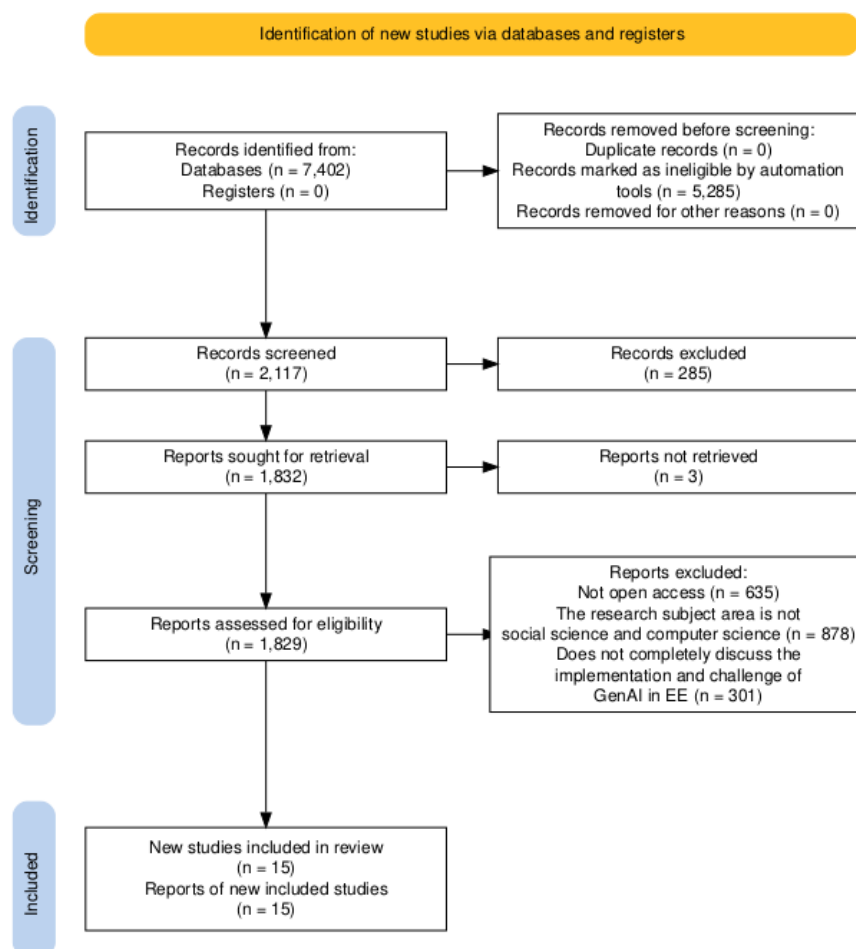


Figure 1. PRISMA Flowchart

Researchers selected articles independently, and disagreements were resolved through discussion until consensus was reached. Data extraction for each article includes: author, year of publication, research objectives, research methodology, sample characteristics, and scope of interest. The data obtained is then synthesized narratively to answer the research questions.

Table 1. List of Analyzed Articles

Number	Authors & year	Title	Type Research	Countries	Focus Theme Article
1.	(Kim & Kwon, 2023)	Exploring the AI competencies of elementary school teachers in South Korea	Mixed-method	South Korea	Curriculum integration and AI literacy
2.	(Park et al., 2022)	Investigating a visual interface for elementary students to formulate AI planning tasks	Mixed-method	USA	GenAI-supported learning activities
3.	(Tai & Chen, 2024)	Improving elementary EFL speaking skills with generative AI chatbots: Exploring individual and paired interactions	Mixed-method	Taiwan	Teacher planning, assessment, and administrative support

4.	(Panday-Shukla, 2025)	Exploring generative artificial intelligence in teacher education	Qualitative method	USA	Reported educational benefits
5.	(Ng, Chan, & Lo, 2025)	Opportunities, challenges and school strategies for integrating generative AI in education	Qualitative method	Canada	Challenges and risks
6.	(Liu, Sun, Sun, Wang, & Yu, 2025)	Designing a generative AI enabled learning environment for mathematics word problem solving in primary schools: Learning performance, attitudes and interaction	Quantitative method	China	Policy and implementation conditions
7.	(Lee & Song, 2024)	Teachers' and students' perceptions of AI-generated concept explanations: Implications for integrating generative AI in computer science education	Quantitative method	Australia	Implementation of Gen AI in computer science education
8.	(Fundi, Sanusi, Oyelere, & Ayere, 2024)	Advancing AI education: Assessing Kenyan in-service teachers' preparedness for integrating artificial intelligence in competence-based curriculum	Quantitative method	Kenya	Integration of GenAI in competency-based curriculum
9.	(Kajiwara, Matsuoka, & Shinbo, 2023)	Machine learning role playing game: Instructional design of AI education for age-appropriate in K-12 and beyond	Quantitative method	Japan	GenAI instructional design
10.	(Pei, Lu, & Jing, 2025)	Empowering preservice teachers' AI literacy: Current understanding, influential factors, and strategies for improvement	Quantitative method	USA	GenAI Literacy in Pre-Service Teachers
11.	(Bem-Haja, Nossa, Ferreira, Pereira, & Silva, 2025)	AI analysis reveals top predictors of first grade success: Insights from multifactorial screening students' early days of school	Quantitative method	Portugal	Factors influencing the use of GenAI
12.	(Collie & Martin, 2024)	Teachers' motivation and engagement to harness generative AI for teaching and learning: The role of contextual, occupational, and background factors	Quantitative method	Australia	Factors influencing teacher motivation to use Gen AI
13.	(Hsu, Abelson, Lao, Tseng, & Lin, 2021)	Behavioral-pattern exploration and development of an instructional tool for young children to learn AI	R&D method	Taipei	GenAI Implementation
14.	(Rutherford et al., 2025)	"I just think it is the way of the future": Teachers' use of ChatGPT to develop	Mixed-method	USA	GenAI Implementation (ChatGPT)

		motivationally-supportive math lessons			
15.	(Sanusi et al., 2024)	Stakeholders' insights on artificial intelligence education: Perspectives of teachers, students, and policymakers	Qualitative method	Nigeria	Gen AI implementation policy

Findings from each article are categorized based on themes and analyzed descriptively using the predefined research questions. The data analysis technique used in this study was categorization. This technique was carried out based on the findings from the articles, which were then categorized according to specific themes or concepts, and the comparative table technique, in which the researcher created tables to compare the findings from various articles systematically (Syahrir, Pujiriyanto, Musdalifa, & Fitri, 2024).

Based on the article selection findings, 15 research articles were identified related to the specified research topic, namely, the implementation and challenges of GenAI in elementary education. The sample or research subjects in the evaluated studies were primarily students, prospective teachers, teachers, and all stakeholders in elementary schools. The research methodologies used in the reviewed publications were mixed methods, qualitative, quantitative, and R&D.

3. FINDINGS AND DISCUSSION

Based on the results of the data analysis, the research results are presented in the following table:

Table 2. Key Findings from Gen AI Implementation and Challenges

Number	Authors & year	Title	Key findings on implementation and challenges to GenAI in EE
1.	(Kim & Kwon, 2023)	Exploring the AI competencies of elementary school teachers in South Korea	Implementation: Using MIT App Inventor, Google Teachable Machine, and Entry for projects involving problem-solving (e.g., trash categorization). Problem: Compared to their pedagogical understanding, teachers are less secure in their Content understanding (CK) about GenAI.
2.	(Park et al., 2022)	Investigating a visual interface for elementary students to formulate AI planning tasks	Implementation: Students use visual blocks to create an action plan for the GenAI agent in the simulation. Challenge: Students' misconceptions about the sequence of blocks and complaints about the repetitive nature of the tasks
3.	(Tai & Chen, 2024)	Improving elementary EFL speaking skills with generative AI chatbots: Exploring individual and paired interactions	Implementation: The chatbot is used as a speaking partner, either individually or in pairs, to practice pronunciation. Challenge: Linguistic barriers such as GenAI vocabulary that is too advanced or sentences that are too long for children

4.	(Panday-Shukla, 2025)	Exploring generative artificial intelligence in teacher education	Implementation: Used for brainstorming ideas, content creation, and research assistance. Challenges: Concerns about academic integrity (cheating), excessive dependence, and low AI literacy
5.	(Ng et al., 2025)	Opportunities, challenges and school strategies for integrating generative AI in education	Implementation: Integration into material design, administration (summarizing reports), and automated assessment. Challenges: Lack of technical support, data privacy concerns, and stress from changes in teaching methods.
6.	(Liu et al., 2025)	Designing a generative AI enabled learning environment for mathematics word problem solving in primary schools: Learning performance, attitudes and interaction	Implementation: The system provides step-by-step adaptive feedback based on student input. Challenge: Need to ensure accessibility for students with different abilities and the risk of dependency on GenAI assistance.
7.	(Lee & Song, 2024)	Teachers' and students' perceptions of AI-generated concept explanations: Implications for integrating generative AI in computer science education	Implementation: Using GPT-3.5 to explain the concept of control structures (sequence, selection, iteration) Challenge: Students prefer explanations from human teachers because they are more communicative and contextually relevant
8.	(Fundi et al., 2024)	Advancing AI education: Assessing Kenyan in-service teachers' preparedness for integrating artificial intelligence in competence-based curriculum	Implementation: Introduction to coding with Scratch as a foundation for computational thinking. Challenge: Knowledge of GenAI ethics and subjective norms greatly influences teachers' readiness, but the perceived threat of GenAI is not yet significant.
9.	(Kajiwara et al., 2023)	Machine learning role playing game: Instructional design of AI education for age-appropriate in K-12 and beyond	Implementation: Students role-play as a GenAI model that classifies the "rock-paper-scissors" moves. Challenge: Lower elementary school students (K1-K3) still require intensive parental guidance due to the complexity of ML mathematics.
10.	(Pei et al., 2025)	Empowering preservice teachers' AI literacy: Current understanding, influential factors, and strategies for improvement	Implementation: Structured training from basic understanding to high-level application. Challenge: The low level of comfort and confidence among prospective teachers in using complex GenAI mechanisms.

11.	(Bem-Haja et al., 2025)	AI analysis reveals top predictors of first grade success: Insights from multifactorial screening students' early days of school	Implementation: Random Forest and Extra Trees models analyze initial screening data for early intervention. Challenge: The importance of caregiver involvement and executive function training to mitigate the risk of failure
12.	(Collie & Martin, 2024)	Teachers' motivation and engagement to harness generative AI for teaching and learning: The role of contextual, occupational, and background factors	Implementation: The use of ChatGPT/Dall-E for administrative tasks and student learning activities. Challenge: Change-related stress and lack of autonomous leadership support in schools
13.	(Hsu et al., 2021)	Behavioral-pattern exploration and development of an instructional tool for young children to learn AI	Implementation: Students use MIT App Inventor and Personal Image Classifier to train the robot car. Challenge: A strategy is needed to encourage students to plan and predict before execution (trial and error).
14.	(Rutherford et al., 2025)	"I just think it is the way of the future": Teachers' use of ChatGPT to develop motivationally-supportive math lessons	Implementation: Creating story problems based on students' specific interests (e.g., sports or video games). Challenge: The limited time for teachers to design physical media (game boards) even tho ChatGPT provides ideas quickly.
15.	(Sanusi et al., 2024)	Stakeholders' insights on artificial intelligence education: Perspectives of teachers, students, and policymakers	Implementation: GenAI is seen as a tool for task assistance and automation for community development. Challenges: Very limited infrastructure (electricity, computers) and concerns about job loss and privacy issues.

3.1 Implementation of Generative AI in Elementary Education

Based on the results of a review of articles, the forms of implementation of GenAI in learning and elementary education include integrating GenAI into the curriculum in elementary schools starting in 2025 in South Korea (Kim & Kwon, 2023). The study revealed that one of the challenges in elementary school education is integrating GenAI with practical arts, STEM, and other science subjects. Additionally, in the learning process, computers or smart devices are already being utilized, adopting block-based programming languages such as Machine Learning for Kids, Scratch, and AI-based programs, including Chatbot, Teachable Machine, Autodraw, and Google AI experiments. Further research conducted by Park et al (2022) in the United States focused on teaching AI literacy, which includes understanding, evaluating, communicating with, and effectively using AI. Additionally, online learning platforms such as ReadyAI, Curiosity Machine, AI with MIT App Inventor, and AI for Oceans Code.org were utilized. The study also proposes a Primary GenAI learning approach in elementary education for GenAI integration planning. Further research focuses on the use of GenAI

chatbots to improve speaking skills in elementary schools (Tai & Chen, 2024). The implementation of GenAI chatbots in the form of the CoolE Bot application had a significant impact on improving the speaking skills of elementary school students. The application is GenAI-based and can be used to interact in Mandarin and English, as well as other languages. Students who used the GenAI CoolE Bot experienced a significant improvement in their English-speaking skills compared to students who learned traditionally without the use of GenAI assistance.

Research conducted by Panday-Shukla (2025) discusses perceptions of GenAI use among elementary and secondary school teachers and teacher candidates. They state that GenAI use in education and learning will be effective if used responsibly, but some also express concerns that GenAI may cause concern and worry in future education. Teacher candidates and teachers use GenAI for course assignments, particularly ChatGPT for brainstorming. Furthermore, research conducted by Ng et al. (2025) explores the opportunities and challenges associated with integrating Generative Artificial Intelligence (GenAI) in education, as well as identifying strategies to encourage teachers and students to adopt GenAI in school settings. Practices involving GenAI integration were implemented in learning, administration, and assessment. In the learning section, GenAI is used to improve lesson planning, provide teaching material recommendations, generate innovative learning tasks, develop rubrics, adjust teaching progress, and help explore lesson plan ideas, administration tasks, and assessment. Research conducted by Liu et al. (2025) on the implementation of ChatGPT in learning. The study found that using a ChatGPT-supported Mathematics Problem-Solving System (ChatGPT-MPS) can improve and deepen grasp of mathematical ideas, academic inquiry, and skills in solving problems. This GenAI has pedagogical features that assist in the learning process, such as personalized learning and scaffolding, adaptive feedback, and language support, as well as core functional capabilities to offer dynamic solutions and response tones tailored to the respondent's age.

Research conducted by S. Lee & Song (2024) reveals that the implementation of GenAI in learning is related to basic programming concepts: sequence, selection, and iteration. The study utilized GPT-3.5 to generate concept explanations, which were compared with those created by human teachers. The findings revealed implications for integrating GenAI into computer science education, suggested strategies for designing GAI-based explanations tailored to students' needs, and emphasized the importance of AI literacy instruction. Next is research conducted by Fundi et al. (2024), revealing that GenAI integration in primary education in Kenya is still in its early stages. AI has not yet been incorporated into the curriculum, but it has already been integrated into the education system and curriculum. Digital literacy and programming explicitly include programming with Scratch in elementary schools to develop computational thinking and creativity. However, non-governmental and private institutions, such as iLab, have begun holding GenAI boot camps for children, indicating growing interest outside formal education. Research conducted by Kajiwaru et al. (2023). This research was conducted in Japan. The study explains GenAI education through the development of a Machine Learning Role-Playing Game (ML-RPG). The ML-RPG was implemented interactively using a theoretical approach based on mathematics.

Furthermore, research conducted by Pei et al. (2025) in the US on AI literacy in pre-service teacher education revealed that the current level of AI literacy among teachers is "less than ideal." This requires proactive efforts to equip prospective teachers with the skills to use GenAI for various educational practices by integrating an AI curriculum for teachers and focusing on the practical and ethical use of GenAI in a responsible manner. Furthermore, research conducted by Bem-Haja et al. (2025) revealed that supporting the implementation of GenAI, particularly machine learning models (Random Forest, Gradient Boosting, and Extra Trees), is a superior approach compared to traditional statistical methods. Additionally, research on GenAI in primary education was conducted by Collie & Martin (2024). The study revealed that machine learning can generate new content such as text, images, and audio using GenAI tools like ChatGPT, Midjourney, Dall-E 2, GPT-4, Bing Chat AI, and Bard AI. The implementation of GenAI in primary education aims to assist teachers in their instructional tasks, such

as planning, teaching, and assessment. For students, GenAI with devices to complete their learning tasks.

Research conducted by Wen et al. (2020) indicates that the implementation of GenAI in Taiwan involves learning to build and apply GenAI. The Taiwanese Ministry of Education has implemented a strategy to incorporate GenAI into the curriculum and promote AI from elementary school to university levels, with computational thinking (CT) as the foundation. Additionally, online platforms such as Machine Learning for Kids, eCraft2Learn, and Cognimates are used for programming education and GenAI experiences for children. Furthermore, GenAI technology is integrated into STEM education and practical applications, such as robotics and app development. Additionally, research conducted by Rutherford et al. (2025) indicates that GenAI implementation in primary education involves using ChatGPT to enhance mathematics learning motivation. This is achieved by teachers using ChatGPT to create story problems and games to spark students' interest in mathematics learning. ChatGPT assists teachers in designing curricula, developing instructional materials, supporting self-reflection, evaluating students, and providing career guidance. Furthermore, research conducted by Sanusi et al. (2024), the form of GenAI implementation carried out is the development of a GenAI curriculum by incorporating GenAI into the national education curriculum, utilizing adaptive platforms and intelligent guidance systems using AI-based applications.

Based on the explanation above, GenAI tools can be categorized by their functions, including designing learning activities, creating personalized story-based questions, assessment rubrics, and presentation materials. Examples of GenAI tools that can be used include ChatGPT and Magic School. Furthermore, GenAI tools that can be used for language learning include CoolE Bot and Grammarly. These GenAI tools can help practice English speaking skills by acting as virtual conversation partners, proofreading writing, and correcting sentence structure. For solving math problems, GenAI tools that can be utilized include ChatGPT-MPS and ChatGPT. These GenAI tools can provide step-by-step guidance (scaffolding) and real-time feedback to solve complex math word problems. GenAI tools that can be utilized for assessment and feedback include ChatGPT and GPTutor. Furthermore, GPT-3.5 is a GenAI that can be used to explain basic programming concepts in language tailored to children. Additionally, GenAI can be used to generate multimedia-based visual content and enhance creativity, including tools such as Midjourney, Dall-E 2, Gemini (Bard), and Snapchat AI.

Based on the results of data analysis from all articles, research findings regarding the impact of GenAI integration in elementary education and learning include improving teacher professionalism, creating effective learning, providing feedback tailored to the needs of teachers, and designing instructional curricula. To improve lesson planning, elementary school teachers can utilize GenAI tools such as ChatGPT and Magic School as instructional co-designers to generate new ideas, for example, creating lesson plans, presentation materials, and student worksheets. A key advantage of using GenAI is that teachers can incorporate students' specific interests, thereby personalizing content and boosting students' motivation and enthusiasm for learning.

Teachers also benefit in the areas of assessment and evaluation, as these tools help them develop assessment rubrics, quizzes, and exam questions that are tailored to students' ability levels and are more adaptive. Additionally, GenAI technology can facilitate the analysis of performance data or learning outcomes, enabling teachers to make data-driven decisions regarding learning evaluations. This, in turn, helps teachers identify patterns in students' academic achievement. The implementation of GenAI also benefits teachers by enabling them to provide specific, meaningful, and timely feedback compared to conventional methods. GenAI systems can automatically generate personalized suggestions for revisions or improvements based on students' strengths and weaknesses in completing school assignments. This responsive feedback assists both teachers and students in the learning process and reduces cognitive stagnation during independent study.

The use of GenAI by teachers also offers the benefit of reducing their heavy administrative workload. Teachers can make the most of their time by automating repetitive administrative tasks. They can use GenAI to draft proposals, summarize articles, and handle school correspondence. This

can reduce emotional exhaustion among teachers. With a reduced administrative burden, teachers have more time and energy to focus on providing emotional support to students, engaging in personal interactions, and developing their pedagogical skills.

The availability of GenAI can also help teachers develop their professional skills, such as AI literacy and TPACK (Technological Pedagogical Content Knowledge) competencies. Teachers can do this by using GenAI as a mentor and applying prompt engineering techniques to ensure that the AI's outputs are more accurate and educationally relevant. In addition, they can use GenAI for hands-on practice in real classroom settings.

Integration of GenAI in elementary education and learning also increases student participation through interface features, motivation, interest in learning, communication skills, problem-solving, computational skills, self-efficacy, and deep conceptual understanding. Specifically, the integration of GenAI into learning can boost students' motivation because it can create instructional videos featuring a charismatic conversational style, human-like voices, and cartoon characters, making the learning process enjoyable and motivating for students (Tai & Chen, 2024). This aligns with findings from previous research indicating that using GenAI to integrate elementary students' specific interests, such as illustrations or video games, into story problems directly increases students' situational interest and enthusiasm for the subject matter (Tasdelen & Bodemer, 2025). This increased interest and enjoyment fosters intrinsic motivation, leading to higher-quality engagement with the learning material (Jauhiainen & Garagorry Guerra, 2024). In this study, several GenAI tools that can be used to foster learning motivation in elementary school students include CoolE Bot and ChatGPT-MPS.

In terms of increasing participation in learning, GenAI can foster emotional, behavioral, and cognitive engagement. This encourages learners to invest more time and effort in completing tasks due to the responsive interactions. Additionally, an immersive learning environment and the use of game-based learning that integrates GenAI can help students stay focused and actively engaged in the learning narrative.

GenAI helps improve English speaking skills because it acts as a chatbot (conversation partner) during conversations or when speaking in English. Furthermore, the use of GenAI also provides a safe environment that helps students build confidence in speaking English and reduces anxiety about using a foreign language. GenAI can assist students in speaking a foreign language through coherent dialogue and provide real-time feedback on pronunciation.

The improvement in computational thinking among students includes, among other things, an understanding of algorithms through interaction with GenAI's visual interface, as well as an understanding of the logic of sequences, selection, and iteration. Additionally, computational thinking can be developed through indicators such as abstraction, decomposition, and pattern recognition via activities that train machine learning models. Furthermore, computational thinking develops in children when they build AI-based robots.

The conceptual understanding of elementary school students also develops through the integration of GenAI with real-time assistance mechanisms that clarify students' misunderstandings during learning, making mathematical and scientific concepts clearer. Additionally, GenAI is capable of generating concept explanations using simple language and everyday analogies that are easy for elementary school-aged children to understand. Furthermore, the use of graphics and visual representations in AI tools helps students transition from concrete understanding to a more abstract conceptual understanding.

Potential risks reported in previous studies include over-reliance on AI, which may reduce opportunities for developing critical and creative thinking when used without appropriate pedagogical guidance. Academic integrity and data privacy issues are also drawbacks if not used responsibly. GenAI can also lead to misinformation due to inaccurate data presented by AI if not checked. Another drawback is the digital divide due to differences in GenAI adoption in education and learning across regions, stemming from varying levels of readiness for AI-based education and learning.

The findings of this study can be understood through the framework for the implementation of Artificial Intelligence in Education (AIED), which emphasizes that the success of AI integration in education is determined not only by technological capabilities but also by pedagogical aspects, personalized learning, teacher readiness, institutional governance, and the ethics of AI use. Based on this framework, the synthesis results indicate that the implementation of GenAI in elementary education is primarily focused on supporting the learning process, such as the creation of teaching materials, content development, providing personalized feedback, assessment, language learning, and the enhancement of computational thinking skills. These findings align with the research by Yohanes, Fredy, & Rapsanjani (2024), which shows that AI is utilized in intelligent tutoring systems, adaptive learning, and automated learning assessment. Similarly, Satria, Sidauruk, Sutarni, & Pirmansah (2025) found that GenAI helps reduce teachers' administrative workload by creating various types of learning content, while Han et al. (2024) showing that AI supports teachers in developing adaptive instructional materials, generating learning ideas, and providing more personalized feedback to students. The findings of Jauhiainen and Jauhiainen & Guerra (2023) also show that ChatGPT is capable of personalizing learning materials according to students' knowledge levels, while Marzano (2025) notes that the implementation of AI in K–12 education contributes to personalized learning, improved assessment systems, and the development of more innovative learning strategies.

Nevertheless, this study offers a broader perspective than previous research. Most prior studies have focused on the use of GenAI for specific learning functions, user perceptions, or implementation in specific national contexts. In contrast, this study synthesizes empirical evidence from various countries, enabling it to identify patterns of GenAI implementation more comprehensively while also revealing the challenges that arise in various primary education contexts. The results of this synthesis indicate that the success of GenAI implementation depends not only on the technology's ability to support learning but is also influenced by teachers' AI competencies and literacy, school readiness, infrastructure availability, policy support, as well as ethical and data privacy considerations. Thus, this study expands upon previous research findings by demonstrating that the implementation of GenAI in elementary education is a multidimensional process, requiring the strengthening of pedagogical, institutional, and governance aspects to ensure its effective and responsible implementation.

3.2 The Challenges of Generative AI in Elementary Education

In addition to the positive impacts of GenAI integration in elementary education and learning, there are also challenges in its implementation. Research conducted by Kim & Kwon (2023) reveals that the challenges in integrating GenAI in elementary education in South Korea are the varying levels of teacher readiness and GenAI competence. This causes difficulties in GenAI-based learning and teaching students, as well as in designing and delivering the curriculum. Additionally, limitations in infrastructure and learning environments that are not supportive of implementing generative AI-based education, such as wireless internet connections and digital devices for students, pose further challenges. Opportunities for teachers to develop competencies in GenAI education are also limited. School culture in South Korea also acts as a barrier to GenAI use in education, as it may lead to criticism from colleagues, pupils, and parents. Park et al. (2022) revealed that the challenges in integrating GenAI into primary education include difficulties in conveying conceptual aspects of GenAI learning, such as programming. Additionally, limited accessibility and information support also pose challenges in AI education at the elementary school level. Tai & Chen (2024) revealed that the challenges faced in teaching foreign languages using GenAI (CoolEBot) include linguistic difficulties and students' understanding of the application's vocabulary, as the vocabulary of CoolEBot continues to evolve and sentences become longer, making it difficult for students to follow smoothly, which hinders interaction in learning.

Research conducted by Panday-Shukla (2025) reveals the obstacles and challenges faced by teachers and prospective teachers in integrating AI, namely limited knowledge and understanding of GenAI, which makes GenAI implementation difficult. In addition, developing GenAI literacy and

concerns about ethics and stigma in the use of AI are also challenges. Time constraints and reluctance to adopt GenAI technology in education are also reasons why teachers are less likely to adopt GenAI in education and teaching. The lack of guidelines and institutional support also hinders innovation in GenAI integration in primary education. Another study conducted by Ng et al. (2025) reveals that the challenges of implementing GenAI in primary education include school readiness, teacher readiness and GenAI competence, student readiness, and GenAI literacy. School readiness is related to the lack of clear policies and guidelines, acceptance of technological changes in GenAI, infrastructure, and resources. Teacher readiness and GenAI competencies are related to inadequate professional development and disparities in AI implementation. Inadequate student readiness and GenAI literacy also pose challenges because misuse can lead to issues related to academic integrity, data privacy and security, promote learning laziness, and excessive dependence on GenAI. (Liu et al., 2025) noted in their research that the challenges of GenAI in education include difficulties in continuous learning, lack of foundational knowledge, limitations in logical reasoning, and gaps in the application of existing GenAI.

S. Lee & Song (2024) In their study revealed that challenges in the application of GenAI include ethical issues and educational values that can cause concerns in the use of AI, research gaps in user perceptions, and difficulties for students in distinguishing between unbiased sources of information or content. Further research conducted by (Fundi et al., 2024) indicates that challenges in learning using GenAI include the lack of a teacher training curriculum in the use of GenAI, inadequate professional development in GenAI and ICT for teachers, lack of knowledge, skills, and confidence, as well as difficulties in developing teachers to design AI guidelines in basic learning. Kajiwarra et al. (2023) revealed that challenges in using GenAI in learning include concern and worry about using GenAI and the lack of comprehensive research on GenAI. Additionally, other challenges include the potential loss of interest among students who struggle with using GenAI, and the learning environment also plays a role. Students in lower grades still require adult support, necessitating a slower learning environment to improve learning outcomes. Furthermore, cultural limitations also influence the acceptance of GenAI.

Pei et al. (2025) revealed that the challenges of integrating GenAI in primary education include a lack of AI literacy among teachers and prospective teachers, which leads to low confidence and comfort in interacting with GenAI. A lack of basic knowledge about GenAI literacy can be a major obstacle to the effective integration of AI in primary education. In addition, inadequate professional development limits opportunities for exploration and deep reflection for teachers. Ethical knowledge gaps also cause problems in the use of GenAI. Teachers also express concerns about the accuracy of GenAI information and the threat of GenAI to students, which hinders critical and creative thinking among students. Bem-Haja et al. (2025) revealed that the challenges of integrating GenAI in education and teaching are issues of privacy and ethics in the use of student data. Collie & Martin (2024) revealed that the challenges in integrating GenAI in primary education include the lack of research on teacher motivation and engagement in GenAI in primary education and the differences in findings between secondary and primary schools, which have led to various speculations in learning. Additionally, teachers are concerned about the accuracy of content and the ethical implications of information provided by GenAI, as well as overreliance on data reported by GenAI.

Hsu et al. (2021) revealed the challenges of using GenAI in their research. Their findings were not significantly different from those of Collie & Martin (2024), that the issue of students' trust in GenAI. Children place too much trust in GenAI, which poses potential risks to data security and privacy. Additionally, another challenge is the highly complex nature of GenAI technology, which makes it difficult for teachers to design curricula. Rutherford et al. (2025) revealed that the use of ChatGPT in elementary education and learning has significant challenges, including the limited output of ChatGPT in learning. This is related to the difficulty of the material, the inaccuracy of the content, and the need for very specific prompts. Learning using ChatGPT also poses challenges for teachers in terms of pedagogy and classroom management. Additionally, teachers require guidance and AI literacy to serve as role models for students in GenAI-based learning. Sanusi et al. (2024) identified challenges in

integrating AI into education and AI-based learning, including a lack of understanding about AI learning among all school stakeholders at the outset of implementation. Furthermore, insufficient teacher readiness and involvement, ethical concerns, and infrastructure limitations also pose challenges. The complex design of the GenAI curriculum for K-12 (primary to secondary education) also poses challenges in learning due to the greater diversity of students' interests, abilities, and needs, as well as differences in resources and visions among schools. Furthermore, the absence of comprehensive policy frameworks regulating the use of GenAI in education and learning, as well as how to evaluate it, also presents challenges.

So, the challenges in integrating GenAI into elementary education and learning include the different levels of GenAI knowledge and understanding and infrastructure for AI-based learning. In addition, a learning environment and organizational readiness for technological innovation that varies across schools also pose challenges. Opportunities for GenAI-based competency development training for teachers are also still limited. The challenges of GenAI itself are the complexity of its features, which make students or teachers find it difficult to use. This is exacerbated by the limited knowledge and AI literacy of students and teachers in using GenAI, so they are unaware of the accuracy of the data generated by AI. Furthermore, challenges in integrating GenAI into GenAI learning include the need for clearer institutional guidelines and institutional support for the use of AI in elementary education and learning, which can lead to other issues, such as data privacy and data usage ethics.

This challenge must be addressed and solutions found so that its implementation can be carried out effectively and efficiently. Strategies that can be implemented include having relevant educational institution officials formulate guidelines for using GenAI in elementary education and learning, so that teachers and pupils understand how to use AI, its privacy, and ethical policies, and how to prevent academic integration issues and data breaches. Additionally, teachers and students need to be better prepared to conduct learning processes using GenAI. Training should be provided for teachers to enhance their qualifications and competencies in GenAI literacy for using GenAI, enabling them to teach elementary school students. Schools should also facilitate the necessary infrastructure and resources for GenAI-based learning. Furthermore, all stakeholders must foster an open culture toward technological advancements, as this can help alleviate the workload of human labor.

When comparing countries, the findings of this review indicate that the challenges of implementing GenAI in elementary education are influenced by the level of readiness of each country's education system. Countries with relatively advanced digital infrastructure, such as South Korea, the United States, Taiwan, Canada, Australia, and Portugal, tend to face challenges in pedagogical aspects, teacher competency development, the integration of GenAI into the curriculum, and the development of policies and ethics regarding the use of GenAI in schools ((Bem-Haja et al., 2025; Collie & Martin, 2024; Kim & Kwon, 2023; Ng et al., 2025; Park et al., 2022; Tai & Chen, 2024). In contrast, developing countries such as Kenya and Nigeria still face more fundamental challenges, namely limited digital infrastructure, institutional readiness, access to devices and the internet, and strengthening GenAI literacy among teachers and education stakeholders (Fundi et al., 2024; Sanusi et al., 2024). Meanwhile, Japan and China have adopted approaches that are more focused on developing computational skills, instructional design, and the integration of AI into STEM education starting at the elementary school level (Kajiwara et al., 2023; Liu et al., 2025). Although the nature of the challenges varies according to each country's national context, all of the studies analyzed share the common finding that enhancing teacher competencies, strengthening AI literacy, establishing clear policies, and providing institutional support are key prerequisites for the effective implementation of GenAI in elementary. These findings indicate that strategies for implementing GenAI cannot be standardized but must be tailored to each country's level of technological readiness, human resource capacity, and educational policies.

The results of this study are in line with previous research, which revealed that there are challenges in integrating GenAI in elementary schools in the form of limited technological infrastructure and digital literacy among teachers that need to be improved (Sumarni & Muhibbin, 2024). Digital literacy is a skill required by instructors and students to grasp content in digital media and prevent hoaxes and

other issues (Atmojo et al., 2022). Other research also reveals that training on AI for teachers can improve GenAI literacy among elementary school teachers, thereby encouraging innovation in learning by utilizing the latest technology, developing more interactive, adaptive, and individualized learning through implementation, and improving the efficiency of the learning process (Patty & Lekatompessy, 2024). Kotsis (2024) in his study found that the steps needed to protect data and ensure there is no bias in algorithms are that teachers need to undergo effective GenAI training and understand the limitations of GenAI technology. This will reduce the risk of potential issues in the use of GenAI.

The results of this study are expected to contribute to improving the quality of technology-based education and learning, particularly at the elementary school level. In line with the implementation of policies on coding and artificial intelligence (AI) education in the Indonesian elementary school curriculum, the findings of this study can serve as input for the government, curriculum developers, schools, and teachers in formulating policies, implementation guidelines, and GenAI-based learning designs that are appropriate for the characteristics of elementary school students. Furthermore, since this study is a synthesis of GenAI implementations across various countries, its results can serve as a reference for adapting relevant practices while taking into account the conditions, needs, and readiness of Indonesia's education system.

Nevertheless, this study has several limitations. The systematic review only included open-access empirical research articles indexed in Scopus and published between 2020 and 2025; thus, there may still be relevant studies from other databases or non-open-access articles that have not been included. Furthermore, the distribution of countries among the analyzed articles is not entirely even, as most of the studies originated from countries that already have a higher level of readiness for GenAI implementation compared to developing countries. Therefore, the findings of this study should be interpreted with due consideration for differences in the educational contexts of each country. Future research is recommended to expand the scope of the database, include a more diverse range of countries, and combine a systematic literature review with a meta-analysis to produce a more comprehensive synthesis with a stronger level of generalizability.

4. CONCLUSION

This study successfully identified implementation patterns and challenges in the use of Generative Artificial Intelligence (GenAI) in elementary education based on a synthesis of 15 empirical articles published between 2020 and 2025. The results show that the implementation of GenAI in elementary education is primarily utilized to support the learning process, including the creation of teaching materials, curriculum development, language learning, math problem-solving, providing feedback, and strengthening computational thinking skills and GenAI literacy. Additionally, several countries have begun integrating GenAI into their curricula, particularly in STEM-based learning and computational thinking. This study also identifies that the challenges of GenAI implementation are not limited to technological aspects but also include teachers' GenAI competencies and literacy, school readiness, infrastructure availability, clarity of policies and implementation guidelines, as well as issues related to ethics, data privacy, and academic integrity. These findings provide an overview of the implementation patterns and challenges of GenAI in elementary education based on available empirical evidence, thereby serving as a reference for researchers, policymakers, and education practitioners in designing GenAI implementations appropriate for the elementary education context. Meanwhile, future research should expand the scope of the study and conduct empirical research to evaluate the effectiveness of GenAI implementation in various learning contexts.

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