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Integration of Artificial Intelligence (AI) and Digital Technology in Enhancing 21st Century Skills

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ABSTRACT

Objective: *This literature review aims to analyze and synthesize findings from 21 scholarly journals on the integration of digital technology and Artificial Intelligence (AI) in education to enhance 21st-century skills, such as critical thinking, collaboration, and digital literacy.* ***Method:*** *A Systematic Literature Review (SLR) approach was used to identify research issues, methodologies, and key outcomes from studies focusing on AI, digitalization, and student skill development.* ***Results:*** *The synthesis reveals that AI and digital technologies play a significant role in personalizing learning through adaptive systems and Deep Learning, improving Higher-Order Thinking Skills (HOTS), including creativity and mathematical reasoning, and enabling holistic adaptive assessments encompassing cognitive, affective, and psychomotor domains.* ***Novelty:*** *The review emphasizes AI literacy as a fundamental skill and the need for teacher development in utilizing AI platforms. It concludes that the strategic integration of AI and digital technologies, supported by a constructivist framework and curriculum integration, is crucial in producing graduates prepared for the challenges of the 21st century and Society 5.0.*

INTRODUCTION

Entering the 21st century, humanity is facing a period of significant change. A disruption that is transforming how we live, learn, and work. This change is marked by a shift in global social and economic paradigms, driven by the massive acceleration of technology. This transition is characterized by the waves of the Fourth Industrial Revolution and supported by the vision of Society 5.0, which focuses on creating smart, data-driven societies [1], [2]. In the midst of this transformation, Artificial Intelligence (AI), encompassing machine learning technologies and advanced algorithms, emerges as a key force that is not only reshaping industries, governments, and services but also fundamentally redefining the education ecosystem [3], [4].

In the educational field, the demands for graduate profiles have shifted significantly from mere mastery of passive, isolated academic content to the mastery of complex and dynamic 21st-century skills. These skills, often summarized in the 4C formula (Critical Thinking, Collaboration, Communication, and Creativity), have become essential assets for individuals to function and adapt in data-driven societies [5], [6]. In an era where AI can take over routine tasks, the ability to analyze and solve unprecedented problems is far more valuable than pure memorization.

In response to these global pressures, educational institutions must urgently realign their curricula and pedagogy. Traditional learning models, often one-size-fits-all and rigid, have proven inadequate in preparing students for the complexities of Society

5.0. Education must now shift to a more adaptive, personalized, and relevant approach, leveraging AI capabilities, including Deep Learning, to create unique learning profiles for each student and tailor content individually, thus enhancing their extending knowledge [7], [8].

This urgent need is further emphasized by the real challenges in developing Higher-Order Thinking Skills (HOTS) among students, an issue that, empirically, remains relatively low in Indonesia [9]. Therefore, the development of specific HOTS dimensions, such as Creative and Mathematical Thinking, becomes a key focus that must be effectively integrated amid the growing use of AI [10]. This pedagogical transformation demands the integration of technology with a robust theoretical framework, such as Constructivism, to ensure that AI integration truly supports the holistic development of 21st-century competencies [11].

RESEARCH METHOD

2.1. Research Design

This study adopts the Systematic Literature Review (SLR) method. The SLR method was chosen because it allows for an objective, transparent, and replicable process of identifying, evaluating, and interpreting all primary studies relevant to the specific research questions. This design ensures that the synthesis of findings from 21 published scholarly journals is comprehensive, structured, and minimizes researcher bias. The main objectives of using SLR are:

1. To map the existing literature on the integration of AI and digital technology in learning.
2. To analyze the methodologies, issues, and key findings from the selected journals.
3. To synthesize these findings to formulate conclusions regarding the role of AI in the development of 21st-century skills.

2.2. Data Analysis Procedure

Data for this research were collected from 21 scholarly journals and research articles identified as relevant. These journals come from various national and international indexed sources.

The literature search strategy focused on a combination of core keywords relevant to educational transformation: "Artificial Intelligence (AI)", "Digital Technology", "21st Century Skills", "Adaptive Learning", "HOTS", and "AI Literacy". To maintain focus and quality, strict inclusion criteria were applied:

2.3.1. Topic Focus

The journals must primarily focus on the application or impact of Artificial Intelligence (AI) or Digital Technologies (such as E-assessment or Gamification) in the context of Education/Learning.

2.3.2. Student Skills

The journals must explicitly discuss the impact of AI or Digital Technologies on the development of student skills, including 21st-century skills (such as 4C, critical thinking, or digital/AI literacy) or Higher-Order Thinking Skills (HOTS).

2.3.3. Article Type

The articles must be empirical research results (quantitative or qualitative) or literature reviews published in peer-reviewed journals within a relevant time range (e.g., the last 5 years, 2021-2025).

2.3. Data Analysis and Synthesis Procedure

Data analysis is carried out using a qualitative content analysis approach, divided into three stages:

2.3.1. Data Extraction

Key data from the 21 journals were extracted using a standard extraction form. The extracted components include: Journal/Article Title, Authors and Citations, Research Methodology, and Research Issues/Main Objectives. The results of this extraction are presented in Table 1.

2.3.2. Thematic Coding

The Results and Discussion sections of each article are analyzed in depth. The main findings are grouped (coded) and categorized into sub-themes that emerge from the data, such as: Learning Personalization (Deep Learning), HOTS Improvement (Creative & Mathematical), Assessment Innovation (Holistic), and AI/Teacher Literacy Challenges and Needs.

2.3.3. Qualitative Synthesis

The grouped sub-themes are then synthesized and interpreted to identify patterns, causal relationships, and research gaps. This synthesis forms the basis for the results and discussion sections of this literature review, highlighting how AI and digital technologies collectively contribute to achieving the goals of 21st-century education.

RESULTS AND DISCUSSION

Table 1. Data extraction results presented**.**

No.	Journal/Article Title	Author(s) (Year)	Research Problem/Main Objective
1	Application of Artificial Intelligence in Educational Technology: Trends and Innovations	Tuti Ulpiana (2025)	Analyzing the latest trends and innovations in the application of AI in educational technology, including adaptive learning.
2	Implementation of Artificial Intelligence (AI) in Education	Sofi Liza Zahara et al. (2021)	Clarifying the role of AI in education, particularly in personalizing learning for each student (learning profiles).
3	Utilization of Artificial Intelligence (AI) in Automated Assessment and Feedback	Cisia Padila (2025)	Analyzing the use of AI in automated assessment systems and instant

			feedback to improve student learning outcomes.
4	Revolution in Learning Assessment: How AI is Changing How Teachers Evaluate Student Progress	Hendri A et al. (2025)	Analyzing AI innovations in the evaluation process for holistic assessment (cognitive, affective, and psychomotor).
5	INTEGRATION OF ARTIFICIAL INTELLIGENCE (AI) IN 21ST CENTURY CURRICULUM DESIGN: A CASE STUDY OF ADAPTIVE LEARNING IN MADRASAH	Dwiraja Adinata et al. (2025)	Reviewing the integration of AI in 21st-century curriculum design, particularly in the context of adaptive learning in Madrasah.
6	Integrating Constructivism Theory and Artificial Intelligence in Developing 21st Century Competencies	Zeli Utari & Wedra Aprison (2025)	Reviewing the integration of Constructivism Theory and AI as a pedagogical framework for developing 21st-century competencies.
7	Preparing Students for the Future: AI Literacy as a 21st Century Skill	Linna Maleni et al. (2025)	Identifying the urgency of AI literacy as a foundational competency for students to face technological advancements.
8	Artificial Intelligence: Risks, Challenges, and Responsible Use in Education	Ahmad Abdul Rochim (2024)	Exploring the risks, challenges, and proposing actions for the responsible use of AI in the context of education.
9	The Impact of AI-Based Lecture Methods on Students' Higher-Order Thinking Skills	Ayu Harisa et al. (2025)	Measuring the impact of integrating AI in lecture methods on improving students' HOTS.
10	Analysis of Student Learning Outcomes on Fluid Statics with AI-Based Modules	Tantri Mugi Utami Rosandhi et al. (2025)	Describing the improvement in student learning outcomes after using AI-based modules.
11	DIGITAL LEARNING TRANSFORMATION WITH ARTIFICIAL INTELLIGENCE	Sri Sunarti (2024)	Understanding the utilization of AI as a digital learning transformation,

			including AI platforms that can be used.
12	Innovative Learning Design Using Deep Learning Approach Based on Artificial Intelligence (AI) on Extending Knowledge of Students in the Society 5.0 Era	Muh. Inayah A.M. et al. (2025)	Designing and evaluating the effectiveness of AI-based Deep Learning approaches on extending students' knowledge.
13	Utilization of Digital Technology to Improve the Effectiveness of Indonesian Language Learning in Elementary Schools	Laila Ashila et al. (2024)	Identifying and analyzing the application of digital creativity (Gamification, AR/VR, AI) to enhance the effectiveness of learning.
14	Digital Learning Media Workshop for Teachers Using Artificial Intelligence (AI) Technology	Febrianto Hakeu et al. (2023)	Enhancing teachers' skills in utilizing AI technology to create interactive and personalized learning materials.
15	E-Assessment Model Based on Applications in High Schools in the Digital Era: A Systematic Literature Review	Muhammad Khakim Ashari et al. (2023)	Analyzing the relevance and implementation of application-based e-assessment in high schools in the digital era.
16	DEVELOPMENT OF CRITICAL THINKING SKILLS ASSESSMENT INSTRUMENTS USING QUIZIZZ APPLICATION IN SCIENCE SUBJECTS FOR JUNIOR HIGH SCHOOL	Erica Meilia Safitri et al. (2023)	Evaluating the validity, practicality, and effectiveness of critical thinking assessment instruments based on Quizizz.
17	DEVELOPMENT OF LKPD BASED ON PROBLEM-SOLVING APPROACH WITH 4C APPROACH TO IMPROVE STUDENT'S CRITICAL THINKING SKILLS	N.K.I. Sapitri et al. (2022)	Developing a problem-solving-based LKPD prototype with a 4C approach to improve students' critical thinking skills.
18	Implementation of Formative Assessment in Physics Learning with Educational Game Quizzes and Student Self-Assessment in Senior High Schools	Indro Wicaksono et al. (2023)	Implementing formative assessment using educational game quizzes (Kahoot!) and student self-assessment.

19	Introduction to Artificial Intelligence for Elementary School Students Through Digital Literacy	Fitria Rahmawati et al. (2025)	Providing socialization to introduce AI and digital technology in a wise, effective, and responsible manner (AI Literacy).
20	CREATIVE AND MATHEMATICAL THINKING SKILLS IN THE MIDST OF THE RISE OF ARTIFICIAL INTELLIGENCE (AI)	Endang Istikomah et al. (2025)	Reviewing the challenges and the role of AI in developing students' creative and mathematical thinking skills.
21	The Impact of Excessive Gadget Use on Students' Social Interaction Skills in Schools	Muhammad Miftahul Huda (2025)	Examining the impact of excessive gadget use on the social interaction skills of elementary school students as a risk of digitalization (relevant to the collaboration dimension of 4C).

Table 2. Synthesis of findings (the role of AI and digitalization in 21st century skills).

No	Synthesis of Findings	Description
1	The Role of AI in Personalizing Learning and Enhancing Higher-Order Thinking Skills (HOTS)	AI is key in creating adaptive and personalized learning. AI systems work by creating unique learning profiles for each student, allowing the content to be adjusted according to their abilities, learning styles, and experiences. **Skill Enhancement:** The use of AI-based modules has proven to yield better learning outcomes and significantly improve Higher-Order Thinking Skills (HOTS). Specifically, AI also plays an important role in developing Creative and Mathematical Thinking Skills as components of 21st-century skills. **Innovative Learning and Curriculum:** A deeper AI approach, such as Deep Learning, is applied in innovative learning design to promote the extending of students' knowledge in the face of the Society 5.0 era. Additionally, AI needs to be integrated into 21st-century curriculum design to support adaptive learning, even in religious educational institutions like madrasahs. **Pedagogical Framework:** The integration of AI is further strengthened when based on Constructivist Theory,

No	Synthesis of Findings	Description
		which supports the development of 21st-century competencies through enhanced learning experiences and reflection.
2	Digital Transformation and 21st Century Assessment	Digital technology has transformed the assessment process from traditional to E-Assessment. AI plays a role in automated assessment and instant feedback, increasing teacher efficiency and student learning outcomes. **Holistic Assessment:** AI's revolution in assessment offers innovations in the evaluation process by providing holistic data analysis, addressing the limitations of conventional assessments that focus primarily on the cognitive aspect, allowing for the inclusion of cognitive, affective, and psychomotor domains. **Critical Development:** Educational game applications (such as Quizizz) are effective digital tools for formative assessment and can be used to develop and measure Critical Thinking Skills.
3	The Urgency of AI Literacy and Teacher Skill Development	AI literacy is identified as a fundamental 21st-century skill that must be mastered, encompassing understanding the principles, benefits, risks, and ethical implications of AI. Introducing AI and digital literacy responsibly should be done from an early age, such as in elementary school students. **Improving Educator Competencies:** The digital learning transformation with AI demands the development of educator competencies. Workshops and training on AI-based digital media are crucial for enhancing teachers' skills in utilizing this technology to create interactive and personalized materials. **Teacher Task Automation:** AI is utilized to automate processes in training, even helping academics write SINTA-indexed research articles.
4	Risks, Ethics, and Psychosocial Impacts	The adoption of AI and digital technologies must be done wisely. Key risks include potential errors/inaccuracies in AI systems, moral issues, and psychological impacts from dependence. Socially,

No	Synthesis of Findings	Description
		excessive gadget use is associated with negative impacts on students' social interaction skills.

Qualitative Synthesis

Collectively, these 21 journals provide significant and focused contributions in four main areas of educational transformation in the digital era, as presented in Table 3.

Table 3. Key contribution areas of the 21 selected journals in digital-era education.

No	Contribution Area	Detailed Description	Supporting Journals (Examples)
1	Personalization and Adaptive Learning	This review successfully maps the vast potential of AI, particularly Deep Learning technology and recommendation systems, in realizing learning that is tailored to each student's unique profile, pace, and learning style. This is at the core of the promise of Society 5.0 education.	No. 1 (Trends & Innovations), No. 2 (Personalization), No. 5 (Adaptive Curriculum), No. 12 (Deep Learning)
2	Innovation in Assessment and Feedback	A strong focus is placed on the revolution of assessment. The journals highlight the efficiency of E-assessment (digital) and AI's ability to provide automatic and instant feedback (No. 3). Furthermore, the emerging idea of holistic assessment (No. 4) that includes cognitive, affective, and psychomotor dimensions marks a shift from merely measuring knowledge.	No. 3 (Automated Assessment), No. 4 (Holistic Assessment), No. 15 (E-Assessment Model)
3	Emphasis on HOTS and 4C Cognitive Skills	Several studies explicitly target the development of 21st-century skills, especially the cognitive dimension. This includes efforts to improve Critical Thinking (No. 16, 17) and challenges in developing Creative and Mathematical Thinking amid AI interventions (No. 20).	No. 9 (AI & HOTS), No. 17 (4C), No. 20 (Creative & Mathematical)

No	Contribution Area	Detailed Description	Supporting Journals (Examples)
4	Ethical Dimensions and Human Resource Readiness	Some journals begin to address important issues regarding the ethics and risks of AI usage (No. 8) and the urgency of improving teacher competencies (No. 14) as well as AI literacy for students (No. 7, 19). This highlights the awareness of the need for HR preparation alongside technology adoption.	No. 7 (AI Literacy), No. 8 (Risks & Ethics), No. 14 (Teacher Workshops)

Despite its significant contributions, this review also reveals several collective limitations in the existing literature, as presented in Table 4.

Table 4. Collective limitations identified in the reviewed literature.

No	Limitation/Shortcoming	Detailed Description	Related Journals (Implicit)
1	Dominance of Conceptual Studies and Small-Scale Research	The majority of studies discussing the potential of advanced AI (Deep Learning, Holistic Assessment) tend to be literature reviews (conceptual) or small-scale/descriptive experimental studies (No. 1, 2, 7, 11). This means that, although the theoretical potential is large, strong empirical evidence regarding the long-term effectiveness of AI is still insufficient.	No. 1, 2, 7, 11 (Conceptual), No. 10 (Descriptive Qualitative)
2	Limited AI Implementation (Generic Tools)	The empirical implementation of AI in learning (e.g., for modules, assessments, or gamification) is still limited to generic digital tools (Quizizz, Kahoot!) or simple tutoring systems. There is a significant gap in exploring the impact of generative AI tools (ChatGPT, Copilot) on complex cognitive processes.	No. 16, 18 (Use of Game Applications), No. 10 (Simple AI Modules)
3	Gap in Non-Cognitive Skills	AI's main focus is on the cognitive aspects (HOTS/creative/mathematical). 21st-	No. 21 (Impact of Gadgets), No. 17 (4C, but focusing

No	Limitation/Shortcoming	Detailed Description	Related Journals (Implicit)
		century skills that are non-cognitive, especially Collaboration and Communication, are only addressed from the perspective of risks (Impact of Gadgets - No. 21) or teacher training (No. 14), with minimal empirical research measuring AI platform designs aimed at enhancing social interaction and teamwork.	on critical thinking)
4	Lack of Validated Pedagogical Frameworks	While there are efforts to integrate AI with Constructivism (No. 6), there is no widely validated pedagogical model that can guide teachers in balancing the use of AI with student-centered learning principles.	No. 6 (Constructivism Integration)

Based on the shortcomings above, here are three main research gaps that should be the focus of future studies (Research Gaps):

3.1. Empirical Validation of the Scalability of Generative AI and Its Impact on HOTS

The literature claims that AI enhances HOTS (No. 9, 20), but the majority of studies are limited to simple designs or tools. Experimental studies are needed to measure the causal effects of interventions involving Generative AI (e.g., AI-as-a-tutor or AI-as-a-collaborator) on measurable improvements in Critical and Creative Thinking skills across domains (Mathematics, Science, Language). The focus should be on testing the implementation models, not just the potential of the tools [12], [13].

3.2. Development and Measurement of Collaboration and Communication Skills Quality in AI Environments

Digitalization has the potential to isolate students (No. 21), while AI can help personalize learning but risks neglecting social interactions. Therefore, research in design and development (R&D) is needed to create AI/digital platforms explicitly designed to mediate and enhance the quality of Collaboration and Communication (i.e., developing automated assessment metrics for team discussion quality, peer feedback, and contributions). This would bridge the gap between the promise of the 4Cs and the reality of increasingly digitalized learning [14], [15], [16].

3.3. Development of Teacher Competency Models (Pedagogy-AI) and National Readiness

Teacher readiness and AI literacy remain challenges (No. 8, 14), but no comprehensive picture exists yet. Mixed-methods research or meta-analysis is needed to:

3.3.1. Build and validate a Pedagogy-AI Competency Framework that integrates AI knowledge with Constructivist principles (No. 6).

3.3.2. Measure the national readiness of teachers (knowledge, attitudes, skills) to use such models at the national level, and link this with 21st-century curriculum policies [17], [18], [19], [20].

CONCLUSION

Fundamental Finding : This review highlights the transformative potential of Artificial Intelligence (AI) in addressing the challenges of personalization and assessment in 21st-century education. AI significantly facilitates adaptive and deep learning through recommendation systems and Deep Learning, adjusting content to students' cognitive profiles and speeds (No. 1, 2, 12). It also revolutionizes assessment by enabling automatic and instant feedback and promoting holistic evaluation (No. 3, 4), while showing great promise in enhancing Higher-Order Thinking Skills (HOTS), including critical, creative, and mathematical thinking (No. 9, 20). **Implication :** AI's contributions are essential for educational advancements, particularly in personalizing learning experiences and improving assessment processes. However, its application in enhancing non-cognitive skills, such as collaboration and communication, remains underexplored. **Limitation :** Despite the recognized potential, the majority of the existing literature remains conceptual or based on small-scale experimental studies, with insufficient empirical validation of AI's long-term effectiveness at scale. Furthermore, research has largely overlooked the development and measurement of non-cognitive 21st-century skills. **Future Research :** Future studies must focus on validating the causal effects of Generative AI on complex cognitive processes and the development of pedagogical models and AI platforms explicitly designed to mediate and enhance social interaction and teamwork. Additionally, there is a need to establish a comprehensive competency framework to prepare teachers for the ethical challenges and AI literacy required in modern education (No. 6, 7).

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