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Technology Integration by 21st Century Teachers for Generation Alpha: Systematic Literature Review

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Abstract: This study explores the role of teachers in integrating technology to meet the learning needs of Generation Alpha through systematic literature review and bibliometric analysis. Using the Scopus database, 21 relevant articles were analyzed to identify forms, strategies, and trends. The findings show a significant increase in research on technology integration since 2024, reaching its peak in 2025. In-depth analysis reveals four main roles of technology integration in learning: teachers as architects and designers of learning, teachers as facilitators and guides of learning, teachers as evaluators and analysts of learning data, and teachers as lifelong learners and collaborators. This study concludes that integrating technology into learning provides benefits for both teachers and students. Future research is encouraged to expand cross-disciplinary and cross-regional bibliometric data and delve deeper into the challenges of technology implementation, especially in developing countries that focus on digital learning, and the impact of its utilization.

Keywords: Technology integration, 21st century teachers, Generation alpha, Systematic literature review.

Introduction

21st century education requires teachers to integrate technology into the learning process in order to meet the increasing digital competency demands of students. Technology integration is not merely the use of digital devices, but a learning strategy that effectively supports active and collaborative learning. In the context of elementary schools, technology integration is important because it is the initial stage of developing 21st century skills in students. Research shows that teachers need to have strong digital literacy competencies to ensure that the use of technology supports the quality of learning (Fatmasari et al., 2023). Digital literacy is not only a technical skill but also includes a pedagogical understanding of the use of technology for meaningful learning (Thummar, 2023).

The integration of technology in 21st century learning is important for fostering 21st century skills such as critical thinking, collaboration, and creativity in elementary schools. Educational technology serves as a tool to encourage students to actively engage in the learning process, for example, through collaborative tasks based on digital applications (Og'li, 2025). This kind of integration helps students develop the ability to solve complex problems, which is an important characteristic of the 21st century curriculum. Elementary schools have a strategic role in building the foundations of digital literacy from an early age so that students can compete in the digital age (Auyelbayeva et al., 2024). Thus, technology-based learning strategies can expand learning outcomes beyond just content knowledge.

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Research on Generation Alpha shows that learning approaches must be flexible, contextual, and interactive to suit their learning styles and needs in the digital age (Sisnorio, 2025; Arslan et al., 2023; Höfrová et al., 2024). Static and conventional learning tends to be less effective for a generation that is accustomed to multimedia variety and digital interaction. Approaches such as project-based learning, blended learning, and the use of interactive digital media are becoming increasingly relevant to increase student engagement (Kaakandikar et al., 2025); Anvarovna, 2025). Teachers play an important role in selecting and adapting appropriate technologies and methods so that students can learn actively and meaningfully. Formulating strategies such as these helps to create a learning system that is not only informative but also enjoyable for Generation Alpha. However, the main challenge faced in integrating technology in elementary schools is not just the technology itself, but also the readiness of teachers to apply it effectively in the classroom. Many teachers still face limitations in adequate digital skills, so that the use of technology in the classroom is sometimes not optimal (Purnomo, 2024; Wau et al., 2025). Systematic research in the context of global education shows that a lack of knowledge and skills is a significant barrier to technology integration, even when the technology is available (Rahman, 2024). This underscores the importance of continuous professional development for teachers so that they can keep updating their digital skills in line with technological developments. Thus, teacher education is an important part of a successful technology integration strategy. In addition to teacher skills, gaps in access to technology and infrastructure support are also barriers to the effective implementation of learning technology in elementary schools. Research shows that these access gaps can widen the disparity in education quality between schools in urban and rural areas (Dai, 2025; Zou, 2025). Schools with adequate technological infrastructure tend to be better able to implement digital learning strategies optimally. Conversely, schools that lack technological facilities find it difficult to provide an equal learning experience for their students (Asyaari, 2025; Kultsum, 2025). Therefore, policy support that ensures equitable access to technology is important in order to realize inclusive technology integration.

On the other hand, the opportunities for integrating technology in the context of 21st century learning are vast, as technology can provide tools that enable more personalized and meaningful learning for students (Costa et al., 2024). With the help of technology, teachers can tailor learning experiences to the individual needs of students, open up access to global content, and encourage collaboration across space and time that would be impossible to achieve with traditional methods (Surur et al., 2024). These opportunities not only support the achievement of curriculum goals but also help students develop skills that are relevant to the needs of the future workplace. In the context of Generation Alpha, learning technology can increase student motivation and engagement in the learning process. Taking advantage of these opportunities is an important part of 21st century education strategies (Rzońca & Warchoń, 2024). However, implementing a technology integration strategy in learning remains complex because it involves various factors such as teacher readiness, infrastructure support, digital content quality, and student readiness to use technology optimally. Research shows that to achieve effective technology integration, collaboration between teachers, schools, policymakers, and other education stakeholders is necessary. This includes providing professional training for teachers, improving technology facilities, and developing a curriculum that supports digital learning (Og'li, 2025; Napitupulu et al., 2025; Fernández-sánchez et al., 2022). These challenges require a holistic and sustainable approach so that technology can truly become a tool for transforming learning, not just an aid. Thus, a comprehensive research approach is needed to capture the complexity of this phenomenon.

Given the complexity and relevance of the phenomenon of technology integration by 21st century teachers in supporting the learning needs of Generation Alpha, the Systematic Literature Review (SLR) approach was chosen as the research method for this study. SLR allows for a comprehensive analysis of published scientific evidence to answer research questions in a systematic and transparent manner (Prasetio, Supardi, Waspada, et al., 2025). This method helps map strategies, challenges, opportunities, and research trends in the field of technology integration in elementary schools, thereby strengthening and measuring the contribution of the research. With a deeper understanding of these practices and phenomena, the research is expected to provide practical and theoretical recommendations for the development of 21st century education. Thus, this article formulates several research questions to be answered in this systematic review.

What are the forms and strategies of technology integration applied by 21st-century teachers in learning for Generation Alpha?

How do trends in technology integration research by 21st-century teachers in learning for Generation Alpha vary based on publication year and type of technology?

What are the challenges and opportunities faced by 21st-century teachers in integrating technology to meet the learning needs of Generation Alpha?

Method

This study uses a systematic literature review (SLR) and bibliometric analysis approach to generate broad and in-depth insights into the integration of technology by 21st century teachers in the learning process for Generation Alpha. Simply put, SLR is used to identify, evaluate, and synthesize relevant research findings in a systematic and transparent manner (Kumar, 2025); (Dhakal & Pandey, 2023); (Paul, 2025). Bibliometric analysis is then used to measure and analyze patterns in scientific literature, assessing research developments by providing researchers with knowledge about publication patterns and synergies between researchers (Vaishya et al., 2025; Prasetyo et al., 2025).

In this SLR method, the PRISMA diagram was initially used to screen appropriate and relevant literature from the Scopus database to obtain usable literature. Each article obtained from the search was critiqued based on inclusion and exclusion criteria to ensure that the quality of the research remained relevant to the synthesis. On the other hand, bibliometric methods quantitatively assess the development of research on the topic of technology integration and learning processes for Generation Alpha. This method provides researchers with knowledge about publication patterns, such as temporal and geographical trends, as well as synergies between authors and institutions (Ananda et al., 2024; Mohd et al., 2024). In this study, software such as VOSviewer was used to perform network analysis, which allows visualization of the relationships between articles, authors, and keywords (Kumar, 2025; Stefanis et al., 2025). Through this approach, we can see how the topic of technology integration relates to the learning needs of Generation Alpha.

Data Source

The data source used in this study is Scopus, as the primary source for collecting scientific literature with the largest and most reliable database in the world, covering scientific publications from various disciplines (Passas, 2024). Therefore, it is appropriate for this study to draw accurate and relevant conclusions in order to avoid research bias and ensure comprehensive research.

Data Search Strategy

The literature search process was conducted systematically through the Scopus database using a search string designed by combining four keywords, namely: teacher pedagogical competence, technology integration, basic education, and Generation Alpha. The search string used was: TITLE-ABS-KEY (“teacher role” OR “pedagogical role” OR “teaching practice” OR “instructional role”) AND (“technology integration” OR “educational technology” OR “digital pedagogy” OR “ICT”) AND (“primary education” OR “elementary education” OR “young learners”).

This search string was designed with Boolean operators to ensure comprehensive literature coverage while maintaining the relevance of the results (Purssell & McCrae, 2020). The search was conducted using keywords (TITLE-ABS-KEY) to obtain articles that discussed research topics relevant to the title, abstract, and keywords of the article (Mckenna, 2024). From the initial search using the keywords “teacher. pedagogical competence,” “technology integration,” “elementary education,” and “Generation Alpha,” we found 818 articles in the initial search results.

Relevance Screening

In this study, a relevance screening process was conducted to ensure that only articles relevant to the topic focus were included in the analysis (Galli, 2025). The inclusion and exclusion criteria used in this study are presented in Table 1. A total of 818 articles were found in the initial stage and then filtered based on relevance using the inclusion and exclusion criteria in Figure 1, resulting in 195 articles. We then screened the abstracts using criteria relevant to the topic, resulting in 65 documents that would enter the final stage of relevance screening. In the final screening stage, we conducted a complete and thorough analysis of the titles, keywords, and abstracts with reference to the main research topic and research questions used in this study. The final screening process resulted in 21 articles to be considered in the analysis. The detailed relevance screening process is shown in Figure1 PRISMA diagram

Table 1. Article relevance screening criteria

Criteria	Description	Category
Language	Articles written in English.	Inclusion
	Articles written in languages other than English.	Exclusion
Document Type	Article	Inclusion
	Types of documents in the form of books, conference papers, other publications.	Exclusion
Publication Time Range	Articles published between 2020 and 2025.	Inclusion
	Articles published before 2020.	Exclusion
Focus Topics	Articles discuss teacher pedagogic competence, technology integration, basic education or Generation Alpha.	Inclusion
	The article does not address any or all of the main pillars of the topic, or only mention them at a glance without in-depth analysis.	Exclusion
Full Text	The full text of the article can be accessed and downloaded in full through institutional or open access databases.	Inclusion
	Only abstracts are available, or the full text of the article is not accessible.	Exclusion

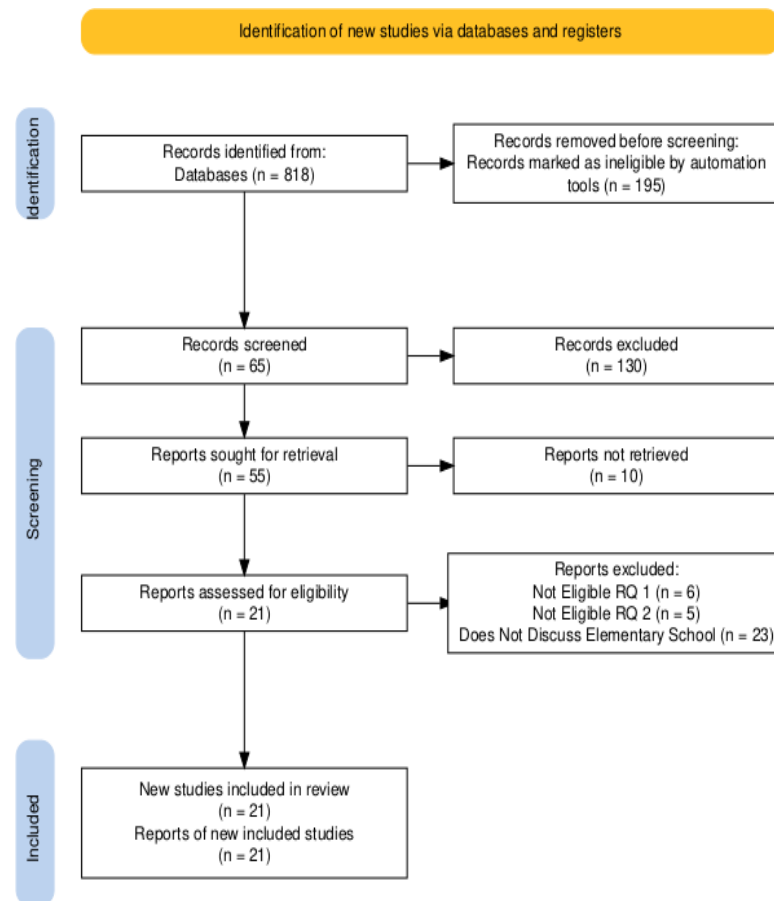


Figure 1 Prisma SLR flowchart

Results and Discussion

Forms and Strategies of Technology Integration

Based on the results of an in-depth analysis of various forms and strategies of technology integration, a mapping of 21st century learning practices has been revealed, describing a picture in which technology is no longer just a tool, but has evolved into an active partner in designing meaningful learning experiences (Silva, 2025; Faig, 2023;

Kabudi et al., 2020). At the most basic level, we see technology integration in the form of hardware such as computers, projectors, and tablets, as well as digital platforms such as Google Classroom and Kahoot. At this stage, the dominant strategy is often still teacher-centered, where technology serves to reinforce the delivery of material visually and interactively (Raave et al., 2024; Eden et al., 2024).

A significant paradigm shift has led to technology being used as a primary tool to help teachers design creative learning experiences, such as the use of generative artificial intelligence (AI), such as Chat GPT, which is now seen not as a machine, but as a collaborative assistant (Mishra, 2025). Teachers demonstrate pedagogical wisdom by utilizing AI to overcome real challenges in the classroom, from completing time-consuming administrative tasks, generating creative activity ideas when resources are limited, to developing learning plans that can be tailored to the individual development and interests of each student (Rajput, 2025). Technology is used to free up teachers' time so they can focus more on personal interaction and facilitate differentiated learning, which is essentially an effort to appreciate the uniqueness of each child.

The development of technology integration can also be seen from the shift in focus. Teachers no longer just show videos from YouTube but creatively produce their own animated videos using a range of AI tools such as Leonardo.ai and CapCut to align moral narratives with learning objectives (Fatmawati & Raharjo, 2024; Yanti et al., 2025). Similarly, the concepts of digital storytelling and video-based project creation place students as active subjects and creators, rather than passive viewers. This strategy not only increases engagement but also develops crucial 21st-century skills such as creativity, collaboration, and digital literacy (Morisson et al., 2024).

In essence, it emphasizes that successful technology integration is not determined by the sophistication of the tools used, but rather by the underlying pedagogical strategy. These teachers act as reflective learning architects, deliberately selecting and combining technologies ranging from virtual manipulatives for understanding mathematical concepts to multimodal platforms for coding instruction to achieve learning objectives (Tammets et al., 2022; Choi & Young, 2021). They also demonstrate professional maturity by adopting new technologies, ensuring that each choice is based on educational and responsible considerations. Thus, the picture that emerges is that of a 21st century teacher who is not only technically proficient but also has the wisdom to use technology as an extension of their hands in understanding, nurturing, and inspiring each student.

Analysis of the Type of Technology

Based on the mapping of technology types from the 21 documents analyzed, it can be seen that several types of technology can be categorized into six categories, namely fundamental technology, artificial intelligence (AI) and emerging technology, collaboration and communication tools, digital learning platforms, interactive media and gamification, and immersive technology.

Kategori Teknologi	Contoh Teknologi	Frekuensi	Persentase
Teknologi Fundamental	Smartboards, Komputer, Tablet, Chromebooks	15	22.7%
AI & Teknologi Emergent	ChatGPT, LLMs, AI Tutoring, Chatbots	13	19.7%
Alat Kolaborasi & Komunikasi	Zoom, Meet, WhatsApp, Padlet, Google Docs	12	18.2%
Platform Pembelajaran Digital	LMS, MOOCs, Google Classroom	11	16.7%
Media Interaktif & Gamifikasi	Kahoot, Wordwall, Quizziz, Digital Storytelling	10	15.2%
Teknologi Imersif	VR, AR, Multimodal Learning	5	7.6%

Figure 2. Technology use analysis

A more in-depth analysis of the types of technology used by teachers provides a clear picture of how technology is used in elementary schools. Based on the data presented above, basic technology ranks highest with a frequency 15 times higher, or 22.7%. This category, which includes common devices such as interactive whiteboards (Smartboards), shows that the basis for technology integration in elementary schools is still largely based on established, inexpensive devices that are easier to use in conventional learning structures.

Conversely, more advanced technologies, such as Virtual and Augmented Reality, are integrated only 5 times (7.6%). This indicates that there are major issues, such as high costs, the need for special training for teachers, and difficulties in fully integrating them into the curriculum, which hinder the widespread adoption of these innovative technologies. However, the fact that new AI technologies such as ChatGPT are included in the list is a very important finding. Although the number of adoptions may not be as high as for basic technologies, their emergence marks the beginning of a paradigm shift. Teachers' engagement with these artificial intelligence-based tools demonstrates an awareness of the latest advances. These tools have the potential to personalize student learning experiences, improve administrative efficiency, or even inspire creative learning designs.

Publications by Year

Based on an annual analysis of publications, research on technology integration conducted by elementary school teachers shows a significant trend over the past decade. Between 2023 and 2021, the number of publications was relatively low, with only 2 to 1 document published per year. A dramatic increase began in 2024 and 2025, marked by four publications in 2024 and peaking at 13 publications in 2025.

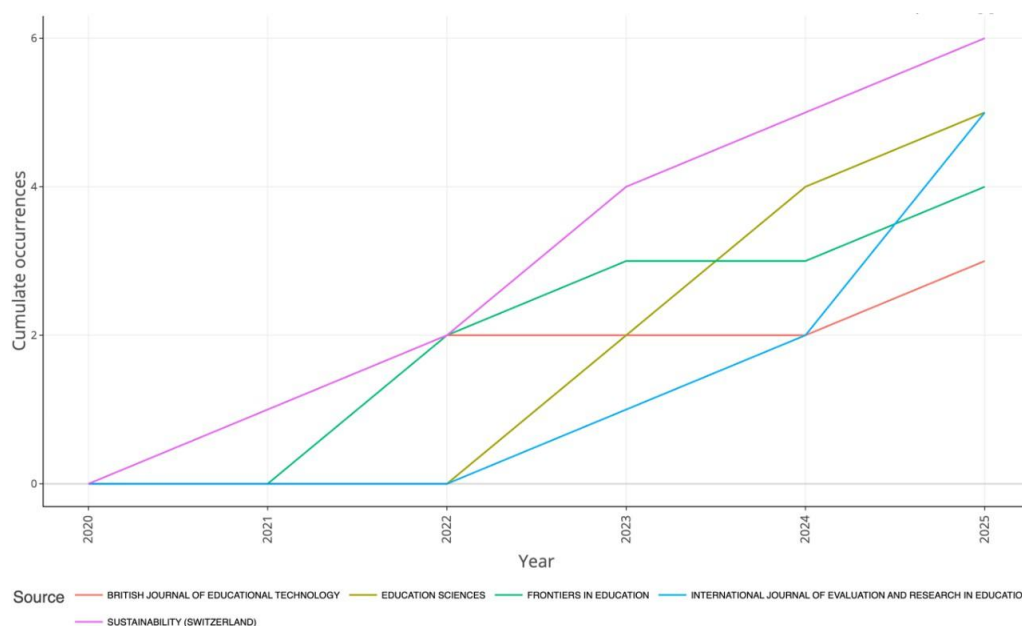


Figure 3. Publications by year

The trend of increasing publications on technology integration by elementary school teachers after 2023 shows that this topic is gaining more attention in the academic world. Technology integration is not an additional skill but a basic competency for elementary school teachers. The high level of research interest in technology integration in 21st-century primary education is clearly reflected in the line graph that maps the cumulative number of scientific publications from 2020 to 2025. This graph shows data from five well-known journals, namely the British Journal of Educational Technology, Education Science, Frontiers in Education, International Journal of Evaluation and Research in Education, and Sustainability (Switzerland).

Overall, these five sources show a consistent upward trend, indicating that this topic is gaining widespread attention among academics. The most notable feature is the exponential growth that occurred after 2023, where almost all lines experienced a steep increase. The journal Sustainability (Switzerland), represented by the purple line, even shows the most significant growth with the highest cumulative number of publications at the end of the period. This phenomenon not only confirms that the integration of technology by teachers has become a central issue in modern educational discourse but also underscores the need for ongoing research

Keyword Analysis

Keyword analysis in research on technology integration by elementary school teachers in the 21st century is important for identifying dominant themes and emerging trends. By examining frequently occurring terms, we can understand the main areas of focus and their relevance to technology integration in learning.



Figure 4. Frequency of treemap keywords

The Treemap above provides a more detailed overview of the focus of these research studies. The themes of “basic education” and ‘teaching’ emerge as the largest domains, directly reflecting the core of the topics studied. This is followed by “educational technology,” indicating a focus on the technological aspects themselves. Sub-themes such as “teaching practices” and “teacher education” emphasize that the focus of the research is not only on technology as a tool, but more on how teachers implement it in their daily practices and how they are prepared to do so. The presence of the theme “COVID-19” is also an important marker that encourages the adoption of technology. Overall, this visualization illustrates that the study of technology integration is multidimensional, covering context (basic education), actors (teachers), practices, and is influenced by global events, thus providing a strong foundation for your research.

Network Visualization

Based on the co-occurrence network mapping of the 21 documents analyzed, it can be seen that several key words, such as “primary education,” “teaching,” and “educational technology,” form a dense and strongly interconnected core triangle. This is not merely a statistical coincidence, but rather a reflection of a fundamental understanding that discussions about technology can never be separated from the real context of teaching and learning in elementary schools. This close relationship illustrates that the focus of the research is not on technology itself as an isolated entity, but rather on how technology influences, challenges, and enriches the art and science of teaching.

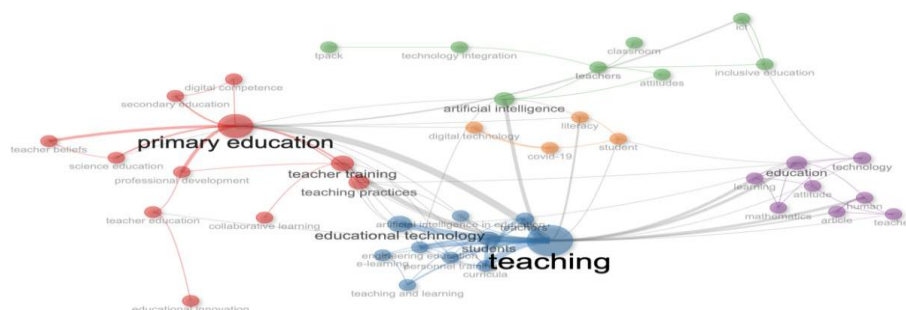


Figure 5. Network mapping

Overall, this network map is more than just a visualization of data; it is a reflection of a dynamic knowledge ecosystem. It depicts a complex and interconnected educational research environment. Its aspects are interrelated and form an ecosystem in which humanity, technology, and pedagogy must work together to create education that benefits everyone.

Challenges and Opportunities in Technology Integration

Table 2. Challenges and opportunities

No	Title	Author	Challenge	Opportunities
1	Technology integration in pedagogical processes: digital competence and teaching practices of primary school teachers in Turkey	Alptekin, Z., Taneri, A.	Limited Teacher Competence Inadequate Infrastructure Time Constraints Teacher-Centered Approach	Post-Pandemic Experiences Professional Development Program Learning Transformation Potential
2	Investigating Teachers' Changing Perceptions Towards MOOCs Through the Technology Acceptance Model	Patrick Camilleri, Abeer Watted, & Michelle Attard Tonna	Initial difficulties in navigating MOOC platforms Difficulty in managing time between professional commitments and completing online courses Concerns about a lack of personal interaction and individualized feedback from the instructor	MOOCs offer time flexibility and access to experts and learning resources from around the world Competency Development: Improve 21st century skills such as critical thinking, time management, and problem-solving
3	What drives L2 teachers to embrace artificial intelligence (AI)? A phenomenological inquiry into the role of personal and job resources	Yan Wu	Self-efficacy of technology, lack of AI literacy, closed attitude towards innovation, and lack of resilience to face Lack of support from institutions (school leaders) Concerns about diminished authentic human interaction and threats to teachers' autonomy and professional identity	Teachers who have high self-efficacy, good AI literacy, are open to innovation, and are resilient will see AI as an opportunity to improve teaching effectiveness Strong institutional support, access to reliable AI tools, and AI-related training will significantly increase teachers' willingness and ability to integrate AI
4	ChatGPT in Early Childhood Science Education: Can It Offer Innovative Effective Solutions to Overcome Challenges?	Mustafa Uğraş, Zehra Cakir, Georgios Zacharis, & Michail Kalogiannakis	Concerns that over-reliance on ChatGPT can reduce teachers' pedagogical skills, creativity, and problem-solving abilities The belief that AI cannot completely replace the emotional bond and interaction between teachers and students, which is crucial at the early childhood education level	Offering creative and alternative solutions to activities when physical materials are not available Enables personalization of learning to meet the individual needs of children Saves time in lesson planning and material preparation
5	Leveraging Multimodal Information for Web Front-End Development Instruction: Analyzing Effects on Cognitive	Ming Lu & Zhongyi Hu	Students have a short attention span and a superficial understanding of complex concepts Teacher-centered instruction limits opportunities for peer-to-	The distribution of information through various sensory channels reduces unnecessary mental burdens and focuses cognitive resources on problem-solving Multimodal tools create richer exchange of ideas and more meaningful social interactions

No	Title	Author	Challenge	Opportunities
	Behavior, Interaction, and Persistent Learning		peer collaboration and adaptive feedback Outcome-oriented evaluations fail to reinforce voluntary practice	
6	Modeling Concrete and Virtual Manipulatives for Mathematics Teacher Training: A Case Study in ICT-Enhanced Pedagogies	Angela Ogbugwa Ochogboju & Javier Díez-Palomar	The cost, storage, and preparation time required to use physical tools in the classroom Limited access to devices, teachers' low digital skills, and the potential for students to be distracted from key tasks Difficulties in effectively integrating both types of manipulatives due to lack of structured models	Physical manipulatives support embodied cognition through physical touch, while virtual manipulatives offer dynamic visualization and limitless exploration Virtual manipulation and ICT simulation models offer scalable and accessible solutions, addressing the logistical challenges of physical tools
7	How digital platforms improve teaching: comparing teacher performance across Peru	Yurfa Carolina Medina-Bedón dkk.	Older teachers may have lower digital competencies, which is a barrier to technology adoption Lack of support from the government or educational institutions for the equitable implementation of technology	The integration of digital platforms has been proven to significantly improve teachers' PCK performance, which will ultimately improve student learning outcomes These findings provide a solid basis for designing professional development programs focused on the most impactful aspects (e.g., for male teachers, teachers in rural areas)
8	Integrating artificial intelligence in literacy lessons for elementary classrooms: a co-design approach	Panagiotis Kosmas dkk.	Initial preparation for workshops, time requirements during workshops, and lack of expertise with specific AI tools Difficulties in adapting materials to fit the needs of all students in diverse classes	Students become more engaged and enthusiastic in AI-integrated learning AI helps students understand texts better, increase interest in lessons, and develop their digital skills
9	Artificial Intelligence Implementation in Teaching English as a Foreign Language: A Qualitative Research Synthesis	Sayyed Mohammad Sayyed Kalan & Diyar Mazharpour	Concerns regarding the collection and use of student data Students may experience decreased critical thinking and independent thinking skills Accuracy of automated feedback, lack of face-to-face interaction, and lack of understanding of cultural nuances and human emotions Lack of training, conflicting attitudes towards technology, and	AI creates an interactive, fun, and anxiety-free learning environment The ability of AI to adapt to the needs and pace of learning of each student (as per the character of Generation Alpha) Opportunity to practice anytime and anywhere via mobile devices Automation of tasks such as assessments, giving teachers more time for valuable interactions with students

No	Title	Author	Challenge	Opportunities
			concerns will be replaced by AI	
10	Supporting teachers' value-sensitive reflections on the cost-benefit dynamics of technology in educational practices	Davinia Hernández-Leo & Karina Ginoyan	Students with better access will benefit Lack of control over student data Contribution to the carbon footprint A platform controlled by a commercial company Students use AI to cheat	Experiments and explorations that would not be possible without technology Supports social interaction and high-level thinking
11	The Role of Digital Storytelling in Jordanian School EFL Classrooms: A Qualitative Exploration of Teachers' Perceptions	Mohammad Hamad Al-khresheh	Lack of interactive whiteboards, computers, software, and reliable internet connections in schools Difficulty in aligning digital storytelling with a dense and rigid curriculum The preparation time required to create digital storytelling materials conflicts with a strict teaching schedule	Significantly helps improve vocabulary, comprehension, and speaking fluency Digital storytelling materials can be easily stored and reused, making them a cost-effective and efficient teaching tool
12	Investigating ESL Teachers' Experience in Teaching Online Classes	Siti Fatimah Abd. Rahman & Nor Fairuz Mohamed Idris	Lack of formal experience and training in online teaching before the pandemic, difficulty adapting the syllabus (CEFR) to local contexts Unstable internet connection, power outages, audio/video interference, and lack of teacher troubleshooting capabilities	The pandemic forced teachers to self-empower and learn new technology skills independently, which improved their long-term competence The adoption of digital assessment tools (Quizizz, Google Forms) opens up opportunities for more efficient assessments, providing instant feedback, and organized documentation
13	Indonesian Teachers' Roles in Designing and Utilizing AI-Powered Animated Videos: A Case Study on Classroom Practices and Character Development	Nafri Yanti, Arono, Fina Hiasa, Febi Junaidi, Noermanzah, Rio Kurniawan	The learning curve was steep. Many teachers struggle with the animation features on Runway and have to rely on the help of peers, showing barriers to technical competence Time-intensive process of creating and customizing AI-powered content, which can collide with other teaching tasks	AI videos open up conversations that wouldn't normally happen; students become more enthusiastic, reflective, and even usually quiet students begin to participate AI videos allow for dynamic assessment methods embedded in the content, such as scenario quizzes and discussion rubrics, to evaluate cognitive understanding and moral development simultaneously
14	Quality Education in the Digital Age: Adapting to 21st Century Primary School Learners	Oleksandr Blyznyuk, Tetiana Kachak, Tetyana Blyznyuk, Stanisława Katarzyna Nazaruk	Unequal access to technology and the internet between students from different socioeconomic backgrounds Lack of training and support for teachers to	Technology makes learning more engaging, interactive, and dynamic Allows students to learn at their own pace and style Fostering creativity, critical thinking, collaboration, and computational thinking

No	Title	Author	Challenge	Opportunities
			integrate technology effectively	
15	Exploring the nexus of attitude, contextual factors, and AI utilization intentions: A PLS-SEM analysis among primary mathematics teachers in China	Mao Li dan Abdul Qawi Noori	Negative attitudes towards AI can hinder adoption Lack of institutional and technical support	AI enables personalized learning as per the needs of students AI creates a more interactive and engaging learning environment AI can improve the efficiency of math learning
16	Teachers' beliefs about technology integration in Ghana: a qualitative study of teachers', headteachers' and education officials' perceptions	Emmanuel Ayisi Abedi, Sarah Prestridge, dan Steven Hodge	Teachers tend to have teacher-centered beliefs The need for training designed to change teacher beliefs Lack of institutional support for pedagogical change	An opportunity to change teachers' beliefs so that technology is seen as a pedagogical tool Opportunities for professional development focused on changing teacher beliefs
17	Implementing Flipped Classroom in the Digital Learning Environment	Marija Sablić, Ana Miroslavljević	Limited internet access, lack of teachers' digital skills Time & effort to create videos Creative learning environment design	Improve self-directed learning Motivation and student collaboration Learning flexibility
18	Greek Primary School Teachers' Professional Experience as Digital Actors	Panagiotis Giavrimis dkk.	Greek education policies are inadequate (infrastructure & teacher training) Lack of administrative support Bureaucratic burden	Improving pedagogical practices Facilitating learning Developing information networks
19	Teachers' Digital Technology Use After a Period of Online Teaching	Benjamin Luke Moorhouse	Overuse of technology Characteristics of learners Technical problems Lack of school investment Increased teacher workload	The pandemic encourages teachers to use technology Increase student engagement Facilitate learning Provide multimodal scaffolding
20	Primary Mathematics Teachers' Understanding of Computational Thinking	Siri Krogh Nordby, Annette Hessen Bjerke, Louise Mifsud	Lack of Teacher Knowledge Lack of teacher training Difficulty connecting CT with Math	Student Motivation and Engagement Relevance to the Real World Available Resources
21	Primary Educational Strategies in Times of Digital Curriculum Content	Isabel María Gallardo-Fernández, Laura Monsalve Lorente, Miriam Elizabeth Aguasanta-Regalado	Economic challenges & access Time constraints & implementation The need for teacher training	Motivation in student learning Inclusion & Equity Process Facilitated

Based on Table 2, we specifically categorize four pedagogical roles of elementary school teachers in integrating technology into learning as follows.

Learning Design

This role is used as a basis for integrating technology into learning in elementary schools, where teachers not only use technology as a supplement but also fundamentally encourage learning experiences around it. Teachers make a significant contribution to institutional transformation (Og'li, 2025; Qamariyah, 2024). Teachers also use AI to design more efficient workflows (e.g., automated grading) and create materials tailored to students' ability levels, which is one aspect of the teacher's role as a personalized learning designer (Hubballi et al., 2025; Tahir et al., 2024; Fitria, 2023). Another study by Yanti et al., (2025) found that the role of teachers here is very creative and modern; they not only use AI, but also "create special videos using a series of generative AI tools" (Leonardo, Runway, CapCut). This is the role of a content creator and learning experience designer who utilizes an ecosystem of tools to achieve language learning and character development goals (Yanti et al., 2025; Almegren et al., 2025). Thus, teachers ensure that the resulting learning design is relevant, contextual, and in line with the curriculum.

Learning Facilitator

This role focuses on how teachers utilize technology so that learning is not only teacher-centered but student-centered. Technology here is not for presenting information, but for "transforming students from passive recipients to active learners" who create and share their own stories (Tzenios, 2022). Teachers use digital storytelling to create a dynamic, interactive, and participatory learning environment (Puspitasari et al., 2025). The role of teachers as facilitators who guide students' individual learning paths, with AI as a tool, found that AI is used to "support differentiated learning" (Yang & Yanqiu, 2025).

Learning Data Evaluators and Analysts

Teachers here act as evaluators who utilize technology to provide "automatic and immediate feedback," enabling more efficient and frequent formative assessments (Khasawneh, 2024; Borte et al, 2023). AI-based Speaking Assessment System "and" Automatic Writing Evaluation (AWE) Program," to conduct dynamic assessments and analyze learning data specific to personal feedback (Jin & Hu, 2025).

A study by Yanti et al. (2025) found that teachers also conduct "dynamic assessments using AI content, such as scenario quizzes and discussion rubrics, to evaluate cognitive understanding and moral development simultaneously." Teachers use "digital quizzes (Quizizz, Google Forms) for formative assessment." This shows a shift from summative to formative assessment, where technology allows teachers to monitor student understanding in real-time and adjust their teaching (Okafor, 2025).

Lifelong Learning and Collaborators

This role highlights that in order to integrate technology, teachers must continuously learn and collaborate. This shows that teacher learning is not only about technical skills, but also about pedagogical paradigm shifts. Developing competencies and encouraging a lifelong learning mindset also opens up opportunities to connect with the global education community. MOOCs directly demonstrate the role of teachers as lifelong learners (Permana & Afriany, 2024).

Conclusion

This study specifically discusses three main aspects related to the integration of technology by elementary school teachers in 21st century learning. First, the forms and strategies used by teachers in integrating technology into elementary school learning show that technology is no longer just a passive tool for teachers but has evolved into an active partner in designing meaningful learning experiences. Teachers demonstrate pedagogical wisdom by utilizing AI to overcome real challenges in the classroom, ranging from completing time-consuming administrative tasks, generating creative activity ideas when resources are limited, to developing learning plans that can be tailored to the individual development and interests of each student. In terms of annual publication

trends, there has been a significant increase since 2023, with the highest surge in 2025. This indicates an increase in academic attention to the issue of technology use in learning, where technology integration is not an additional skill but a basic competency for elementary school teachers. In terms of keyword analysis and network structure, topics such as “Basic Education” and ‘Teaching’ directly reflect the core of the research topic. This is followed by “Educational Technology,” indicating a focus on the technological aspects themselves, which is the core of this research.

Second, through a systematic review of recent findings and an analysis of the challenges and opportunities in integrating technology by 21st-century teachers, this study identifies four pedagogical roles for elementary school teachers: learning architect and designer, learning facilitator and guide, evaluator and data analyst, and lifelong learner and collaborator. These roles emphasize that the integration of technology in learning can make learning innovative, differentiated, and able to meet the learning needs of Generation Alpha, especially in elementary schools. However, several challenges remain in the use of technology in learning, such as limited teacher competence due to a lack of training that provides feedback, challenges of access, and digital liberation. Nevertheless, opportunities in the use of technology are supported by the learning needs of Gen Alpha students who enjoy technology, making it easier for them to understand learning in a real way and based on their environmental experiences.

Although it provides comprehensive contributions, this study has limitations in the number and scope of publications analyzed and in the use of technology in learning practices. Therefore, further research is recommended to expand cross-disciplinary and cross-regional bibliometric data and to explore more deeply the challenges of technology implementation, especially in developing countries. Focusing on digital learning and the impact of digital technology utilization will be crucial in creating learning that can meet the learning needs of Generation Alpha, especially in elementary schools.

Recommendations

Based on the findings of this systematic literature review, several recommendations are proposed for teachers, schools, policymakers, and future researchers. (1) Strengthening Teacher Digital Competence and Training. Given that limited teacher competence remains one of the most frequently cited barriers to technology integration, ongoing and structured professional development programs should be prioritized, particularly those focused on AI literacy, digital pedagogy, and the practical use of emerging tools such as generative AI, digital storytelling platforms, and AI-based assessment systems. Training should move beyond one-time workshops toward sustained mentoring and peer-learning communities that allow teachers to continuously update their skills. (2) Equitable Infrastructure and Access Development. Policymakers and educational institutions should address the digital divide between urban and rural schools by ensuring equitable access to devices, stable internet connectivity, and adequate technological infrastructure. Without this foundation, the benefits of technology integration risk being concentrated only in well-resourced schools, widening existing educational inequalities. (3) Institutional and Policy Support for Pedagogical Change. Schools and education authorities should provide stronger administrative and policy support that encourages teachers to shift from teacher-centered to student-centered practices. This includes reducing bureaucratic burdens, allocating time for lesson redesign, and integrating technology use into formal curriculum frameworks rather than treating it as a supplementary activity. (4) Responsible and Balanced Integration of Artificial Intelligence. While AI tools offer significant opportunities for personalization, formative assessment, and creative content development, their adoption should be guided by clear ethical considerations regarding data privacy, over-reliance, and the preservation of authentic teacher-student interaction. Institutions are encouraged to develop guidelines that help teachers use AI as a collaborative assistant rather than a replacement for pedagogical judgment. (5) Development of the Four Pedagogical Roles. Teacher education programs should explicitly cultivate the four roles identified in this study, namely learning architect and designer, learning facilitator and guide, evaluator and data analyst, and lifelong learner and collaborator, so that technology integration is approached holistically rather than as isolated technical skills. (6) Expansion of Research Scope. Future research is recommended to broaden bibliometric and systematic review data across disciplines and regions, particularly in developing countries where technology adoption challenges differ significantly from those in more resourced contexts. Longitudinal studies examining the long-term impact of technology integration on Generation Alpha's learning outcomes, motivation, and digital citizenship are also encouraged, along with comparative studies across countries to identify context-specific best practices.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS Journal belongs to the authors.

Conflict of Interest

* The author declares that there is no conflict of interest.

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