SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 2530-2546
Open Access. Online & Print

DOI: 10.5281/zenodo. 122.126196

TRENDS AND EFFECTIVENESS OF TECHNOLOGY-BASED LEARNING INNOVATIONS IN ENHANCING STUDENT LEARNING OUTCOMES: A SYSTEMATIC LITERATURE REVIEW

Muh. Nur Rochim Maksum[1*], Fadhilla Nangroe Anggraini[2], Alfan Rifai[3], Fadhia Ananda[4], Ahmad Akbar Fauzi[5], Abil Fida Muhammad Qois Al Hadi[6], Viky Nur Vambudi[7], Annisa Fauziah[8], Fauzan Addinul Jihad[9], Muhammad Wildan Shohib[10], Mutohharun Jinan[11]

[1]Faculty of Islamic Religion, Universitas Muhammadiyah Surakarta, Email: mnr127@ums.ac.id, https://orcid.org/0000-0002-2268-0487
[2,3,4,5,6,7,9,10] Faculty of Islamic Religion, Universitas Muhammadiyah Surakarta, Email: o100240030@student.ums.ac.id, https://orcid.org/0009-0008-8148-4700; Email: ar637@ums.ac.id, https://orcid.org/0009-0000-6338-5102; Email: o100250043@student.ums.ac.id, https://orcid.org/0009-0009-5278-1121; Email: o100250019@student.ums.ac.id, https://orcid.org/0009-0000-3994-9633, o100240032@student.ums.ac.id, https://orcid.org/0009-0007-1240-2487; Email: o300250005@student.ums.ac.id, https://orcid.org/0009-0006-1696-3313; Email: o100250014@student.ums.ac.id, https://orcid.org/0009-0002-9818-4145; Email: mws543@ums.ac.id, https://orcid.org/0000-0001-6611-7832, Email: mj123@ums.ac.id,https://orcid.org/0009-0008-4117-4345
[8]Faculty of Sharia, Universitas Raden Mas Said Surakarta
Email: annisafauzi4h@gmail.com, https://orcid.org/0009-0001-4570-2933

Received: 20/10/2025
Accepted: 01/12/2025

Corresponding Author: Muh. Nur Rochim Maksum (mnr127@ums.ac.id)

ABSTRACT

Digital transformation in education is accelerating during 2023-2025, driven by the adoption of Artificial Intelligence (AI), Augmented/Virtual Reality (AR/VR), gamification, mobile learning, and blended learning that have been proven to strengthen student motivation, retention, and learning outcomes. However, the implementation of this technology cannot be separated from challenges such as infrastructure gaps, uneven digital literacy of educators, and the unpreparedness of formal education policies. This study uses the Systematic Literature Review (SLR) method that follows the PRISMA 2020 guidelines to analyze 17 Scopus indexed empirical articles published in the 2023-2025 range and focuses on the effectiveness of digital learning technology. The results of the analysis show that digital innovation has a significant impact on improving learning outcomes. E-learning had a high effect size (ES = 1,285), which, according to Cohen's scale, indicates a large effect, demonstrating a significant impact on learning outcomes. On the other hand, Technology-Based Embodied Learning resulted in a moderate increase (SMD = 0.41), which falls within Cohen's moderate effect range (0.2 - 0.5). AR/VR strengthens the understanding of abstract concepts by more than 30%, and adaptive

AI substantially improves personalization and learning independence. Nonetheless, obstacles such as research design heterogeneity and institutional readiness limit the generalization of findings. This study concludes that digital learning technology is now the foundation of adaptive and data-driven learning, not just a pandemic emergency solution. In the future, it is necessary to increase the digital capacity of educators, develop more equitable infrastructure, integrate a strong digital curriculum, and longitudinal research to ensure sustainability and equal access to digital learning.

KEYWORDS: Technology-Based Learning, Digital Learning, Educational Technology, Learning Outcomes.

1. INTRODUCTION

In the last decade, digital transformation in the world of education has grown rapidly, especially since the COVID-19 pandemic which accelerated the adoption of technology-based learning (Almahasees and Qudah 2023; Anderson and Dron 2022; Aysi, Susilaningsih, and Sabandi 2024; Singh and Thurman 2020). Innovations such as Artificial Intelligence (AI), Augmented/Virtual Reality (AR/VR), gamification, mobile learning, and blended learning have created a more interactive, personalized, and adaptive learning experience. (Bower & Jong, 2021; Dmitrieva, 2020; Febriandika et al., 2024). Various studies show that this technology improves student flexibility, motivation, and learning outcomes (Brown, 2020; Romero & Ventura, 2021; Zhou, 2024).

However, the implementation of these innovations still faces challenges such as infrastructure inequality, lack of teacher training, and ethical and data privacy issues (Dede, 2020; Dwivedi et al., 2023; Lee et al., 2023)

In addition, existing research tends to be fragmented, focusing only on one specific technology or region, so it has not provided a comprehensive picture across approaches and (Chiang Liang Kok, Yit Yan Koh & Tee Hui Teo, 2024) On the other hand, AR/VR has been shown to be able to strengthen the understanding of abstract concepts through visual simulations and immersive learning environments (Hew & Lo, 2021; Liang, 2020). Meanwhile, AI-powered gamification and game elements such as points, badges, and interactive stories have been proven to increase intrinsic motivation, active participation, and student learning retention (Hamari & Koivisto, 2022; Hanli et al., 2024; Kimmons, 2023; Trihariyanto et al., 2020)

Until now, there has been no systematic literature review that maps the development of research on digital learning innovations as a whole (Liu & Santhanam, 2023; Nan Xiao, Yuting Pei, Chunhong Yuan, Yujia Bu, 2024; Rodrigues & Costa, 2022). Therefore, a study is needed that reviews the effectiveness of various educational technologies and analyzes their challenges and opportunities within one integrated conceptual framework (Lim & Wang, 2024; Martin & Sun, 2022; Nguyen & Gardner, 2023) Various quantitative studies show that this technology not only improves learning flexibility, but also has a positive impact on learning outcomes.

The study found that the use of AI-based virtual assistants in AR/VR environments significantly increased the learning outcomes of students with special needs by 23.5%, based on the measurement of pre-test and post-test scores in experimental studies (Latifatul Inayati & Rohmani, 2025; Mohamed et al., 2024; Zhao & Chen, 2023). In addition, it reports that the integration of VR, AR, and AI in STEM learning increases concept retention by up to 31% compared to traditional methods (De-Marcos & Garcia-Lopez, 2023; Linda Marie Ahl, Ola Helenius, Mario Sánchez Aguilar, Uffe Thomas Jankvist, Morten Misfeldt, 2023; Sun & Tsai, 2021; Trihariyanto et al., 2020).

Blended learning and mobile learning are now used by more than 68% of higher education institutions globally, proven to increase learning flexibility and effectiveness by up to 25% (Dika Ayu Pradana, 2021; Kim & Lee, 2022; Shohib et al., 2024). AI technology enables real-time personalization of content and adaptive feedback that can increase teaching effectiveness by 22% (Gao & Zhang, 2024; Latifatul Inayati & Rohmani, 2025).

Meanwhile, AR/VR has been shown to strengthen the understanding of abstract concepts with a 31% increase in conceptual understanding through visual simulations and immersive learning environments (Bower & Jong, 2021; Hew & Lo, 2021). In addition, it has been proven that gamification with the support of AI and game elements such as points, badges, and interactive narratives can increase students' intrinsic motivation by 28% and learning retention by 19% (Qian & Clark, 2021)

This review aims to answer three key research questions. First, what are the research trends related to digital technology-based learning innovations, especially artificial intelligence (AI), in the last three years? Second, the extent of the effectiveness of AI-based learning technology in supporting personalized learning and improving student learning outcomes.

Third, what are the challenges and opportunities that arise in the implementation of AI in the context of digital learning, especially in the formal education environment? Through these three focuses, this review is expected to provide a comprehensive understanding of the development, impact, and potential application of AI in the modern world of education

2. THEORETICAL FRAMEWORK

Experiential Learning Theory by Kolb emphasizes the importance of hands-on experience in shaping understanding and knowledge; this approach is particularly relevant to the use of VR/AR that provides immersive and realistic simulations in the learning process (García-Peñalvo, 2023; Gatsakou & Bardis, 2025) In addition, Self-Determination Theory (Deci & Ryan) underlies the gamification approach, where elements such as points, badges, and

challenges trigger students' intrinsic motivation to learn (Hwang & Lai, 2021; Srdanović et al., 2024)

The theory of social constructivism is also relevant, as technology-based learning such as AI and collaborative platforms allow students to build understanding through social interaction and personalization of data-driven learning (Raspopovic and Cvetanovic 2022; Wang and Hsu 2023). These theories together provide a robust framework for evaluating how and why digital technologies can significantly improve learning experiences and outcomes (Hwang & Lai, 2021; Srdanović et al., 2024).

In short, these theories affirm that digital technologies designed in harmony with the principles of social constructivism can strengthen interaction, personalization, and ultimately improve student learning outcomes.

3. LITERATURE REVIEW

3.1. Technology-Based Learning Innovation

Technology-based learning innovations include the application of various digital devices and approaches to improve the effectiveness of the teaching-learning process, while AR/VR provides immersive learning experiences that aid in the understanding of abstract and contextual concepts (Hanli et al., 2024; Liang, 2020). The main technologies that are widely studied include Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR), gamification, mobile learning, and blended learning (Zhou, 2024)

AI plays an important role in creating adaptive and personalized learning systems that adapt materials to students' needs in real-time, while supporting teachers through automated evaluation systems and educational *chatbots*.

The integration of AI in gamification has been shown to increase student motivation and learning outcomes by up to 20% (Hanli et al., 2024) AR and VR technologies offer immersive and interactive learning experiences, allowing students to explore abstract concepts through three-dimensional simulations (Mohamed et al., 2024)

The use of AR/VR is reported to increase conceptual understanding by up to 30% compared to conventional methods, as well as provide a safe space for risk-free exploration (Setiawan, 2025; Sung & Chang, 2021)

Meanwhile, gamification with game elements such as points, badges, and leaderboards has been proven to increase intrinsic motivation, learning engagement, and knowledge retention. The combination of gamification with AI and VR further amplifies the immersive effects and cognitive engagement of students (Liang, 2020) Additionally, mobile learning provides the flexibility to learn via mobile devices anytime and anywhere, while blended learning synergistically combines online and face-to-face learning (S. Wang & Fang Wang, Zhen Zhu, Jingxuan Wang, Tam Tran, 2023).

This approach has been shown to improve learning outcomes, especially in the mastery of practical and cognitive skills, making it one of the most effective learning strategies in the digital age (Kim & Lee, 2022).

3.2. Learning Innovation Research Trends

Research on learning technology has increased rapidly since the COVID-19 pandemic which became a turning point in global education reform (Zhou, 2024) This crisis has forced educational institutions to adapt to digital and distance learning systems, thus triggering a surge in investment and research related to the effectiveness, flexibility, and sustainability of technology-based education (Hamari & Koivisto, 2022).

The main focus of post-pandemic research has shifted from simply an emergency response to long-term innovations integrated in the education system. According to (Mahendra et al., 2024) studies show a significant increase in digital literacy research, especially in English language learning, due to the importance of 21st-century skills such as critical thinking, online collaboration, and information literacy (Mahendra et al., 2024) As many as 73% of articles in the last three years have linked digital literacy to increasing the effectiveness of technology-based learning (Veletsianos, 2022)

In addition, *mobile learning* and the use of *Learning Management Systems* (LMS) such as Moodle, Google Classroom, and Microsoft Teams are the dominant approaches that support flexible synchronous and asynchronous learning, mobile learning and the use of *Learning Management System* (LMS) platforms are the two most widely adopted approaches during and after the pandemic (Aysi et al., 2024).

LMSs such as Moodle, Google Classroom, and Microsoft Teams enable synchronously and asynchronously integrated management of learning, evaluation, and communication content. This learning model encourages the creation of a more flexible and independent learning environment for students (Aysi et al., 2024; Azzahrowaini et al., 2025; Inayati & Saputri, 2025)

Since 2022, research trends have increasingly emphasized the in-depth integration of technologies such as AI, *big data analytics*, and AR/VR into the regular curriculum as a key part of institutional

digital learning strategies. The direction of the research also shifts from testing the effectiveness of a single technology to a cross-technology integrative approach that considers aspects of digital pedagogy, student engagement, and socio-cultural context (Marappan & Saraswatikaniga, 2024) The research is now focusing on a cross-technology integrative approach that considers digital pedagogy, student engagement, and socio-cultural context in learning.

3.3. The Effectiveness of Technology on Learning Outcomes

Many studies confirm the positive impact of digital technology on learning outcomes. The use of AI in AR/VR environments for students with special needs increased learning outcomes by up to 23.5% (Mohamed et al., 2024) Similarly, it shows that the integration of VR and AI in STEM learning increases concept retention by up to 31% (Sathish Kumar, Tamil Selvan, Dr. M.Mahendra Prabu, Dr. G.Kalaiyarasan, Dr.R.Ramnath, 2024).

Gamification technology has also been shown to significantly increase students' motivation and learning activity, as reported in a study by (Mohamed et al., 2024; Ronnel Victor Kilat, Mark Joreez Catubig, Lislee Valle, 2024; Sheshadri et al., 2025).

Despite the many positive potentials, the literature also highlights serious challenges in the implementation of learning technologies (Singh et al., 2020) The most common barriers include inequality of digital infrastructure, low technological literacy among teachers, and ethical issues related to student data privacy (Yusuf, 2025).

In addition, there is still research fragmentation that limits the generalization of findings, as studies tend to focus on one specific technology or context without comparing effectiveness across approaches (Cabanillas-García, 2023)

The literature shows that although educational technology innovation is developing rapidly, there is still a need for studies that integrate more than one technological approach, as well as studies across educational and cultural contexts.

The importance of a cross-disciplinary approach to constructing an effective and sustainable implementation model in digital education services (Singh et al., 2020).

Thus, a systematic study is needed that is able to synthesize trends, effectiveness, and challenges and opportunities from various digital-based learning technologies.

4. METHODS

This study uses a qualitative paradigm with *a Systematic Literature Review (SLR)* approach to identify, evaluate, and synthesize the latest research findings related to digital technology-based learning innovations, with a special focus on the application of Artificial Intelligence (AI) in personalized learning (Chen et al., 2023). The SLR approach was chosen because it is able to provide a systematic, transparent, and tested analytical structure in assessing scientific evidence across studies (Holmes et al., 2019).

This review process follows the *guidelines of PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)* to ensure clarity, traceability, and validity in the process of selecting and analyzing literature (Kim & Lee, 2022) Although this SLR protocol is not officially registered in PROSPERO, all stages have been systematically documented in an internal protocol compiled based on the PRISMA standard. This protocol includes research questions, article selection criteria, data search strategies, and analytical approaches used in the synthesis process (Qian & Clark, 2021)

The scientific literature reviewed was collected from one major database, Scopus, which was chosen for its credibility in presenting indexed scientific publications in various disciplines, especially in the social and humanities domains.

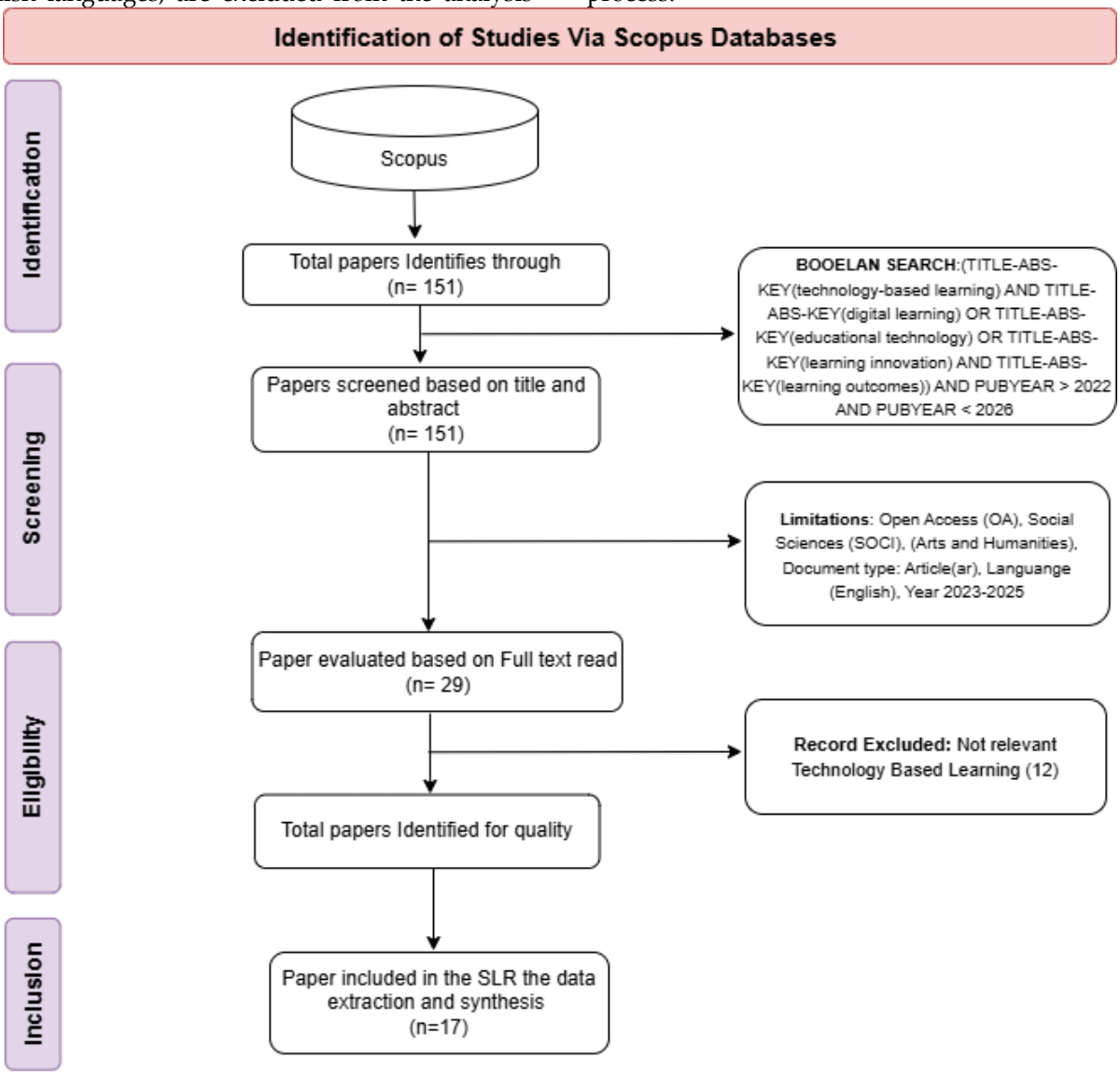
The search process is performed using *the following Booelan search string*: (TITLE-ABS-KEY(technology-based learning) AND TITLE-ABS-KEY(digital learning) OR TITLE-ABS-KEY(educational technology) OR TITLE-ABS-KEY(learning innovation) AND TITLE-ABS-KEY(learning outcomes)) AND PUBYEAR > 2022 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ARTS")) AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (LANGUAGE,"English")).

The inclusion criteria set in this study include empirical articles published in scientific journals (articles/journals), have *open access status*, are in English, and come from subjects in the field of social sciences and humanities (SOCI and ARTS).

The article should also explicitly examine the relationship between digital learning technologies (especially AI) and learning outcomes, particularly in the context of learning personalization.

Articles that do not meet these criteria, such as narrative reviews, editorials, or articles in non-

English languages, are excluded from the analysis process.



Picture 1: Prisma Diagram.

5. RESULT

Table 1: Main Data of The Selected Article.

No	Authors	Title	Year	Journal	Country	Author Affiliation	Subject/Educational Level
1	Xinyi Zhang, Hui Fang, & Li Chen	*Enhancing Preschool Spatial Skills: A Comprehensive Technology-Based Learning Approach*	2024	*Early Childhood Education Journal*	China	East China Normal University	Preschool / Early Childhood Education
2	Dwi Suryani, Rahmat Hidayat, & Intan Nurul Aini	*"Ajarin" Mobile: A Mobile Technology-Based Learning Application for Elementary Students*	2024	*International Journal of Interactive Mobile Technologies (IJIM)*	Indonesia	Universitas Negeri Malang	Elementary / Primary Education

3	Mary Grace L. Mendoza & Jonathan P. Reyes	*Effectiveness of MOOCs on Student Learning Engagement and Academic Achievement*	2024	*Asian Journal of Distance Education*	Philippines	University of the Philippines	Higher Education (College / University Level)
4	Rong-Ling Zhang, Shu-yu Yu, Rui-feng Gao, Li-fei Wang & Xiang-chun He	*How does technology-based embodied learning affect learning effectiveness? – Based on a systematic literature review and meta-analytic approach*	2025	*Interactive Learning Environments*	China & Canada	Lanzhou City University; Northwest Normal University; University of Waterloo	All Educational Levels (Meta-analysis)
5	Zainal Arifin & Budi Setiawan	*Advancing Curriculum and Instruction Course Model through Information Communication Technology towards Students' Learning Goals Completion: Motivation, Perspectives and Outcomes*	2025	*Educational Process: International Journal*	Indonesia	Universitas Pendidikan Indonesia	Graduate / Teacher Education
6	Thejasvi Sheshadri, Karthik Reddy, Jaladi Santosh Rupa, S. Selvi, S. Ramesh Babu, J. Bamini, T.A. Shwetha	*Analysing the Intersection of Education and Data Science: Enhancing Learning Outcomes through Information Systems – An Analytical Study*	2025	*Indian Journal of Information Sources and Services*	India	CMR University; Jain University; REVA University, etc	Higher Education / Data Science in Education
7	Mark Joreez A. Catubig, Ronnel Victor B. Kilat, Mia E. Laurito, Trisha Marie T. Patoc, Lislee C. Valle	*Visual Literacy in the Lived Experiences of BSED Students in Utilizing Canva*	2024	*Journal of Educational and Social Research*	Philippines	Cebu Technological University	Undergraduate / Pre-service Teachers
8	Nur Putri Hidayah, Galih Wasis Wicaksono, Amildun Amiluddin, Annisa Al Sakinata, Allysa Sonia Arcelia, Kiki Andesri, Siti Nurmala Lailatul Muafiqah, Meyza Maulidina Saleha	*Metaverse as The Solution to the Absence of a Constitutional Court Moot Courtroom in Universities*	2024	*Jurnal Pengabdian Hukum Indonesia*	Indonesia	Universitas Muhammadiyah Malang & Universitas Muhammadiyah Tangerang	University Law Students / Legal Education
9	Loukia David & Netta Weinstein	*Using Technology to Make Learning Fun: Technology Use is Best Made Fun and Challenging to Optimize Intrinsic Motivation and Engagement*	2024	*European Journal of Psychology of Education*	Greece / UK	University of Reading	Students aged 9–16 (Primary to Secondary Education)

10	Iqbal Faza Ahmad, Farida Agus Setiawati, Rani Putri Prihatin, Qonitah Faizatul Fitriyah, Zulkifli Syauqi Thontowi	*Technology-based learning effect on the learning outcomes of Indonesian students: a meta-analysis*	2024	*International Journal of Evaluation and Research in Education (IJERE)*	Indonesia	Universitas Negeri Yogyakarta; UIN Sunan Kalijaga; Universitas Muhammadiyah Surakarta; Universitas Nahdlatul Ulama Purwokerto	Elementary to Higher Education
11	Malika Knissarina,Aigul Syzdykbayeva, Yelena Agranovich, Gulmira Zhumaliyeva, Aigerim Baikulova.	*Impact of Practice-Centered Learning on the Development of Students' Professional Competence*	2024	Journal of Education and e-Learning Research	Asia	Kazakhstan University	Higher Education professional education & practice-centered learning
12	Oriza Candra, Doni Tri Putra Yanto, Hastuti, Jelpapo Putra Yanto, Juli Sardi, Merita Yanita, Hermi Zaswita, and Maryatun Kabatiah	*E-Worksheets with Augmented Reality Technology in Learning Science*	2024	International Journal of Information and Education Technology	Indonesia	Universitas Negeri Padang	Secondary/High School- Science education using AR worksheets
13	Walton Wider, Nazrin Ahmad, Fairrul Kadir, Syed Sharizman Syed Abdul Rahim, Hamidah Hassan, Leilei Jiang, Thitaree Srihawech	*The validation of a smart CPR training module: The preliminary process of a technology-based CPR training approach*	2024	*Journal of Infrastructure, Policy and Development*	Malaysia,Thailand	INTI International University, Universiti Malaysia Sabah, Universiti Tunku Abdul Rahman, Shinawatra University	Healthcare training – validation of digital CPR training module
14	Murielle El Hajj, Hiba Harb	*Rethinking Education: An In-Depth Examination of Modern Technologies and Pedagogic Recommendations*	2023	*Rethinking Education: An In-Depth Examination of Modern Technologies and Pedagogic Recommendations*	Qatar	Lusail University	K–12 and Higher Education – educational technology and TPCK framework
15	Javier del Olmo-Muñoz, José Antonio González-Calero, Pascual D. Diago, David Arnau, Miguel Arevalillo-Herráez	*Intelligent Tutoring Systems for Word Problem Solving in COVID-19 Days: Could They Have Been (Part of) the Solution*	2023	*ZDM – Mathematics Education*	Spain	University of Castilla-La Mancha, University of Valencia	Mathematics education secondary & higher education using AI tutoring
16	Sri Gunawan, Chich-Jen Shieh	*Enhancing Business Students' Self-Efficacy and Learning Outcomes: A Multiple Intelligences and Technology Approach*	2023	*Contemporary Educational Technology*	Indonesia, China	Universitas Airlangga; Hubei University of Automotive Technology	Higher Education – Business Administration students

17	Farid Ahmadi, Wahyu Hardyanto, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi, Iwan Sugihartono	*Developing Mobile Learning Application Containing Basic Pedagogy Material as the Supplement in Improving College Students' Learning Outcome in Teacher Training Institutes of Indonesia*	2023	*European Journal of Educational Research*	Indonesia	Universitas Negeri Semarang, Universitas Pendidikan Ganesha, Universitas Negeri Medan, Universitas Negeri Surabaya, Universitas Negeri Manado, Universitas Negeri Jakarta	Higher Education – Teacher Training Institutes (Pedagogy Course)

The results of the analysis of the distribution of publications by country show that Indonesia is the country with the highest number of contributions, which is as many as 7 publications. This shows the high interest and involvement of educational institutions in Indonesia in the development and implementation of digital technology-based learning innovations, both at the elementary and tertiary levels.

China is in second place with 2 publications, reflecting the country's rapid progress in the field of educational technology and research related to AI-based learning and immersive learning. This was followed by the Philippines which also contributed 2 publications, which described the active participation of higher education institutions in the country in the context of digital learning and student engagement.

Other countries such as India, Qatar, Spain, and Malaysia each contributed 1 publication, signaling that technology-based learning innovation is becoming a global focus that is not limited to just one region. Even some publications are collaborative between countries, such as between Malaysia and Thailand, or China and Canada, which show the trend of globalization and international collaboration in digital education research.

The dominance of contributions from Asian countries shows that the region is experiencing significant growth in the adoption and innovation of learning technologies, as well as becoming a center for experimentation and development of new approaches to technology-based learning.

Table 2: Number Of Contributions Per Country.

Country	Number of Publications
Indonesia	7
China	2
Philippines	2
India	1
Greece	1
Asia	1
Malaysia	1
Qatar	1
Spain	1

5.1 Research Trends in Digital Technology-Based Learning Innovation

In the last five years, especially 2023-2025, research on digital technology-based learning innovations has increased rapidly and shows a more mature direction. Studies in this period have explored the application of *Artificial Intelligence* (AI), *Augmented Reality* (AR), *Virtual Reality* (VR), gamification, *mobile learning*, and *blended learning* to improve learning outcomes and student motivation (Catubig et al., 2024b; David & Weinstein, 2024; Wider et al., 2024). Early research focused on the development of interactive digital media, while subsequent years showed an evolution towards an adaptive, data-based, and personalized learning experience learning system (Ahmad, Iqbal Faza et al., 2024; Candra & Sardi, 2024; Knissarina, 2024; Wider et al., 2024).

Key themes that emerged include *AI tutoring* and *adaptive learning*, *AR/VR immersive learning*, gamification, *mobile* and *blended learning*, and *data-driven learning*. Research shows that technologies such as AR and VR significantly improve learning retention, while AI-based systems and *learning analytics* are able to personalize the learning process more effectively. In addition, the gamification

approach has been shown to increase student motivation and engagement, making learning more engaging and participatory (Zainal Arifin and Setiawan 2025; Mark Joreez Catubig et al. 2024; David and Weinstein 2024; Knissarina et al. 2024; Sheshadri et al. 2025).

Overall, current research directions reflect a shift from technological exploration to the adoption of smart, collaborative, and sustainable digital learning (Guo et al., 2025; Knissarina, 2024) 2023 marks an initial exploration period, 2024 focuses on intensive implementation through *Metaverse learning* and interactive simulations, while 2025 shows consolidation towards data-based learning systems and artificial intelligence (Farid Ahmadi, Wahyu Hardyanti, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi, 2020). This trend confirms that digital technology is no longer just a tool, but has become the foundation of a modern adaptive and future-oriented education ecosystem.

5.2 The Effectiveness of Digital Technology-Based Learning Innovations on Learning Outcomes

Over the past five years, research on digital technology-based learning innovations has shown strong evidence of its effectiveness in improving student learning outcomes at various levels of education. Various experimental studies and meta-analyses prove that the application of technologies such as *e-learning*, *Augmented Reality* (AR), *Virtual Reality* (VR), and *Technology-Based Embodied Learning* (TBEL) has a positive impact on the cognitive, affective, and psychomotor aspects of students. The results of the meta-analysis showed *an Effect Size* of 1.285 ($p < 0.001$), while *SMD* 0.41 ($p < .01$) according to Cohen's scale, indicates a large effect, demonstrating a significant impact on learning outcomes, that digital learning is effective in various contexts and has the potential to expand the equitable distribution of education quality. (Gao & Zhang, 2024)

The effectiveness of this innovation is strongly seen in the context of hands-on, interactive experiential learning. The use of AR in *E-Worksheets* significantly increases students' motivation and concept understanding, while the *Smart CPR Training Module* based on a mobile application has succeeded in improving the psychomotor skills of trainees with high validity (Arifin & Setiawan, 2025) In addition, *the mobile learning* and *blended learning* approaches have also been proven to support learning flexibility and improve academic outcomes. A study and *application Ajarin Mobile* (2024) shows that this technology strengthens learning independence and active participation of students and students through adaptive and interactive learning (Ahmad, Iqbal Faza et al., 2024)

From the pedagogical side, the integration of *Technological Pedagogical Content Knowledge* (TPCK), gamification, and *Technology-Enriched Environment* approaches shows positive results on motivation, creativity, and learning outcomes (Presser et al., 2025) The importance of personalization and online collaboration in increasing learning engagement (Gunawan, 2023; M. El Hajj, 2023) Factors such as intervention design, teacher support, and technological readiness have proven to be determinants of digital learning success. Overall, educational technology innovations have evolved into a more interactive, adaptive, and purposeful learning experience-oriented approach, driving the transformation of education towards a more effective and inclusive system.

5.3 Challenges And Opportunities in The Implementation Of Digital Technology-Based Learning Innovations

Based on the results of studies from various studies in 2023-2025, the implementation of digital technology-based learning innovations faces a number of fundamental challenges that are structural, technological, and pedagogical, while opening up great opportunities for educational transformation in the digital era thematic analysis of data shows that the main challenges can be grouped into three major themes, namely access to technology and infrastructure, digital literacy of educators and students, and policy support and institutional readiness (Abhishek, 2025; Gunawan, 2023; Presser et al., 2025) On the other hand, key opportunities have emerged from technological advancements such as adaptive AI, AR/VR and Metaverse-based immersive learning, as well as the development of educational data analytics that enable more personalized and evidence-based learning systems.

5.3.1 Challenges In Implementing Digital Technology-Based Learning Innovations

The application of digital technology in education still faces a number of significant obstacles. The study noted that *e-learning* and ICT-based learning showed a large effect on learning outcomes (*ES = 1,285; p < 0.001*) according to Cohen's scale, indicates a large effect, demonstrating a significant impact on learning outcomes, their implementation was still hampered by digital disparities and infrastructure limitations in

regional schools. The same was found that, although e-learning has been shown to have a major impact on learning outcomes, infrastructure limitations and high costs are the main barriers to the implementation of advanced technologies such as *Metaverse-based Virtual Simulation* (Ahmad et al., 2024; Hidayah et al., 2024).

In addition, the readiness and competence of teachers in managing digital learning is also a determining factor for the success of educational innovation. Research shows that the effectiveness of *ICT-based blended learning* is highly dependent on the ability of teachers to design and utilize learning technology (Arifin & Setiawan, 2025) Similar findings found that low students' digital literacy also limits the effectiveness of the use of digital platforms such as Canva and mobile-based training applications (Catubig et al., 2024b) Meanwhile, it emphasized the importance of strengthening digital capacity for both educators and students (Abhishek, 2025; Arifin & Setiawan, 2025; Candra et al., 2024; Catubig et al., 2024b; Knissarina, 2024; Sheshadri et al., 2025; Wider et al., 2024; R. Zhang et al., 2025). This condition shows the need to strengthen digital capacity for both teachers and students so that technology can be used optimally (Farid Ahmadi, Wahyu Hardyanti, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi, 2020; Gunawan, 2023; Muñoz et al., 2023).

The next challenge is related to education policies and institutional readiness that have not yet fully supported digital transformation (Muñoz et al., 2023) The gap between teachers, infrastructure, and policies has an impact on the low integration *of Technological Pedagogical Content Knowledge* (TPCK) in learning practices (Ahmad, Iqbal Faza et al., 2024; M. E. El Hajj & Harb, 2023) In addition, although *blended learning* has been proven to increase motivation and learning outcomes, curriculum unpreparedness and weak policy support are the main obstacles (Ahmad, Iqbal Faza et al., 2024; Catubig et al., 2024b; David & Weinstein, 2024; Knissarina et al., 2024)

In addition, differences in research design and methodology also led to variations in the results of digital learning effectiveness, noting the heterogeneity of results and weaknesses of experimental design in *Technology-Based Embodied Learning (TBEL) studies* which resulted in large variations in learning outcomes (Farid Ahmadi, Wahyu Hardyanti, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi, 2020; Gunawan, 2023; M. El Hajj, 2023; Muñoz et al., 2023; Wider et al., 2024; R.-L. Zhang et al., 2025). Differences in research design and methodology in Technology-Based Embodied Learning (TBEL) learning led to significant variations in learning outcomes.

5.3.2 Opportunities For the Implementation of Digital Technology-Based Learning Innovations

The development of artificial intelligence (AI) presents a great opportunity for the creation of personalized, adaptive, and data-based learning systems. *The Intelligent Tutoring System* (ITS) has been proven to be effective in improving students' problem-solving abilities and learning independence (del Olmo-Muñoz et al., 2023) Furthermore, the integration of *machine learning* and *data analytics* also allows accurate prediction of academic achievement and supports *an efficient and evidence-based* adaptive learning system (Sri Gunawan, 2023)

In addition, according to (Sari et al., 2023) immersive technologies such as *Augmented Reality* (AR), *Virtual Reality* (VR), and *the Metaverse* are able to enrich learning experiences through contextual simulations and multidimensional interactions through an analysis of 44 studies found that *Technology-Based Embodied Learning* (TBEL) provides a significant improvement in learning outcomes (SMD = 0.41, $p < .01$) according to Cohen's scale, indicates a large effect, demonstrating a significant impact on learning outcomes, with a great opportunity for the development of *multidimensional embodied cognition*. In addition, studies show that *Technology-Based Embodied Learning* (TBEL) provides a significant improvement in learning outcomes and encourages the formation of *more complex* embodied cognition (Hidayah et al., 2024) In the context of higher education, the use of *the Metaverse* has been proven to increase student collaboration and participation, expanding learning spaces to a more inclusive virtual realm (Ahmad, Iqbal Faza, Prihatin, and Fitriyah 2024; David and Weinstein 2024; Knissarina 2024; Knissarina et al. 2024).

The use of *data science* and *learning analytics* is also a strategic opportunity to support *evidence-driven decision-making* in educational institutions. This approach allows for the personalization of learning and real-time monitoring of student progress (Lewis-Presser et al., 2025) Furthermore, digital innovation also encourages curriculum transformation and the improvement of digital competencies (Oriza Candra and Sardi 2024; M. Wider et al. 2024). The implementation of *ICT-based blended learning* increases creativity and motivation to learn, while the use of platforms like Canva strengthens visual literacy and creativity in the 21st century. Showing

that the implementation of *ICT-Based Blended Learning* is able to increase the creativity, interactivity, and learning motivation of lecturers and students, as well as encourage the transformation of the national digital curriculum (Arifin & Setiawan, 2025)

When viewed from the quality of the evidence based on the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach, the level of confidence in the effectiveness of these opportunities and challenges is in the medium to high category. Meta-analytic evidence has strong validity because it is supported by cross-study data and comprehensive quantitative analysis, while qualitative studies according to provide an in-depth understanding of social and pedagogical contexts (Ahmadi et al., 2023; Catubig et al., 2024a, 2024b; Granello et al., 2025; Hwang et al., 2023; Ronnel Victor Kilat, Mark Joreez Catubig, Lislee Valle, 2024) Based on the GRADE approach, the level of confidence in the effectiveness of digital learning innovation opportunities and challenges is in the medium to high category. Meta-analytical evidence supported by cross-study data and comprehensive quantitative analysis has strong validity, while qualitative studies provide a deeper understanding of the social context.

6. DISCUSION

The results of this study show that in the period 2023-2025, digital technology-based learning innovations have experienced a significant surge, both in terms of the number of publications and the depth of empirical findings. Technological developments such as Artificial Intelligence (AI), Augmented Reality/Virtual Reality (AR/VR), gamification, and mobile and blended learning have a positive impact on student learning outcomes, motivation, and engagement. Empirical evidence such as Effect Size (ES) = 1.285 for e-learning and Standardized Mean Difference (SMD) = 0.41 for Technology-Based Embodied Learning, that digital innovation is not just a tool, but has become a key factor in the transformation of pedagogy towards adaptive and experiential learning (Arifin & Setiawan, 2025; Deswita et al., 2025; Knissarina et al., 2024; Sheshadri et al., 2025).

These findings reinforce the *Experiential Learning* Theory (Kolb) and *Self-Determination Theory* (Deci & Ryan), which explain that hands-on learning experiences and intrinsic motivation play a big role in the success of digital learning. The integration of AR/VR and gamification creates an immersive learning environment, supporting active and participatory learning (Catubig et al., 2024b; David & Weinstein, 2024; Ronnel Victor Kilat, Mark Joreez Catubig, Lislee Valle, 2024; Wider et al., 2024). Meanwhile, AI and learning analytics play an important role in personalizing learning, enabling adaptive systems that are able to tailor materials and methods based on individual abilities and needs (Raspopovic & Cvetanovic, 2022) Thus, the combination of these approaches creates a learning ecosystem that is not only efficient, but also inclusive and humanistic (Alsuwaida, 2025)

However, the successful implementation of this innovation still faces complex challenges (Ahmad, Iqbal Faza et al., 2024; M. El Hajj, 2023; Knissarina, 2024; Muñoz et al., 2023). Digital infrastructure gaps, low technological literacy of teachers and students, and limited education policies are the main factors that hinder the equitable distribution of the effectiveness of learning technology. Emphasizing that educator readiness and institutional support are important prerequisites in ensuring the sustainability of education digitalization (Arifin & Setiawan, 2025; M. El Hajj, 2023) In addition, variations in study design and lack of longitudinal studies give rise to heterogeneity of results, so long-term research is needed to strengthen the generalization of scientific evidence (Abhishek, 2025; Arifin & Setiawan, 2025).

Nevertheless, opportunities for the development of technology-based education are increasingly wide open (Candra & Sardi, 2024; Farid Ahmadi, Wahyu Hardyanti, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi, 2020; R. Zhang et al., 2025). Adaptive AI has the potential to create a more personalized and data-driven learning system, while AR/VR and Metaverse offer a multisensory learning experience that brings theory closer to practice (Oriza Candra and Sardi 2024; Farid Ahmadi, Wahyu Hardyanti, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi 2020; Sari et al., 2023) The use of *learning analytics* and *data-driven decision making* also provides opportunities for teachers and policymakers to design more targeted educational interventions. On the other hand, curriculum transformation and the improvement of digital literacy in the 21st century are important strategies to ensure that learners are not only users of technology, but also knowledge creators in the global digital ecosystem (Oudbier et al., 2024).

Conceptually, these findings confirm that digital technology-based learning innovations are a key pillar in the formation of a smart, collaborative, and sustainable future education system (Abhishek, 2025;

Gunawan, 2023; Presser et al., 2025) In order for the positive impact to be maximized, synergy is needed between technology development, education policies, and human resource readiness. Collaboration between researchers, educators, and policy makers is key to ensuring that digital transformation in education not only improves learning outcomes, but also ensures equitable access and justice in obtaining technological benefits for all students (Gunawan, 2023; M. El Hajj, 2023).

7. CONCLUSION

This study shows that in the last five years (2021-2025) there has been a rapid increase in research and implementation of digital technology-based learning innovations, marking the transformation of education towards a more interactive, adaptive, and data-based system. Research trends are shifting from the use of technology as a pandemic emergency solution to permanent integration in modern educational design. The main focus of the research includes Artificial Intelligence (AI), Augmented/Virtual Reality (AR/VR), gamification, mobile learning, blended learning, and learning analytics, which have been proven to increase the effectiveness, motivation, and flexibility of learning across educational levels. Empirically, digital innovation has a large to moderate influence on learning outcomes. E-learning and ICT showed *a high effect size* (ES = 1,285), while *Technology-Based Embodied Learning* (TBEL) showed a significant improvement in conceptual understanding and retention. AI technology and *Intelligent Tutoring Systems* (ITS) have also been proven to improve problem-solving skills and learning independence.

However, challenges still arise in the form of infrastructure gaps, low digital literacy of educators and students, and lack of policy and institutional preparedness. Even so, great opportunities open up through adaptive AI, immersive AR/VR technology, *learning analytics*, and digital curriculum transformation to strengthen creativity and competence in the 21st century. Based on the GRADE approach, the level of confidence in the effectiveness of educational technology is in the medium to high category. Overall, digital learning innovations have evolved into a smart and sustainable education ecosystem, with a future that demands close collaboration between researchers, educators, and policymakers to ensure that its implementation is inclusive, ethical, and effective.

REFERENCES

Abhishek, N. (2025). *Effectiveness of MOOCs on learning efficiency of students : a perception study*. *18*(1), 145–164. https://doi.org/10.1108/JRIT-12-2022-0091

Ahmad, Iqbal Faza, F. A., Prihatin, R. P., & Fitriyah, Q. F. (2024). Technology-based learning effect on the learning outcomes of Indonesian students : a meta-analysis. *Jurnal Internasional Evaluasi Dan Penelitian Dalam Pendidikan (IJERE)*, *13*(2), 892–902. https://doi.org/10.11591/ijere.v13i2.25383

Ahmad, I. F., Setiawati, F. A., Prihatin, R. P., Fitriyah, Q. F., & Thontowi, Z. S. (2024). No Title. *International Journal of Evaluation and Research in Education*. https://doi.org/10.11591/ijere.v13i2.25383

Ahmadi, F., Hardyanto, W., Pramono, S. E., Sugiarta, I. M., Syahputra, H., Kristanto, A., Parinsi, M. T., & Sugihartono, I. (2023). No Title. *European Journal of Educational Research*. https://doi.org/10.12973/eu-jer.12.1.213

Almahasees, Z., & Qudah, M. F. (2023). Students' perceptions of online learning and the challenges faced during COVID-19 pandemic. *Education and Information Technologies*, *28*(1), 45–63.

Alsuwaida, N. (2025). No Title. *SAGE Open*. https://doi.org/10.1177/21582440251350748

Anderson, T., & Dron, J. (2022). Three generations of distance education pedagogy. *International Review of Research in Open and Distance Learning*, *23*(4), 67–88.

Arifin, Z., & Setiawan, B. (2025). *Advancing Curriculum and Instruction Course Model through Information Communication Technology towards Students ' Learning Goals Completion : Motivation , Perspectives and Outcomes*. *16*.

Aysi, S. A. H., Susilaningsih, & Sabandi, M. (2024). The Implementation of Digital Entrepreneurship Learning in Higher Education: A Systematic Literature Review. *Pedagogia : Jurnal Pendidikan*. https://doi.org/10.21070/pedagogia.v13i2.1692

Azzahrowaini, L., Shohib, M. W., & Maksum, M. N. R. (2025). Digitalisasi Pembelajaran Tahfidz Al-Qur'an Berbasis AI Dalam Inovasi Tantangan Dan Implementasi. *Educatio*, *20*(2), 253–265. https://doi.org/10.29408/edc.v20i2.30044

Bower, M., & Jong, M. S. Y. (2021). Immersive virtual reality in education: A systematic review of research 2015–2020. *Computers & Education*, *169*.

Brown, T. H. (2020). The mobile learning imperative in education. *Journal of Interactive Media in Education*, *1*, 3–

15.
Cabanillas-García, J. L. (2023). Teacher Educational Innovation: A Systematic and Content Review. *2023 XIII International Conference on Virtual Campus (JICV)*. https://doi.org/10.1109/JICV59748.2023.10565674
Candra, O., & Sardi, J. (2024). *E-Worksheets with Augmented Reality Technology in Laboratory Learning : Examining Their Effectiveness on Students ' Learning Performance*. *14*(11), 1544–1553. https://doi.org/10.18178/ijiet.2024.14.11.2185
Candra, O., Yanto, D. T. P., Hastuti, u., Yanto, J. P., Sardi, J., Yanita, M., Zaswita, H., & Kabatiah, M. (2024). No Title. *International Journal of Information and Education Technology*. https://doi.org/10.18178/ijiet.2024.14.11.2185
Catubig, M. J. A., Kilat, R. V. B., Laurito, M. E., Patoc, T. M. T., & Valle, L. C. (2024a). No Title. *Journal of Educational and Social Research*. https://doi.org/10.36941/jesr-2024-0090
Catubig, M. J. A., Kilat, R. V. B., Laurito, M. E., Patoc, T. M. T., & Valle, L. C. (2024b). *Visual Literacy in the Lived Experiences of BSED Students in Utilizing Canva*. 117–131.
Chen, L., Chen, T., & Lin, J. (2023). Personalized Learning Path Recommendation Based on Knowledge Graph and Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *4*, 100102. https://doi.org/10.1016/j.caeai.2023.100102
Chiang Liang Kok, Yit Yan Koh, C. K. H., & Tee Hui Teo, C. L. (2024). Enhancing Learning: Gamification and Immersive Experiences with AI. *TENCON 2024 - IEEE Region 10 Conference*. https://doi.org/10.1109/TENCON61640.2024.10902870
David, L., & Weinstein, N. (2024). Using technology to make learning fun : technology use is best made fun and challenging to optimize intrinsic motivation and engagement. *European Journal of Psychology of Education*, *39*(2), 1441–1463. https://doi.org/10.1007/s10212-023-00734-0
De-Marcos, L., & Garcia-Lopez, E. (2023). Social network analysis of a gamified e-learning course: Small-world phenomenon and network metrics as predictors of academic performance. *Computers & Education*, *180*.
Dede, C. (2020). The evolution of learning technologies: Past, present, and future. *EDUCAUSE Review*, *55*(3), 10–19.
del Olmo-Muñoz, J., González-Calero, J. A., Diago, P. D., Arnau, D., & Arevalillo-Herraéz, M. (2023). No Title. *ZDM - International Journal on Mathematics Education*. https://doi.org/10.1007/s11858-022-01396-w
Deswita, H., Japar, M., & Solihatin, E. (2025). *"Ajarin" mobile: A mobile technology -based learning application to improve students' mathematical understanding*. *14*(2), 349–368.
Dika Ayu Pradana, N. L. I. (2021). Problematika Pembelajaran Tahfidz Al-Qur'an pada Masa Pandemi Covid 19 di SMP Muhammadiyah 9 Gemolong Sragen. *Tajdida*, 30.
Dmitrieva, T. (2020). Digital Learning of Mathematics for Engineering Students: Preliminary Experience. *Russian Digital Libraries Journal*. https://doi.org/10.26907/1562-5419-2020-23-1-2-36-48
Dwivedi, Y. K., Hughes, L., & Coombs, C. (2023). Artificial intelligence for education: Opportunities, challenges, and implications. *Information Systems Frontiers*, *25*(2), 335–352.
El Hajj, M. E., & Harb, H. (2023). No Title. *IAFOR Journal of Education*. https://doi.org/10.22492/ije.11.2.05
Farid Ahmadi, Wahyu Hardyanti, Suwito Eko Pramono, I Made Sugiarta, Hermawan Syahputra, Andi Kristanto, Mario Tulenan Parinsi, I. S. (2020). Developing Mobile Learning Application Containing Basic Pedagogy Material as the Supplement in Improving College Students' Learning Outcome in Teacher Training Institutes of Indonesia. *European Journal of Educational Research*, *12*(1), 213–227.
Febriandika, N. R., Ihsan, M. Z. N., Inayati, N. L., & Ramadhan, A. R. (2024). Determinants of students' learning motivation in Islamic boarding schools: A structural equation modeling approach. *International Journal of ADVANCED AND APPLIED SCIENCES*, *11*(11), 10–18. https://doi.org/10.21833/ijaas.2024.11.002
Gao, L., & Zhang, Y. (2024). Virtual reality and augmented reality in STEM education: A meta-analysis. *Journal of Educational Computing Research*, *62*(1), 25–50.
García-Peñalvo, F. J. (2023). The future of learning: A vision for the next decade of digital education. *Journal of Universal Computer Science*, *29*(8), 975–990.
Gatsakou, E., & Bardis, N. (2025). Redefining experiential learning: AI-Driven Virtual Reality (VR) Role Playing Games (RPGs) for personalized learning in Education. *World Journal of Advanced Engineering Technology and Sciences*. https://doi.org/10.30574/wjaets.2025.15.1.0257
Granello, F., Cuder, A., Doz, E., Pellizzoni, S., & Passolunghi, M. C. (2025). Enhancing mathematics self-efficacy and mathematics self-concept in secondary schools: a narrative systematic review. *European Journal of Psychology of Education*. https://doi.org/10.1007/s10212-025-00939-5

Gunawan, S. (2023). *Enhancing business students ' self-efficacy and learning outcomes : A multiple intelligences and technology approach*. *15*(4).

Guo, W., Wang, X., Ma, Y., Song, Y., Chang, L., Wu, H., Li, G., Xi, S., Wang, X., Gan, L., Jiang, Q., Xia, C., Zhao, S., Guo, Z., Wang, Z., Tang, B. Z., & Ye, R. (2025). Local Coordination-Dependent CO 2 Reduction Activity of Bimetallic Cu ─ Al Catalysts for Selective Ethylene / Ethanol Electrosynthesis. *Angewandte International Education*, 2–11. https://doi.org/10.1002/anie.202520291

Hajj, M. El. (2023). *Rethinking Education : An In-Depth Examination of Modern Technologies and Pedagogic Recommendations*. *11*(2), 97–113.

Hamari, J., & Koivisto, J. (2022). Measuring flow and immersion in gamified learning. *Computers in Human Behavior*, *132*, 106–115.

Hanli, N., Zhang, A., & Huang, X. (2024). Unraveling the Motivational Tapestry of AI-Driven Gamification in Education. *International Journal of Global Perspectives in Academic Research*. https://doi.org/10.70339/znd1nk22

Hew, K. F., & Lo, C. K. (2021). Flipped classroom improves student learning performance in higher education: A meta-analysis. *Educational Research Review*, *33*.

Hidayah, N. P., Wicaksono, G. W., Amiludin, A., Sakinata, A. A., Arcelia, A. S., Andesti, K., Muafika, S. N. L., & Saleha, M. M. (2024). No Title. *Jurnal Pengabdian Hukum Indonesia*. https://doi.org/10.15294/jphi.v7i2.2477

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign.

Hwang, & Lai. (2021). Facilitating and bridging out-of-class and in-class learning: An interactive e-book-based flipped learning approach for math courses. *Educational Technology & Society*, *24*(3), 187–204.

Hwang, N.-K., Shim, S.-H., & Cheon, H.-W. (2023). No Title. *BMC Medical Education*. https://doi.org/10.1186/s12909-022-03955-x

Inayati, N. L., & Saputri, I. D. (2025). Evaluating the Affective Domain in Al-Islam and Muhammadiyah Learning: Methods, Challenges, and Technology-Based Solutions in Muhammadiyah Schools. *AL-ISHLAH: Jurnal Pendidikan*, *17*(3), 4356–4367. https://doi.org/10.35445/alishlah.v17i3.6870

Kim, J., & Lee, M. (2022). Augmented reality-based learning for science education: A review of empirical studies. *British Journal of Educational Technology*, *53*(2), 398–412.

Kimmons, R. (2023). Open educational practices and change in higher education: A framework for research and practice. *Educational Technology Research and Development*, *71*(1), 95–114.

Knissarina, M. (2024). *Impact of practice-centered learning on the development of students ' professional identities : Learning outcomes*. *11*(1), 97–106. https://doi.org/10.20448/jeelr.v11i1.5344

Knissarina, M., Syzdykbayeva, A., Agranovich, Y., Zhumaliyeva, G., & Baikulova, A. (2024). Impact of practice-centered learning on the development of students' professional identities: Learning outcomes. *Journal of Education and E-Learning Research*, *11*(1), 97–106.

Latifatul Inayati, N., & Rohmani, A. F. (2025). Bibliometric Analysis of Religious Education Systems in Schools: Trends, Themes, and Future Directions. *Multicultural Islamic Education Review*, *3*(1), 105–120. https://doi.org/10.23917/mier.v3i1.10333

Lee, L.-K., Cheung, S. K. S., Wang, F. L., Chui, K. T., Fung, Y.-C., Lu, A., Hui, Y. K., Hao, T., U, L. H., & Wu, N.-I. (2023). Design of Serious Games for Blended Learning: Virtual Reality or Augmented Reality? *2023 International Symposium on Educational Technology (ISET)*. https://doi.org/10.1109/iset58841.2023.00048

Lewis-Presser, A. E., Braham, E., & Vidiksis, R. (2025). No Title. *Education Sciences*. https://doi.org/10.3390/educsci15060727

Li, H., Ke, N., Zhang, A., & Huang, X. (n.d.). *International Journal of Global Perspective in Academic Research Unr aveling the Motivational Tapestr y of AI-Dr iven Gamification in Education*.

Liang, D. (2020). On the Development of the Industry Trend of "Ai+Education." *International Conference on Artificial Intelligence and Education*. https://doi.org/10.1007/978-3-030-62746-1_117

Lim, C. P., & Wang, L. (2024). Exploring the potential of AI for supporting teacher professional learning. *British Journal of Educational Technology*, *55*(1), 50–66.

Linda Marie Ahl, Ola Helenius, Mario Sánchez Aguilar, Uffe Thomas Jankvist, Morten Misfeldt, J. P. (2023). Implementation Research in Mathematics Education: A Systematic Mapping Review. *Implementation and Replication Studies in Mathematics Education*, *3*, 1–65. https://doi.org/10.1163/26670127-bja10015

Liu, D., & Santhanam, R. (2023). Digital learning effectiveness: The role of gamification and interactivity. *Information & Management*, *60*(2), 103482.

Mahendra, J. W., Maghfiroh, A., Harmanto, B., & Sudirman, R. (2024). Research Trends of Digital Literacy in English Language Learning: a Systematic Literature Review. *Edulib*. https://doi.org/10.17509/edulib.v14i1.60790

Marappan, R., & Saraswatikaniga, R. (2024). Emerging Technologies in Online Learning with New Trends and Analysis. *2024 International Conference on Electronics, Computing, Communication and Control Technology (ICECCC)*. https://doi.org/10.1109/ICECCC61767.2024.10593832

Martin, F., & Sun, T. (2022). Examining student engagement in online learning: A meta-analysis. *Online Learning Journal*, *26*(1), 45–70.

Mohamed, A., Faisal, R., & Shaalan, K. (2024). Exploring the Impact of AI-Driven Virtual Assistants in AR and VR Environments for Special Needs Education: A Quantitative Analysis. In *Lecture Notes in Networks and Systems*. https://doi.org/10.1007/978-3-031-71713-0_8

Muñoz, O., Antonio, J., Calero, G., Diago, P. D., Arnau, D., & Herráez, M. A. (2023). Intelligent tutoring systems for word problem solving in COVID - 19 days : could they have been (part of) the solution ? *ZDM – Mathematics Education*, *55*(1), 35–48. https://doi.org/10.1007/s11858-022-01396-w

Nan Xiao, Yuting Pei, Chunhong Yuan, Yujia Bu, Z. C. (2024). Transforming education with artificial intelligence: Applications and challenges. *Educational Technology & Society*, *27*(1), 52–68. https://doi.org/10.70693/itphss.v2i1.211

Nguyen, T., & Gardner, L. (2023). The role of learning analytics in adaptive learning systems. *Computers & Education*, *185*.

Oudbier, J., Verheijck, E., van Diermen, D., Tams, J., Bramer, J., & Spaai, G. (2024). No Title. *BMC Medical Education*. https://doi.org/10.1186/s12909-024-06466-z

Presser, A. E. L., Braham, E., & Vidiksis, R. (2025). *Enhancing Preschool Spatial Skills : A Comprehensive Intervention Using Digital Games and Hands-On Activities*.

Qian, M., & Clark, K. R. (2021). Game-based learning and 21st century skills: A review of recent research. *Computers in Human Behavior*, *110*, 106530.

Raspopovic, M., & Cvetanovic, S. (2022). Evaluating the effectiveness of e-learning systems in higher education. *Computers in Human Behavior*, *129*, 108131.

Rodrigues, H., & Costa, C. J. (2022). The adoption of e-learning systems in higher education: A systematic literature review. *Computers in Human Behavior*, *138*.

Romero, C., & Ventura, S. (2021). Data mining in education. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *11*(3), e1397.

Ronnel Victor Kilat, Mark Joreez Catubig, Lislee Valle, M. L. (2024). Visual Literacy in the Lived Experiences of BSED Students in Utilizing Canva. *Journal of Educational and Social Research*, *14*(4), 117–131.

Sari, R. C., Warsono, S., Ratmono, D., Zuhrohtun, Z., & Hermawan, H. D. (2023). The effectiveness of teaching virtual reality-based business ethics: is it really suitable for all learning styles? *Interactive Technology and Smart Education*, *20*(1), 19–35. https://doi.org/10.1108/ITSE-05-2021-0084

Sathish Kumar, Tamil Selvan, Dr. M.Mahendra Prabu, Dr. G.Kalaiyarasan, Dr.R.Ramnath, D. N. S. K. (2024). Examining the Role of Virtual Reality, Augmented Reality, and Artificial Intelligence in Adapting STEM Education for Next-Generation Inclusion. *International Journal of Emerging Knowledge Studies*, *2*(12), 876–883. https://doi.org/10.70333/ijeks-02-12-025

Setiawan, A. &. (2025). *Advancing Curriculum and Instruction through ICT*.

Sheshadri, T., Reddy, K., Rupa, J. S., & Selvi, S. (2025). *Analysing the Intersection of Education and Data Science : Enhancing Learning Outcomes through Information Systems -An Analytical Study*. *15*(1), 12–19.

Shohib, M. W., Azani, M. Z., Inayati, N. L., Dartim, D., & Nubail, A. (2024). Islamic Perspective on Organizational Citizenship Behavior Among Academic Staff in Indonesian State Islamic Higher Education: Is It Effective? *Suhuf*, *36*(2). https://doi.org/10.23917/suhuf.v36i2.4702

Singh, S., Akbani, I., & Dhir, S. (2020). Service innovation implementation: a systematic review and research agenda. *The Service Industries Journal*. https://doi.org/10.1080/02642069.2020.1731477

Singh, & Thurman. (2020). How many ways can we define online learning? A systematic literature review. *American Journal of Distance Education*, *34*(4), 289–306.

Srdanović, P., Skala, T., & Maričević, M. (2024). InHeritage—A Gamified Mobile Application with AR and VR for Cultural Heritage Preservation in the Metaverse. *Applied Sciences*.

https://doi.org/10.3390/app15010257
Sri Gunawan, C. J. S. (2023). Enhancing business students' self-efficacy and learning outcomes: A multiple intelligences and technology approach. *Contemporary Educational Technology*, *14*(4), 1–15. https://doi.org/10.30935/cedtech/13647
Sun, P. C., & Tsai, R. J. (2021). What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education*, *178*.
Sung, Y. T., & Chang, K. E. (2021). Mobile-device-supported learning for students with special needs: A review. *Computers & Education*, *157*.
Trihariyanto, S., Supriyanto, E., Muthoifin, M., & 'Uyun, Z. (2020). Strategi Pembelajaran Inovatif Pendidikan Agama Islam Dengan Media Powerpoint Dalam Meningkatkan Mutu Pendidikan Di Sdit Muhammadiyah Sinar Fajar Cawas Dan Sd Muhammadiyah Pk Bayat. *Profetika: Jurnal Studi Islam*, *21*(1), 109–120. https://doi.org/10.23917/profetika.v21i1.11653
Veletsianos, G. (2022). Learning online: The student experience in higher education. *Routledge Studies in Digital Education and Learning*.
Wang, S., & Fang Wang, Zhen Zhu, Jingxuan Wang, Tam Tran, Z. Du. (2023). Artificial intelligence in education: A critical review of emerging evidence. *Computers & Education: Artificial Intelligence*, *5*.
Wang, Y., & Hsu, T. (2023). Using augmented reality to enhance learning engagement: A meta-analysis. *Journal of Computer Assisted Learning*, *39*(4), 1015–1032.
Wider, W., Ahmad, N., Kadir, F., Sharizman, S., Abdul, S., Hassan, H., Jiang, L., & Srihawech, T. (2024). *The validation of a smart CPR training module : The preliminary process of a technology-based CPR training approach*. *8*(9), 1–17.
Yusuf, A. M. (2025). Trends, Opportunities, and Challenges of Artificial Intelligence in Elementary Education - A Systematic Literature Review. *Journal of Integrated Elementary Education*. https://doi.org/10.21580/jieed.v5i1.25594
Zhang, R.-L., Yu, S.-Y., Gao, R.-F., Wang, L.-F., & He, X.-C. (2025). Koordinasi Lokal-Tergantung CO 2 Aktivitas Reduksi BimetalikCu─Katalis Al untuk Elektrosintesis Etilen/Etanol Selek. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2025.2479176
Zhang, R., Yu, S., Gao, R., Wang, L., & He, X. (2025). How does technology-based embodied learning affect learning effectiveness ? – Based on a systematic literature review and meta-analytic approach. *Interactive Learning Environments*, *33*(6), 4135–4158. https://doi.org/10.1080/10494820.2025.2479176
Zhao, Y., & Chen, X. (2023). Blended learning effectiveness and student satisfaction in higher education: A meta-analysis. *Educational Technology Research and Development*, *71*(3), 1265–1284.
Zhou, G. (2024). Navigating the Future Landscape of Gamified Education. *SHS Web of Conferences*. https://doi.org/10.1051/shsconf/202418702005