JTBC:Jurnal Teknologi dan Bisnis Cerdas
Volume 1 Nomor 3, Desember 2025
e-ISSN : 3109-8924
DOI: 10.64476/jtbc.v1i3.20

THE USE OF WEB TECHNOLOGY FOR ADAPTIVE E-LEARNING SYSTEMS IN EDUCATION

PENGGUNAAN TEKNOLOGI WEB UNTUK SISTEM E-LEARNING ADAPTIF DI PENDIDIKAN

Novita Kunia Wahyu [1*], Nurhalima [2], Nurazizah [3], Sardiansyah Sabir [4], Abdillah Sirfanal Hak [5], Muh. Alfarizi Asbir [6]
Universitas Muhammadiyah Kolaka Utara, Lasusua, Indonesia [1,2,3,4,5,6]
novitakunianovi@gmail.com [1*], anjg0838@gmail.com [2], nurazizahnas@gmail.com [3], sardiansyahsabir@gmail.com [4], abdillahsirfanalhak25@gmail.com [5], alfaralfar109@gmail.com [6]

ABSTRACT

The development of web technology has accelerated the adoption of adaptive e-learning systems; however, existing literature indicates variations in approaches, limited integration of artificial intelligence, and a lack of comprehensive mapping of research trends in this field. This study conducts a Systematic Literature Review of 20 studies published between 2020 and 2025 to identify developments, challenges, and opportunities in web-based adaptive e-learning. The findings reveal that the integration of machine learning, learning analytics, and content personalization techniques is increasingly implemented and has been shown to improve learner engagement and learning outcomes. Nevertheless, many studies still focus primarily on higher education, have not fully optimized real-time analytics, and provide limited discussion on the need for ethical regulation of artificial intelligence. Specifically, this study identifies three major trends: (1) the integration of machine learning with real-time learning analytics, (2) more inclusive adaptive designs addressing diverse learner needs and learning styles, and (3) the growing urgency of ethical AI regulation in education. In addition, this review highlights research gaps in vocational and non-formal education, which remain underexplored. These findings provide directions for future research and recommendations for the development of more effective and sustainable web-based adaptive e-learning systems.

Keywords: *web technology, adaptive e-learning, systematic literature review, machine learning, learning analytics, artificial intelligence in education.*

ABSTRAK

Perkembangan teknologi web telah mempercepat adopsi sistem e-learning adaptif, namun literatur menunjukkan masih adanya variasi pendekatan, keterbatasan integrasi kecerdasan buatan, serta belum adanya pemetaan komprehensif mengenai tren riset di bidang ini. Penelitian ini melakukan *Systematic Literature Review* terhadap 20 studi terbitan 2020–2025 untuk mengidentifikasi perkembangan, tantangan, dan peluang pengembangan *e-learning* adaptif berbasis web. Hasil kajian menunjukkan bahwa integrasi machine learning, learning analytics, dan teknik personalisasi konten semakin umum diterapkan dan terbukti meningkatkan keterlibatan serta hasil belajar. Meski demikian, sebagian penelitian masih berfokus pada pendidikan tinggi, belum memanfaatkan analitik real-time secara optimal, dan minim pembahasan mengenai kebutuhan regulasi etika AI. Secara khusus, studi ini menemukan tiga tren utama, yaitu: (1) integrasi machine learning dengan learning analytics real-time, (2) desain adaptif yang lebih inklusif untuk beragam kebutuhan dan gaya belajar peserta didik, dan (3) urgensi regulasi etika kecerdasan buatan di bidang pendidikan, serta mengidentifikasi gap riset pada pendidikan vokasi dan non-formal yang masih jarang dieksplorasi. Temuan ini memberikan arah penelitian lanjutan serta rekomendasi bagi pengembangan sistem *e-learning* adaptif berbasis web yang lebih efektif dan berkelanjutan.

Kata Kunci: teknologi web, *e-learning* adaptif, *systematic literature review, machine learning, learning analytics*, kecerdasan buatan dalam pendidikan.

INTRODUCTION

The transformation of educational technology development over the past five years has shown a significant increase in the use of adaptive e-learning as a learning approach that adjusts materials, difficulty levels, and learning recommendations based on the characteristics and behaviors of each learner. This adaptive system is supported by artificial intelligence, machine learning, and learning analytics, enabling a more personalized learning experience. However, to strengthen the argument regarding its effectiveness, empirical findings from previous studies need to be presented. For example, El-Sabagh (2021) found that integrating adaptive learning systems can increase student engagement by up to 45% through the delivery of content tailored to learners' preferences. Similar findings were also reported by Essa et al. (2023), showing that machine learning–based adaptive learning can improve learners' levels of understanding because materials and recommended learning activities are automatically adjusted based on their performance. These two findings further confirm the potential of adaptive e-learning systems as an approach capable of improving both the learning process and learning outcomes.

Nevertheless, research on adaptive e-learning still faces several limitations. Some prior studies have focused primarily on higher education contexts, meaning that research at the elementary and secondary school levels remains very limited. In addition, many studies assess only short-term effectiveness without evaluating long-term impacts or the sustainability of adaptive system use. Another challenge is the lack of discussion regarding ethical issues, data security, and algorithmic transparency, even though these aspects are critical in the implementation of AI-based technologies. This condition indicates a substantial research gap, particularly related to variations in educational contexts, types of adaptation models, and the impacts of adaptive e-learning on motivation, engagement, and learning outcomes.

Given the growing research in this field yet with findings that remain fragmented, confined to specific contexts, and not providing a comprehensive picture of research directions a study is needed to systematically map trends, challenges, and research gaps. Therefore, this study conducts a Systematic Literature Review (SLR) of 20 articles published between 2020 and 2025 to identify the latest developments in adaptive e-learning, analyze empirical findings, categorize the approaches and technologies used, and map future challenges and development opportunities. In doing so, this SLR not only summarizes existing findings but also provides a research map that can serve as a foundation for further studies and for the future implementation of adaptive e-learning.

METHODS

This study employs a Systematic Literature Review (SLR) approach by referring to the PRISMA 2020 guidelines. This method aims to systematically identify, evaluate, and synthesize findings from previous studies relevant to the use of web technology in adaptive e-learning systems in the field of education. The SLR approach was selected because it can provide a comprehensive overview of research developments, trends, challenges, and opportunities in the field in a transparent and replicable manner.

The SLR process was conducted through three main stages identification, screening, and eligibility to ensure that the analyzed literature was highly relevant and met scientific quality standards.

The identification stage was carried out by searching for scholarly articles in reputable international databases. The literature search used relevant keywords combined with Boolean operators to obtain systematic and reproducible search results.

Table 1. Literature Search Strategy

Element	**Description**
Databases	Scopus; Web of Science; IEEE Xplore

Search String	("adaptive e-learning" OR "personalized learning") AND ("web technology" OR "machine learning" OR "learning analytics")
Publication Year Range	2020–2025
Language	English and Indonesian
Document Type	Peer-reviewed journal articles and conference proceedings

Based on the initial search, 35 articles related to the research topic were identified.

To ensure the quality and relevance of the literature, the retrieved articles were then selected using the following inclusion and exclusion criteria.

Table 2. Inclusion and Exclusion Criteria

Category	Criteria
Inclusion Criteria	Articles published in 2020–2025
	Peer-reviewed articles
	Discuss the application of web technology in adaptive e-learning
	Empirical studies or SLRs with system implementation
	Written in English or Indonesian
Exclusion Criteria	Duplicate articles
	Not focused on web-based adaptation in e-learning
	Theoretical reviews without implementation
	Empirical studies with sample size < 30
	Grey literature (theses, reports, or non–peer-reviewed documents)

After the screening stage based on these criteria, the number of articles that passed the selection process was reduced to 20.

The article selection followed the PRISMA 2020 flow. In the identification stage, 35 articles were retrieved from all databases. Next, during screening, duplicate and irrelevant articles were removed based on titles and abstracts. In the eligibility stage, the remaining articles were reviewed in full text based on the inclusion and exclusion criteria as well as methodological quality assessment. The final results showed that 20 articles met all criteria and were further analyzed in this study.

To ensure validity and scientific quality, a quality appraisal was conducted for the selected articles using the Critical Appraisal Tools from the Joanna Briggs Institute (JBI). This assessment aimed to ensure that the analyzed articles employed robust methodologies and produced accountable findings.

Table 3. Article Quality Appraisal Criteria (JBI)

Assessment Aspect	Indicator
Clarity of Objectives	Research objectives are stated explicitly
Study Design	The design is appropriate to the research objectives
Data Collection Methods	Methods are clearly and systematically described

Assessment Aspect	Indicator
Data Analysis	Analytical techniques are appropriate and justifiable
Validity of Findings	Results are supported by adequate data
Research Relevance	Contributions are relevant to web-based adaptive e-learning

Articles that did not meet at least 70% of the quality appraisal criteria were eliminated from the synthesis process.

The twenty articles that passed the quality appraisal were then analyzed using a thematic synthesis approach. The analysis focused on:

- The web technologies used
- Learning adaptation methods (AI, machine learning, learning analytics)
- Integration with Learning Management Systems (LMS)
- Impacts on learner engagement and learning outcomes

The synthesis results indicate that the use of artificial intelligence, learning analytics, and web-based personalization has become the dominant approach in the development of adaptive e-learning.

Based on the literature synthesis, a conceptual framework was formulated to describe the relationships among web technology, learning adaptation strategies, and user needs. This framework serves as the basis for developing a more effective, inclusive, and sustainable adaptive e-learning system.

RESULT AND DISCUSSION

In this study, the literature selection process was conducted systematically through several stages, beginning with an initial search that yielded thirty-five potentially relevant articles. The articles were then screened by evaluating their titles, abstracts, and the availability of complete full-text documents to ensure alignment with the research focus on the use of web technology in adaptive e-learning. Based on the predefined inclusion and exclusion criteria, twenty articles were found to meet all requirements and were therefore included in the analysis and synthesis of findings. To provide a more structured overview of the characteristics, methods, and contributions of each selected article, a comprehensive summary is presented in the following table of the 20 selected articles.

Table 4. SLR Result

No.	Reference (Year)	Title	Objective	Method	Findings
1	Hassan A. El-Sabagh (2021)	*Adaptive e-learning environment based on learning styles and its impact on development students' engagement*	The aim of this study is to design and examine the impact of an adaptive e-learning environment based on students' learning styles on improving their learning engagement.	This study used a quasi-experimental design with pretest and posttest to measure the effect of the adaptive e-learning environment on student engagement.	The findings reinforce the usefulness of adaptive learning environments in improving engagement and learning performance in higher education.

No.	Reference (Year)	Title	Objective	Method	Findings
2	Saadia Gutta Essa, Turgay Celik, Nadia Emelia Human-Hendricks (2023)	*Personalized Adaptive Learning Technologies Based on Machine Learning Techniques to Identify Learning Styles*	This study aims to conduct a systematic review of the literature related to the use of artificial intelligence approaches—particularly machine learning techniques—in personalized adaptive learning systems.	Systematic Literature Review (SLR).	The results confirm that the use of AI and ML in learning-style-based adaptive learning systems is developing and promising, but further development is still needed to improve accuracy and enable broader adoption in education.
3	Andhika, Amalia Shifa Aldila, Lawrence Adi Supriyono, Cantika Nur Previana, Dedi Rahman Habibie (2024)	*The Effectiveness of Adaptive Learning Systems Integrated with LMS in Higher Education*	To assess how effective Adaptive Learning Systems (ALS) integrated with a Learning Management System (LMS) are in improving learning outcomes, student engagement, and overall satisfaction in higher education.	Mixed-methods approach.	The results show that implementing LMS-integrated ALS has a positive impact on various aspects of learning in higher education.
4	Andri Christodoulou, Charoula Angel (2022)	*Adaptive Learning Techniques for a Personalized Educational Software in Developing Teachers' Technological Pedagogical Content Knowledge*	To develop and test an adaptive and personalized e-TPCK system in improving Technological Pedagogical Content Knowledge (TPCK) for pre-service teachers.	Experimental design with control and experimental groups.	The use of the e-TPCK system significantly improved learners' TPCK competence during the learning process.
5	Wafaa S. Sayed, Ahmed M. Noeman, Abdelrahman Abdellatif, Moemen Abdelrazek, Mostafa G. Badawy, Ahmed Hamed, Samah El-Tantawy (2022)	*AI-based adaptive personalized content presentation and exercises navigation for an effective and engaging e-learning platform*	To develop an adaptive and personalized online learning platform using AI to improve effectiveness and student engagement, particularly in early K–12 education.	Development of an adaptive learning platform combining DQN (Deep Q-Network) reinforcement learning and an online rule-based decision-making system.	The AI-based adaptive platform—especially using DQN reinforcement learning and online rule-based approaches—had a positive effect on learning effectiveness and student satisfaction.

No.	Reference (Year)	Title	Objective	Method	Findings
6	Onur Mahmut Pişirir (2023)	*Adaptive learning based content management tool for online education platforms*	To develop an adaptive-learning-based tool that helps instructors create and tailor course content individually according to students' learning needs.	Random forest algorithm.	Classifying students' learning tendencies using a random forest algorithm achieved a fairly good level of accuracy.
7	Rusdiana, M. Ramli AR (2024)	*Utilization of an Artificial Intelligence (AI)-Based E-Learning Model in Islamic Education*	To describe the utilization of an AI-based e-learning learning model in Islamic education.	Library research (literature study).	The study shows that AI-based e-learning is a type of learning model that leverages advanced technology integrated with AI.
8	Ahmed Elmabaredy, Ebada Elkholy, Abdul-Aziz Tolba (2020)	*Web-based adaptive presentation techniques to enhance learning outcomes in higher education*	To improve understanding of the effectiveness of various adaptive presentation techniques in enhancing learning outcomes and student performance through web-based systems.	Quasi-experimental approach.	The results indicate a significant improvement in learners' outcomes after the intervention using both techniques.
9	Aan Sajiatmojo (2021)	*The Use of E-Learning in the Online Learning Process*	To assess the relevance of e-learning as a solution for distance learning and as an alternative learning approach in the future.	Literature review by collecting data from books and digital media.	E-learning proved effective during the pandemic because it offers lower costs, flexibility in time and place, and promotes learner independence.
10	Balya Aulia Assiddiqi, Lailatul Nuraini, Miranda Evi Murniati, Shabira Hafiz Azura, Vira Safitri, Yuliyantika (2023)	*Design and Development of E-Learning Media Assisted by the Berdu.Id Website on the Topic of Ethnophysics*	E-learning learning media is an online medium that uses internet networks and computers to provide information and communication; with e-learning, the learning process between students and teachers becomes more interactive.	SDLC (System Development Life Cycle).	Student responses toward the e-learning media were in the "very good" category, with an average score percentage of 87.15%.

No.	Reference (Year)	Title	Objective	Method	Findings
11	Winna Dharmayanti, Ratih Widya Nurcahyo (2021)	*Analysis and Design of Adaptive E-Learning in a Vocational High School*	To examine and design adaptive e-learning media needed by teachers and students at SMK Mandiri.	R&D method using the ADDIE model, limited to the Analysis and Design stages.	The study identified that the required adaptive e-learning media should support three learning styles (visual, auditory, kinesthetic), then designed the adaptive e-learning media and created a flowchart to illustrate the design.
12	Sampurna Dadi Riskiono, Donaya Pasha (2020)	*Analysis of Load Balancing Methods to Improve E-Learning Website Performance*	To improve system performance.	Load balancing.	Testing shows that load balancing implementation achieved a response time of 36.4 ms, lower than a single server's 51.1 ms, in a 500/10 sec connection test.
13	Muhammad Rizal H, Tamra, Ilham, Amran Amiruddin, Nur Idil Fitri Idris, Listia Utami, Fira Auliyah Putri (2025)	*Implementation of a Web-Based E-Learning System to Optimize Staff Training Programs at Sultan Hasanuddin Air Base, Makassar*	To build and implement a web-based e-learning system to improve staff competence at Lanud Sultan Hasanuddin Makassar.	Combination of Participatory Action Research (PAR), the ADDIE instructional development model, and the Kirkpatrick evaluation framework, supported by Agile Scrum practices.	Results show very high acceptance (satisfaction score 4.8–4.9), an 18% post-test score increase, and reductions in costs and lost personnel hours by ±45%. New behavior adoption reached 65%, indicating the need to strengthen device infrastructure and connectivity. Overall, the system is effective and beneficial, serves as a replication model for other air bases, and may accelerate the digital transformation roadmap for internal Indonesian Air Force training.

No.	Reference (Year)	Title	Objective	Method	Findings
14	Jimi Asmara (2020)	*Design of a Web-Based E-Learning System at SMPN 2 Busalangga*	To design an e-learning system to support learning materials and Try Out exams for SMP Negeri 2 Busalangga, reviewed in terms of human resources, learning materials, and infrastructure.	Qualitative method.	The outcome is a design of an e-learning website media that can be used for IT-based teaching and learning activities at SMP Negeri 2 Busalangga.
15	Muhammad Nasrulloh Mubarak, Jesica Febriani Nura (2021)	*Improving and Equalizing Education Through E-Learning*	To summarize existing technology trends related to the education Sustainable Development Goals (SDGs), especially e-learning, as a reference for future technology development.	Literature study.	The results present a summary of technology trends implemented in education, particularly related to SDGs in education, focusing on e-learning during the COVID-19 pandemic.
16	Indah Purwandani, Nurfiah Oktaviani Syamsiah (2021)	*Website Quality Analysis Using the WebQual 4.0 Method: Case Study of the MyBest E-Learning System at UBSI*	To analyze and identify user satisfaction levels with the MyBest e-learning website at UBSI using WebQual 4.0.	Online questionnaire distribution using a four-point Likert scale (1 = strongly disagree to 4 = strongly agree).	All four WebQual 4.0 variables—usability, information quality, service interaction quality, and user satisfaction—were in relatively high categories, with overall user satisfaction categorized as "satisfied."
17	Muhammad Khakim Ashari, Sukijan Athoillah, Moh Faizin (2023)	*Application-Based E-Assessment Model in Senior High Schools in the Digital Era*	To observe an application-based e-assessment model in the digital era by reviewing journals related to e-assessment.	Systematic Literature Review (SLR).	E-assessment is relevant to implement in senior high schools because students have the skills to access and operate various available applications.
18	Azzam Izzudin Hasan, Annisa Safa, Alda Eva Saputri, Fitroh (2022)	*The Influence of Critical Success Factors on the Success of E-Learning in Supporting Learning*	To answer the question of what constitutes the critical success factors (CSFs) for successful e-learning implementation.	Systematic Literature Review (SLR).	The study identifies 23 CSFs that play important roles in successful e-learning implementation.

No.	Reference (Year)	Title	Objective	Method	Findings
19	Johni Eka Putra, A. Sobandi, Aisah Aisah (2024)	*The urgency of digital technology in education: a systematic literature review*	To investigate the urgency, impacts, efforts, and challenges in integrating digital technology in education in Indonesia, focusing on improving learning quality, reducing gaps in access to education, and preparing students for a technology-integrated future.	Systematic Literature Review (SLR).	Based on the analysis, the study concludes that using digital technology in education has become a necessity to address future challenges.
20	Lutfi, Risma Haris, Akhmad Kurnia, Ardiansah Hasin, Wahyu Siswanto (2024)	*Effectiveness of E-Learning-Based Learning in Higher Education in the Society 5.0 Era*	To analyze the implementation of e-learning in higher education in the Society 5.0 era, where technology becomes part of everyday life.	Systematic review / Systematic Literature Review (SLR).	E-learning in higher education can enhance the learning experience; however, ensuring the availability of systems and supporting facilities is essential for successful implementation (Jara Jara et al., 2023; Lutfi, 2024).

Comparative analysis of the twenty reviewed studies shows fairly significant differences depending on educational level and context. Studies conducted in higher education (e.g., El-Sabagh, 2021; Andhika et al., 2024; Lutfi et al., 2024) consistently report improvements in student engagement, satisfaction, and learning outcomes after the implementation of web-based adaptive e-learning systems, especially when these systems are integrated with a Learning Management System (LMS) and supported by machine learning and learning analytics technologies. These findings indicate that technological readiness, learner autonomy, and students' digital literacy are key supporting factors for the successful implementation of adaptive e-learning.

In contrast, research in secondary and vocational education (e.g., Dharmayanti & Nurcahyo, 2021; Asmara, 2020) is still predominantly at the needs analysis and system design stages. Although several studies have successfully adopted learning style approaches (visual, auditory, and kinesthetic), the main limitation lies in the lack of longitudinal testing to examine long-term impacts on learning outcomes and student engagement. This highlights a gap between system development and the evaluation of implementation effectiveness in real-world settings.

From a methodological perspective, experimental and mixed-methods studies tend to generate stronger empirical evidence than purely literature-based studies. However, most research still has limitations related to inclusivity, such as minimal analysis of gender, disability, and rural contexts. In addition, many studies report real-world implementation challenges, particularly related to data privacy, human resource readiness, cross-system data integration, and cultural resistance to digitalization—especially in vocational education and

1) institutional training contexts.
Therefore, although web-technology-based adaptive e-learning shows strong potential to improve learning quality, future research should be directed toward long-term testing, non-formal and vocational education contexts, and strengthening ethical and AI regulatory aspects so that its implementation becomes more sustainable and inclusive.

2) Adaptive Learning dan Student Engagement
El-Sabagh (2021) shows that implementing a learning-style-based adaptive e-learning environment has a significant impact on improving student engagement and academic performance. Using a quasi-experimental approach, this study demonstrates that adaptive systems can support learner-centered learning by tailoring materials and activities to individual characteristics. This is reinforced by Andhika et al. (2024), who report that adaptive learning systems integrated with an LMS can increase active engagement and student satisfaction in higher education. Overall, the literature indicates that adaptive learning contributes positively to student engagement, especially in higher education contexts where technological readiness and learner autonomy are relatively high.

3) Artificial Intelligence dan Personalisasi Pembelajaran
Kajian Essa et al. (2023) emphasizes that artificial intelligence and machine learning form the primary foundation for the development of modern adaptive learning systems. Various techniques such as learning style classification and learner behavior modeling are used to enhance learning personalization. This aligns with Sayed et al. (2022), who developed an AI-based adaptive e-learning platform using a reinforcement learning approach and a rule-based system. Their findings show improved learning effectiveness and student satisfaction, particularly at the elementary and secondary education levels. Nevertheless, some studies still highlight challenges related to model complexity, large data requirements, and issues of learner data privacy and security.

4) Integrasi Sistem Adaptif dan Learning Management System
Integration between adaptive learning systems and Learning Management Systems (LMS) has been proven to enhance learning quality. Andhika et al. (2024) report that an LMS-integrated Adaptive Learning System (ALS) has a positive impact on learning outcomes, engagement, and student satisfaction. This is consistent with Christodoulou and Angel (2022), who developed an adaptive e-TPCK system for pre-service teachers, where the results show significant improvements in pedagogical and technological competencies. The literature suggests that integrating adaptive systems with LMS strengthens monitoring, evaluation, and systematic learning personalization functions.

5) Algoritma Adaptif dan Pengembangan Konten Pembelajaran
The use of adaptive algorithms in content development is an important trend in web-based e-learning. Pişirir (2023) applied a Random Forest algorithm to classify students' learning tendencies and to personalize learning content individually. The results show fairly high accuracy, indicating the strong potential of data analytics in personalized learning. In addition, Elmabaredy et al. (2020) demonstrate that web-based adaptive presentation techniques can significantly improve student learning outcomes. These two studies confirm that data-driven and adaptive algorithm approaches directly contribute to learning effectiveness.

6) E-Learning sebagai Solusi Akses dan Pemerataan Pendidikan
Several studies highlight the role of e-learning in increasing access and educational equity. Sajiatmojo (2021) shows that e-learning became an effective distance learning solution, particularly during the pandemic, due to flexibility in time, place, and cost. Mubarak and Nura

(2021) also emphasize that e-learning contributes to the achievement of the Sustainable Development Goals (SDGs) in education, especially in expanding equitable learning access. These findings indicate that even when not fully adaptive, web-based e-learning systems have strong potential to support educational inclusivity.

7) Perancangan Media dan Infrastruktur E-Learning
Media design and infrastructure are crucial factors for e-learning success. Dharmayanti and Nurcahyo (2021) designed adaptive e-learning in vocational secondary schools by considering three main learning styles: visual, auditory, and kinesthetic. This study emphasizes the importance of user needs analysis before system implementation. In addition, Riskiono and Pasha (2020) highlight the importance of technical infrastructure through the implementation of load balancing to improve e-learning website performance. Their results show a significant improvement in response time compared to a single-server setup.

8) Inovasi Media Pembelajaran Berbasis Web
The development of web-based learning media is also widely discussed in the literature. Assiddiqi et al. (2023) designed website-assisted e-learning media and reported very high user satisfaction. Meanwhile, Asmara (2020) designed a web-based e-learning system for secondary schools with a focus on human resource readiness, learning materials, and infrastructure. These studies show that innovation in web-based learning media can improve interactivity and the effectiveness of teaching and learning processes.

9) Evaluasi Kualitas dan Keberhasilan Sistem E-Learning
System quality evaluation is an important aspect of e-learning implementation. Indah and Nurfia (2021) used the WebQual 4.0 method to measure user satisfaction with an e-learning system, with results indicating a relatively high level of satisfaction. In addition, Hasan et al. (2022) identified 23 Critical Success Factors (CSFs) that influence e-learning success, covering technical, organizational, and human resource aspects. These findings confirm that e-learning success is determined not only by technology, but also by institutional support and user readiness.

10) E-Assessment dan Evaluasi Pembelajaran Digital
Ashari et al. (2023) reviewed an application-based e-assessment model in senior high schools and concluded that it improves the efficiency and flexibility of the assessment process. However, the study also highlights challenges related to instrument validity and data security. These findings suggest that e-assessment development should be accompanied by clear evaluation standards and robust data protection policies.

11) Transformasi Digital Pendidikan dan Society 5.0
The reviews by Putra et al. (2024) and Lutfi et al. (2024) emphasize that the integration of digital technology, including web-based e-learning, is an urgent necessity in responding to the Society 5.0 era. E-learning plays a role in improving learning quality and preparing learners to face future challenges. However, the literature also stresses the importance of digital literacy, infrastructure readiness, and adaptive education policies to ensure that digital transformation can proceed sustainably.

CONCLUSION

Based on the results of a Systematic Literature Review of 20 scientific articles published between 2020 and 2025, it can be concluded that the use of web technologies in the development of adaptive e-learning systems shows significant potential for improving learning quality across various educational contexts. The integration of web technologies with artificial intelligence, machine learning, and learning analytics has been proven to

support learning personalization, increase learner engagement, and positively impact learning outcomes, particularly in higher education.

The review findings indicate that the main trends in the development of web-based adaptive e-learning include: (1) the use of machine learning algorithms to model learners' characteristics and behaviors, (2) the real-time integration of learning analytics to support adaptive learning decision-making, and (3) the development of more inclusive learning designs by considering learning styles, individual needs, and learner diversity. In addition, the integration of adaptive systems with Learning Management Systems (LMS) has been shown to strengthen the effectiveness of monitoring, evaluation, and systematic learning personalization.

Nevertheless, this review also identifies several limitations and research gaps. Most studies still focus on higher education contexts, while research in vocational education, secondary education, and non-formal education remains relatively limited. Moreover, many studies have not evaluated the long-term impacts of adaptive e-learning system use and have not discussed in depth issues related to ethics, data privacy, information security, and algorithmic transparency in artificial intelligence—factors that are crucial for implementing AI-based technologies in education.

Therefore, future research is recommended to focus on longitudinal testing, expanding research contexts to vocational and non-formal education, and strengthening ethical and regulatory frameworks in the development of web-based adaptive e-learning. Overall, the results of this SLR provide conceptual and practical contributions as a foundation for developing adaptive e-learning systems that are more effective, inclusive, and sustainable in the future.

ACKNOWLEDGMENT

We would like to express our gratitude to all parties who have provided support and contributions throughout the preparation of this research.

REFERENCE

Andhika, A., Aldila, A. S., Supriyono, L. A., Previana, C. N., & Habibie, D. R. (2024). The Effectiveness of Adaptive Learning Systems Integrated with LMS in Higher Education. Jurnal KomtekInfo, 11, 49–56. https://doi.org/10.35134/komtekinfo.v11i2.505

Ashari, M. K., Athoillah, S., & Faizin, M. (2023). Model E-Asesmen Berbasis Aplikasi pada Sekolah Menengah Atas di Era Digital: Systematic Literature Review. TA'DIBUNA: Jurnal Pendidikan Agama Islam, 6(2), 132. https://doi.org/10.30659/jpai.6.2.132-150

Asmara, J. (n.d.). PERANCANGAN SISTEM E-LEARNING BERBASIS WEB PADA SMP N 2 BUSALANGGA. 29–37.

Assiddiqi, B. A., Nuraini, L., Murniati, M. E., Azura, S. H., Safitri, V., Studi, P., Fisika, P., Jember, U., Artikel, I., Pembelajaran, M., Assiddiqi, B. A., Studi, P., Fisika, P., Jember, U., & Education, J. (2023). RANCANG BANGUN MEDIA PEMBELAJARAN E-LEARNING BERBANTUAN WEBSITE BERDU . ID POKOK BAHASAN. 11(2), 95–100. https://doi.org/10.37081/ed.v11i2.4593

Christodoulou, A., & Angeli, C. (2022). Adaptive Learning Techniques for a Personalized Educational Software in Developing Teachers' Technological Pedagogical Content Knowledge. Frontiers in Education, 7(June), 1–14. https://doi.org/10.3389/feduc.2022.789397

Dharmayanti, W., & Nurcahyo, R. W. (2021). Analisis dan Perancangan E-Learning Adaptif di Sekolah Menengah Kejuruan. Edumatic: Jurnal Pendidikan Informatika, 5(1), 1–10. https://doi.org/10.29408/edumatic.v5i1.2544

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. International Journal of Educational Technology in Higher Education, 18(1). https://doi.org/10.1186/s41239-021-00289-4

Elmabaredy, A., Elkholy, E., & Tolba, A. A. (2020). Web-based adaptive presentation techniques to enhance learning outcomes in higher education. Research and Practice in Technology Enhanced Learning, 15(1). https://doi.org/10.1186/s41039-020-00140-w

Essa, S. G., Celik, T., & Human-Hendricks, N. E. (2023). Personalized Adaptive Learning Technologies Based on Machine Learning Techniques to Identify Learning Styles: A Systematic Literature Review. IEEE Access, 11(April), 48392–48409. https://doi.org/10.1109/ACCESS.2023.3276439

H, M. R., Amiruddin, A., Idil, N., & Idris, F. (2025). Penerapan Sistem E-Learning Berbasis Web untuk Optimalisasi Program Pelatihan Staf di Lanud Sultan Hasanuddin Makassar. 1(1), 2027.

Hasan, A. I., Saputri, A. E., Safa, A., & Fitroh, F. (2022). Pengaruh Critical Success Factors terhadap Keberhasilan E-Learning dalam Mendukung Pembelajaran : Systematic Literature Review. JURNAL IPTEKKOM Jurnal Ilmu Pengetahuan & Teknologi Informasi, 24(1), 37–50. https://doi.org/10.17933/iptekkom.24.1.2022.37-50

Islam, U., Antasari, N., Islam, U., & Antasari, N. (2024). PEMANFAATAN MODEL PEMBELAJARAN E-LEARNING BERBASIS ARTIFICIAL INTELEGENT (AI) PADA PENDIDIKAN ISLAM. 7(2), 69–84. https://doi.org/10.47732/adb.v7i2.513

Keguruan, J. I., & Vol, I. P. (2021). No Title. 1(3), 229–235.

Lutfi, L., Haris, R., Kurnia, A., Hasin, A., & Siswanto, W. (2024). Systematic Literature Review: Efektivitas Pembelajaran Berbasis E-Learning pada Perguruan Tinggi di Era Society 5.0. Journal on Education, 7(1), 4004–4013. https://doi.org/10.31004/joe.v7i1.6882

Mubarak, M. N., & Nura, J. F. (n.d.). Peningkatan dan Pemerataan Pendidikan Melalui. 1–10.

PİŞİRİR, O. M. (2023). Adaptive learning-based content management tool for online education platforms. Uluslararası Teknolojik Bilimler Dergisi, 15(2), 73–79. https://doi.org/10.55974/utbd.1346970

Purwandani, I., & Syamsiah, N. O. (2021). Analisis Kualitas Website Menggunakan Metode Webqual 4 . 0 Studi Kasus : MyBest E-learning System UBSI . Website Quality Measurement Based on Webqual 4 . 0 Method . A Research on MyBest E-learning System UBSI . 09(3), 300–306. https://doi.org/10.26418/justin.v9i3.47129

Putra, J. E., Sobandi, A., & Aisah, A. (2024). The urgency of digital technology in education: a systematic literature review. Jurnal EDUCATIO: Jurnal Pendidikan Indonesia, 10(1), 224. https://doi.org/10.29210/1202423960

Riskiono, S. D., & Pasha, D. (2020). ANALISIS METODE LOAD BALANCING DALAM MENINGKATKAN KINERJA WEBSITE E-LEARNING. 14(1), 22–26.

Sayed, W. S., Noeman, A. M., Abdellatif, A., Abdelrazek, M., Badawy, M. G., Hamed, A., & El-Tantawy, S. (2023). AI-based adaptive personalized content presentation and exercises navigation for an effective and engaging E-learning platform. Multimedia Tools and Applications, 82(3), 3303–3333. https://doi.org/10.1007/s11042-022-13076-8