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Research Article

Development of a WebXR-Based Collaborative LMS System with 3D Virtual Features and Artificial Intelligence

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Ayung Candra Padmasari*, Ahamad Tarmizi Azizan, Burieva Kibrio Ergashevna

Abstract:
Background of Study: The advancement of immersive technology and artificial intelligence (AI) offers new opportunities for creating more adaptive and interactive learning systems. However, higher education institutions still face challenges such as limited industry-standard facilities and the high cost of multimedia equipment.
Aims and Scope of Paper: This study aims to develop a prototype of a WebXR-based Collaborative Learning Management System (LMS) equipped with 3D virtual features and AI integration to enhance student learning experiences.
Methods: The research employed the Multimedia Development Life Cycle (MDLC) method, which consists of six stages: conceptualization, design, material collection, assembly, testing, and distribution. The study involved 30 Multimedia Education students from Universitas Pendidikan Indonesia selected through purposive sampling.
Result: Feasibility testing using a Likert-scale questionnaire revealed that the system achieved a highly feasible category with average scores of 81,7 % for Learnability 85,6 %, for system performance 76,93%, for Efficiency 79,9%, for memorability 74,2%, satisfaction 85,4 %. Resulting in an overall feasibility of 81.7%. Semi-structured interviews confirmed that AI integration significantly supported learning personalization and provided content recommendations, although the AI feature was limited to text-based responses.
Conclusion: The results indicate that combining WebXR and AI in an LMS can address the challenges of industry-based learning by providing immersive, adaptive, and accessible learning experiences. This system demonstrates strong potential as a future-ready digital learning solution, with future research suggested to evaluate its impact on learning outcomes and improve AI capabilities for deeper contextual interaction.

Keywords: Artificial Intelligence, Collaborative Learning Management System, Immersive Learning, Multimedia Development Life Cycle, WebXR.

1. INTRODUCTION

This Higher education institutions are under pressure to align their teaching practices and curricula with the technological competencies demanded by modern industries (Aver et al., 2021). This challenge has become increasingly significant with the emergence of Industry 4.0, where digital transformation and immersive technologies are reshaping educational ecosystems. In Indonesia, the urgency for producing graduates with advanced digital literacy and technical skills continues to rise. Although many universities have integrated multimedia and XR (Extended Reality) technologies (Alnagrat et al., 2022), current implementations often fail to provide realistic and adaptive learning experiences that mirror industry environments. Students still face limitations in accessing industry-standard facilities, and the high cost of multimedia equipment prevents widespread deployment in classrooms.

WebXR, a browser-based immersive technology that enables seamless access across devices without dedicated software installations, offers a promising solution for modern learning systems (Mouttalib et al., 2023). However, most conventional Learning Management Systems (LMS) remain limited in terms of interactivity and adaptivity. These platforms often deliver static content, which does not cater to the unique needs and learning styles of individual students. As a result, learners lack personalized experiences and dynamic engagement, reducing the effectiveness of knowledge transfer.

This study addresses the gap between the ideal vision of an interactive, adaptive LMS supported by WebXR and the current reality of existing systems. Previous implementations have primarily focused on providing 3D virtual environments without embedding Artificial

Intelligence (AI) for adaptive learning. The scope of this research is restricted to developing a prototype WebXR based LMS system integrated with AI through free Web APIs.

The system supports immersive navigation, 360 degree panoramic interaction, and basic adaptive features. Initial evaluations are limited to usability and user interaction assessments, with large-scale implementation and comprehensive learning outcome evaluations identified as future work. AI integration is a fundamental aspect of this system, providing adaptivity and intelligence in various ways. First, AI is used for personalized learning by leveraging free Web APIs such as natural language processing and recommendation engines to adapt the learning path dynamically based on user interactions. Second, AI performs user behavior analysis by monitoring interaction patterns, session durations, and navigation activities to modify content complexity in real time. Third, AI recommends additional learning resources based on user-input keywords, enhancing literacy and content diversity through connections with free AI platforms. These features transform the system from a static learning environment into an intelligent and responsive platform that aligns with modern educational demands.

Recent research emphasizes the importance of integrating AI with immersive technologies to improve educational outcomes (Bosman et al., 2024). Generative AI frameworks in virtual reality environments have demonstrated positive impacts on adaptive content delivery and learner engagement (Hemminki-Reijonen et al., 2025). Studies on AI and metaverse integration highlight the role of intelligent systems in enhancing motivation and adaptability in higher education contexts (Almeman et al., 2025). Similarly, immersive and AI-driven technologies are recognized for their potential to provide interactive and adaptive learning, although infrastructure and privacy remain challenges (Ifraheem et al., 2024). Hybrid approaches combining VR and AI-driven personalization show promising results for flexible and learner-centered instruction (Khan Soomro et al., 2025). AI-enabled intelligent assistants are increasingly adopted in higher education for adaptive pathways, yet their application in WebXR environments remains underexplored (Sajja et al., 2024). Research on immersive cognitive systems positions AI as an active participant in human learning interactions, contributing to the development of adaptive learning models (Ugwu et al., 2025). Intelligent tutoring systems based on generative AI have been employed to automate quizzes and deliver real-time feedback, creating highly personalized experiences (Liu et al., 2024). Generative AI has also been applied to create dynamic VR learning environments, enriching interactivity and personalization (Huang et al., 2025). Additionally, WebVR combined with wearable technologies has been proven to enhance conceptual understanding, underscoring the benefits of immersive interaction compared to traditional methods (Bhatt et al., 2025). Despite these advancements, comprehensive personalization in immersive education is still in its early stages, highlighting the need for a cost-effective, adaptive WebXR-based LMS (Marougkas et al., 2024). The novelty of this research lies in its unique approach to combining browser-based WebXR, free AI integration, and collaborative features in a single system. Unlike previous studies that focus on expensive VR systems or proprietary AI solutions, this prototype employs open Web APIs for AI functionality, minimizing technical and financial barriers. The resulting platform allows collaborative interactions in a shared 3D virtual space while AI dynamically adapts content and recommends resources in real time. This combination offers a modern, intelligent, and accessible learning solution designed to bridge the gap between academic environments and industry expectations. Therefore, this research focuses on developing and evaluating a WebXR-based collaborative LMS system equipped with 3D virtual features and AI capabilities to provide personalized, interactive, and scalable learning experiences.

2. MATERIAL AND METHOD

This research employed the Multimedia Development Life Cycle (MDLC) method, which was considered the most suitable approach for developing an interactive multimedia-based system such as a WebXR platform integrated with artificial intelligence. MDLC was selected because it provides well-structured phases that include conceptualization, design, material collection, assembly, testing, and distribution. These stages are essential for projects that require complex synchronization of visual components, immersive interactions, and API integration for adaptive learning experiences (Bramantyo & Astuti, 2025). Unlike other methods such as Agile or Waterfall, MDLC offers flexibility in its design and testing stages, allowing for iterative improvements during the development process. This adaptability is crucial for building immersive educational media, where both usability and technological compatibility need to be optimized. Agile is generally more effective for generic software development, while MDLC focuses on multimedia-specific elements such as graphics, interactivity, and integrated AI features (Solehatin et al., 2023). Moreover, MDLC ensures comprehensive documentation at each phase, which facilitates validation by experts and structured user evaluation (Putri et al., 2023).

The study is categorized as research and development, aiming to produce a WebXR-based LMS prototype integrated with artificial intelligence features. The research was conducted over five months, from January to May 2025, in the Multimedia Laboratory of Universitas Pendidikan Indonesia, Cibiru Campus. The participants consisted of 30 students from the Multimedia Education program, selected through purposive sampling. The selection criteria included active enrollment in semesters four to six and prior experience using conventional LMS platforms

(Padmasari et al., 2025). The development process followed six MDLC stages.

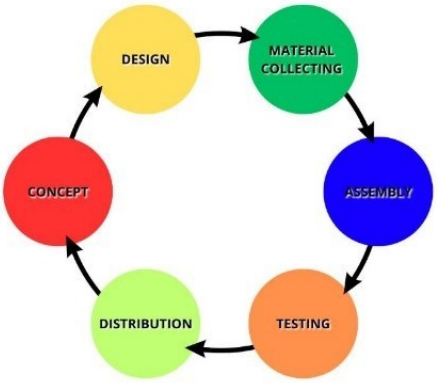


Figure 1. MDLC Method

The conceptualization phase involved identifying system requirements and technical specifications. The design phase covered interface layout and navigation flow for WebXR implementation. During material collection, 3D models were created, and appropriate AI APIs were selected. The assembly phase integrated WebXR technology using Three.js and REST APIs for AI-powered personalization. Testing consisted of two types: functional testing to verify system features and user testing to assess feasibility. The instruments used included a five-point Likert scale questionnaire evaluating usability, along with semi-structured interviews for qualitative feedback (Wardana et al., 2023). Quantitative data from the questionnaires were analyzed descriptively by calculating mean scores for each indicator and converting them into feasibility categories. Qualitative data from interviews were processed using thematic analysis to identify patterns in user experiences. The scope of this study was limited to prototype development and feasibility testing, while future research will address learning effectiveness and the impact on student performance.

The target respondents as users were 30 students of the Multimedia Education Study Program at the UPI Campus in Cibiru, and the prototype was developed to a medium fidelity level. prepared in advance for users when interacting with the system being tested. This task was given to 30 respondents from students. This task was used as a means of interaction in usability measurement.

Table 1. Variables For Media Testing

Instrument	Indicator
Learnability	The user control menu in the interface functions well and is easy to use
System Performance	While using the web, no bugs, hangs, or errors were found. Main menu exit can run Keyboard program for navigation control can run well (no bugs or errors)
Efficiency	There is no delay found for controlling using the keyboard to walk in the immersive web menu presented. No visual graphic delay found in WebXR Users are able to see the visualization of photos, videos and applications clearly
Memorability	The main menu in the WebXR view is easy to find The sign in and out menus are easy to find and haven't changed
Satisfaction	The colors displayed are comfortable and not disturbing The layout and buttons are appropriate and not distracting. 3D interior design in main menu to attract The displayed photo panorama can be seen easily Modeling for 3D asset and property visualization in WebXR according to the theme

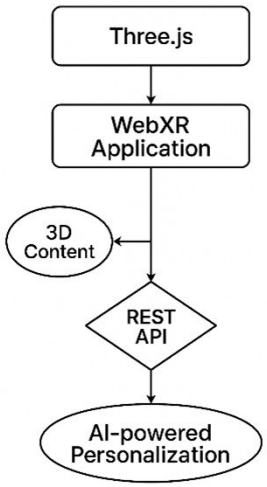


Figure 2. Flowchart Three.js and REST APIs for AI Personalization Tools

The next step was to distribute a questionnaire to lecturers, staff, and students containing 14 questions that represented the five usability aspects. Users filled out the distributed questionnaire based on their experiences (what they saw and felt) while performing the task. Each question in the questionnaire aims to show the level of usability according to user acceptance, which will be assessed on a scale of 5.

According to the aspects of usability testing include five things (Ntoa, 2025), namely:

1. Learnability, describes the level of ease for users to complete basic tasks when they first see or encounter an existing system.
2. Efficiency, describes how quickly users can complete existing tasks when they first learn the system.
3. Memorability, explains the level of ease of use for users in using the system properly, after not using it for some time.
4. Errors, explains the possibility of errors or mistakes made by users and how easily they can overcome them.
5. Satisfaction, This section explains the level of user satisfaction in using the system that has been created.

3. RESULTS AND DISCUSSION

3.1 Result

Tabel 2. Result Testing

Result	Learnability	Sistem Performance	Efficiency	Memorability	Satisfaction	Total
Score obtained	428	577	799	371	1063	3268
Maximum Score	500	750	1000	500	1250	4000
Percentage (%)	85,6	76,933	79,9	74,2	85,04	

$$\text{Overall Percentage} = \frac{\text{Total Scores Obtained}}{\text{Maximum Score}} \times 100\%$$

$$\text{Overall percentage} = \frac{3268}{4000} \times 100\% = 81{,}7\ \%$$

The main results of this study include the successful implementation of a WebXR based LMS integrated with artificial intelligence (AI) and the findings from feasibility testing. The developed system combines immersive 3D learning environments with 360 degree navigation and integrates AI features through free Web APIs. These AI features allow the system to provide adaptive responses, including recommending learning resources, answering conceptual questions, and suggesting topic-based learning sequences. Feasibility testing was conducted with 30 respondents using a Likert scale questionnaire with three main indicators: highly feasible category with average scores of 81,7 % for Learnability 85,6 %, for system performance 76,93%, for Efficiency 79,9%, for memorability 74,2%, satisfaction 85,4 %. Semi-structured interviews revealed that most respondents found AI integration helpful for accessing additional learning resources and understanding the material more effectively. However, some noted limitations, such as AI responses being text-only and limited contextual understanding.

3.2 Discussion

The discussion highlights that integrating WebXR and AI in LMS creates a more immersive and adaptive learning experience compared to conventional LMS platforms. AI integration enhances personalization by

recommending relevant content and providing automated responses, aligning with the growing trend of data-driven learning in higher education. This directly addresses the challenges identified in the introduction, such as the lack of industry-standard learning resources and the need for interactive and future-ready educational technologies.

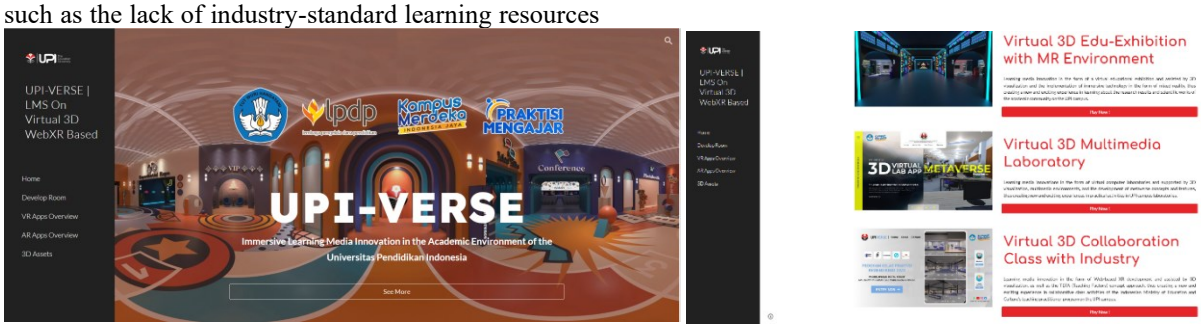
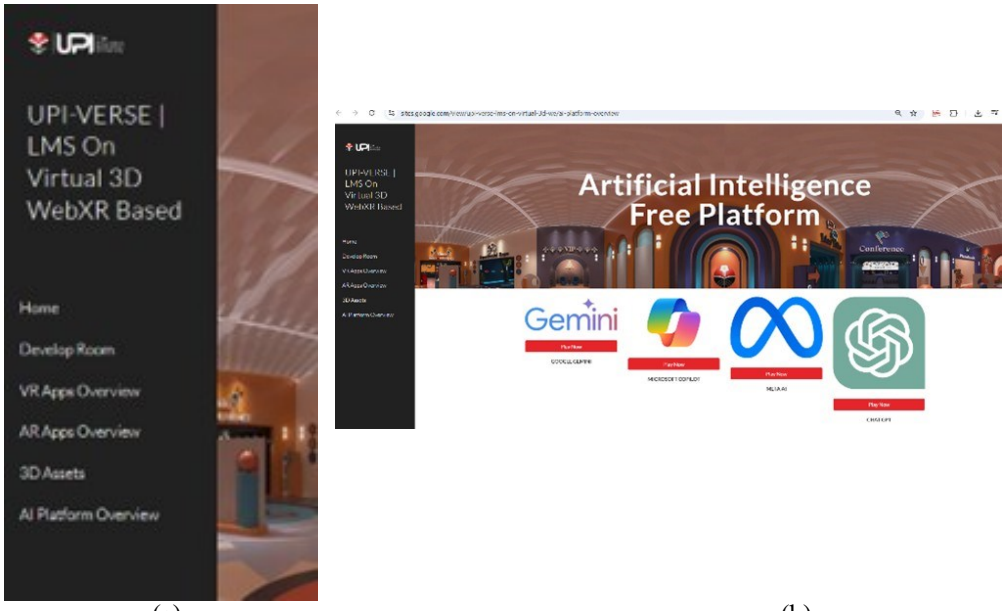
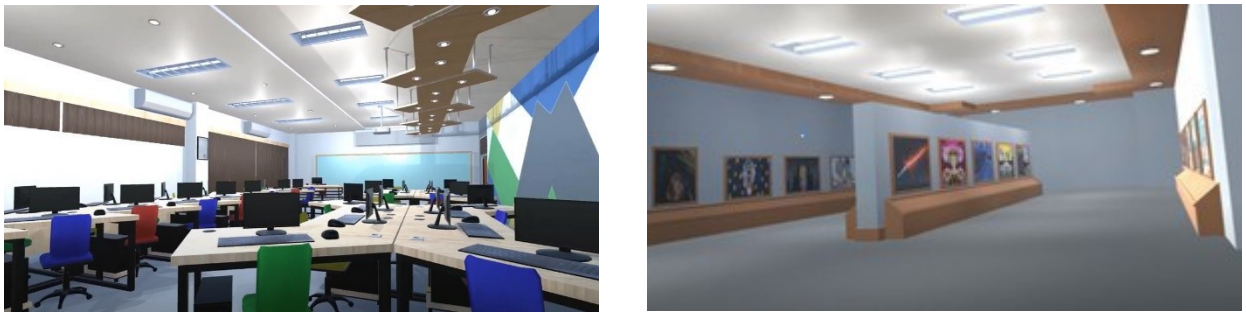


Figure 3. WebXR Homepage



(a) (b)

Figure 4. (a). WebXR Menu. (b). APIs for AI Platform Integration



(a) (b)

Figure 5. (a) Overview WebXR Virtual Laboratory. (b) Overview WebXR Virtual Edu-Exhibition

3.2.1 Implications

The implementation of this system can help higher education institutions improve student competencies to meet industry demands. The use of AI for content recommendations and literacy support reduces dependence on costly physical resources, increasing accessibility to advanced learning experiences.

3.2.2 Research contribution

This study introduces a prototype of a WebXR based LMS integrated with AI personalization features, a combination that remains rare in Indonesia's educational technology landscape. The research successfully demonstrates the integration of immersive WebXR environments and AI-driven intelligent information support.

3.2.3 Limitations

This research was limited to small-scale testing with 30 respondents from a single study program Pendidikan

Multimedia Universitas Pendidikan Indonesia. AI features were restricted to text-based responses without deep user behavior analysis. Additionally, AI integration depends on external APIs, making system performance sensitive to internet connectivity.

3.2.4 Suggestions

Future studies should involve larger and more diverse participant groups. AI features could be expanded with advanced natural language processing, behavior analytics, and voice-based interaction for improved user experience. Further research should also measure the system's impact on learning outcomes to provide empirical evidence of its effectiveness.

4. CONCLUSIONS

This study successfully developed a WebXR-based LMS prototype integrated with artificial intelligence (AI) to support immersive and adaptive learning experiences. The feasibility test results indicate that the system achieved Feasibility testing was conducted with 30 respondents using a Likert scale questionnaire with three main indicators highly feasible category with average scores of 81,7 % for Learnability 85, 6 %, for system performance 76,93%, for Efficiency 79,9%, for memorability 74,2%, satisfaction 85,4 %. These findings demonstrate that integrating WebXR and AI can enhance personalized learning, provide intelligent content recommendations, and expand access to learning resources without relying on expensive physical facilities. More broadly, this research contributes to the development of digital learning systems in higher education, particularly in addressing the gap between industry competency requirements and limited access to advanced learning technologies. The system has the potential to support future-oriented learning models and serve as a reference for innovative LMS development combining immersive environments and AI technologies. However, this study is limited by its small-scale testing and the current AI features being text-based only. Future research should examine the system's effectiveness on learning outcomes and improve AI capabilities through natural language processing and user behavior analytics to create a more adaptive and intelligent learning experience.

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6. AUTHOR CONTRIBUTION STATEMENT

ACP served as the lead author responsible for research design, development of the WebXR-based LMS integrated with AI, data collection, and manuscript preparation. ATA contributed to the validation of the methodology, analysis of results, and refinement of the discussion section to ensure academic relevance and research contribution. BKE provided conceptual input on immersive technology-based learning systems and reviewed the manuscript for quality and implementation feasibility in an international context. All authors read, reviewed, and approved the final manuscript.

AUTHOR INFORMATION

Corresponding Authors

Ayung Candra Padmasari, Universitas Pendidikan Indonesia, Jawa Barat, Indonesia
https://orcid.org/0000-0001-5837-8055
Email: ayungcandra@upi.edu

Authors

Ahamad Tarmizi Azizan, Universiti Malaysia Kelantan, Malaysia
https://orcid.org/0000-0003-4361-147X
Email: tarmizi@umk.edu.my

Burieva Kibrio Ergashevna, Chirchik State Pedagogical University, Uzbekistan
https://orcid.org/0009-0007-3942-1450
Email: kibriosha85@gmail.com

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