Design and Evaluation of an AI-Based E-Learning System for Graduate Education

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Abstract. The advancement of information and communication technology has driven innovation in higher education, particularly in intelligent learning systems. This study develops an Artificial Intelligence (AI)–based e-learning system to improve learning in the Educational Management Graduate Program at Universitas Negeri Medan. Using a Research and Development (R&D) approach with the ADDIE model, data were collected through interviews, surveys, and curriculum analysis involving lecturers and graduate students. The system integrates adaptive learning recommendations, automated feedback, learning analytics, and an NLP-based chatbot. Results show significant improvements, including increased learning efficiency (58%), faster feedback response time (65%), and high user satisfaction (89%). Interactivity and student motivation also improved by 54% and 61%, respectively. Expert validation through Focus Group Discussion (FGD) confirmed strong system feasibility (92%) and pedagogical relevance (85%). These findings indicate that AI-based e-learning enhances personalization, engagement, and data-driven learning in higher education.

Keywords: Artificial Intelligence; e-learning; ADDIE, adaptive learning, intelligent systems.

1 Introduction

The rapid expansion of information and communication technology (ICT) has significantly transformed the landscape of higher education, particularly through the adoption of digital learning platforms. E-learning systems have become essential in supporting flexibility, accessibility, and scalability in teaching and learning processes [1]. However, many conventional Learning Management Systems (LMS) still rely on static content delivery, limited personalization, and minimal real-time learning support, which may reduce learning effectiveness in advanced academic contexts [2]. As a result, graduate students may experience

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delayed feedback, lack of engagement, and reduced motivation, which can hinder learning outcomes and learning continuity [3].

In graduate education, learning demands are typically more complex, requiring higher-order thinking, independent inquiry, and continuous monitoring of academic progress. These needs call for learning environments that are not only flexible but also responsive and adaptive. Artificial Intelligence (AI) has emerged as a promising solution to overcome limitations in traditional LMS platforms. Recent systematic reviews highlight that AI in education has been widely applied through adaptive learning systems, intelligent tutoring support, and learning analytics to improve personalization and learning decision-making [4, 5]. AI-driven e-learning systems can enable adaptive learning pathways, automated feedback mechanisms, student learning analytics, and conversational agents such as chatbots to provide academic assistance instantly and continuously [6].

At Universitas Negeri Medan, particularly in the Educational Management Graduate Program, e-learning has been used as a learning support tool but has not fully integrated intelligent capabilities such as adaptive recommendation systems, predictive learning analytics, or automated personalized support [7]. Therefore, there is a pressing need to develop an AI-based e-learning system that improves learning efficiency, increases interaction, and supports data-driven academic decision-making. This need is aligned with recent research emphasizing that learning personalization using LMS data is increasingly important for improving learner outcomes and engagement in higher education settings.

This study aims to design and develop an AI-based e-learning prototype to enhance adaptive and data-driven learning in graduate education. The system integrates several intelligent modules: (1) adaptive learning recommendation, (2) automated feedback and assessment support, (3) learning analytics dashboard, and (4) an NLP-based chatbot for academic interaction. The study also evaluates the effectiveness and feasibility of the developed system through empirical testing and expert validation.

2 Materials and Method

This section presents the methodological framework adopted in this study, including the ADDIE-based R&D process, research setting and participants, data collection techniques, and the core components of the developed AI-based e-learning system.

2.1 Research Design and Data

This study applied a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five systematic phases: Analysis, Design, Development, Implementation, and Evaluation [8].

In the analysis phase, learning needs, existing LMS limitations, and user expectations related to adaptive and data-driven learning were identified through preliminary interviews and document analysis. This phase involved graduate students and lecturers to capture challenges in learning personalization, feedback timeliness, and learning analytics support within the existing LMS environment.

During the design phase, the system architecture, learning workflow, and AI module specifications were formulated based on curriculum requirements, graduate learning characteristics, and learning outcome alignment. The design included adaptive learning flows, feedback mechanisms, analytics visualization, and chatbot interaction scenarios integrated into the LMS framework.

In the development phase, an AI-based e-learning prototype was built and integrated into an LMS-supported environment. The AI implementation adopted a machine learning–based approach, primarily using supervised learning algorithms for learning recommendation and prediction of learning progress, complemented by rule-based mechanisms for prerequisite enforcement and learning pathway constraints. Algorithms such as Logistic Regression and ensemble-based models were employed to analyze learner interaction data and generate adaptive recommendations, while an NLP-based model was utilized to support chatbot-driven academic assistance.

The implementation phase involved limited operational testing with real users to evaluate system functionality and usability. The system was deployed in selected graduate courses within the Educational Management Graduate Program, Universitas Negeri Medan. Participants consisted of approximately 40–60 graduate students as primary users, 8–10 lecturers as subject-matter experts and evaluators, and 5–7 expert validators who participated in Focus Group Discussions (FGD) for feasibility and pedagogical assessment.

In the evaluation phase, system usability, learning impact, and feasibility were assessed using both quantitative and qualitative methods. User perceptions and system effectiveness were measured through questionnaires, while expert validation was conducted through structured FGD sessions.

To collect comprehensive data for development and evaluation, several instruments and techniques were employed. The primary instrument was a questionnaire consisting of approximately 25–30 items, measured using a 5-point Likert scale ranging from strongly disagree to strongly agree. The questionnaire evaluated system usability, perceived usefulness, learning support quality, and user satisfaction. Instrument validity was examined through expert judgment and item correlation analysis, while reliability testing yielded a Cronbach's alpha coefficient greater than 0.80, indicating high internal consistency. In addition, semi-structured interviews were conducted to explore user needs and refine system features, particularly in relation to adaptive learning support, feedback mechanisms, and interaction challenges. Curriculum and LMS content analysis was also performed to ensure alignment between learning outcomes, course structure, and AI-generated recommendations.

The developed AI-based e-learning system prototype consisted of several core components supporting adaptive and intelligent learning. These included an adaptive learning recommendation engine for personalized learning pathways, an automatic feedback module to accelerate assessment responses, a learning analytics dashboard to visualize learning performance and engagement patterns, and an NLP-based chatbot to facilitate interactive academic support. The system also integrated a database and content management module for managing learning resources and user activity data, along with a web-based user interface designed in accordance with LMS usability principles to ensure accessibility and effectiveness in the graduate learning environment.

2.2 Measurement and Formula

a) Percentage improvement formula

The percentage improvement formula was used to quantify the relative change in key performance indicators after the implementation of the AI-based e-learning system. This metric compares post-implementation outcomes to baseline conditions and expresses the improvement as a percentage of the initial value.

$$\text{Improvement (\%)} = \frac{X_{after} - X_{before}}{X_{before}} \times 100 \quad (1)$$

where X_{before} is the baseline value and X_{after} is the post-implementation value [9].

b) User satisfaction index

The user satisfaction index was calculated to determine the overall level of user acceptance of the developed system based on questionnaire responses. Satisfaction was computed as the proportion of the total score obtained relative to the maximum possible score and converted into a percentage.

$$\text{Satisfaction (\%)} = \frac{\sum S}{S_{max}} \times 100, \quad (2)$$

where $\sum S$ is the total score obtained and S_{max} is the maximum achievable score [10].

c) Feasibility and Pedagogical Relevance (FGD)

To assess system feasibility and pedagogical relevance, expert validation scores obtained through Focus Group Discussion (FGD) were calculated using a percentage-based validation formula. The final validity score reflects the degree to which the system meets technical feasibility and pedagogical suitability criteria.

$$\text{Validity (\%)} = \frac{\sum V}{V_{max}} \times 100 \quad (3)$$

where $\sum V$ is the total expert score and V_{max} is the maximum possible validation score [11].

d) Interpretation scale for percentage scores

To interpret the percentage scores obtained from user evaluation and expert validation, this study applied the following classification criteria [12] [13]:

Table 1. Interpretation scale for percentage scores

Percentage Range	Interpretation Category	Percentage Range
85–100%	Excellent / Highly Valid	85–100%
70–84%	Very Good / Valid	70–84%
55–69%	Good / Moderately Valid	55–69%
40–54%	Fair / Low Validity	40–54%
0–39%	Poor / Not Valid	0–39%

Percentage scores were interpreted using a five-level classification scale, where values between 85–100% indicate excellent performance or high validity, while lower values represent

decreasing levels of quality and feasibility. This scale was used to classify user satisfaction results and expert validation outcomes for system feasibility and pedagogical relevance.

3 Results and Discussion

The results of this study present the developed AI-based e-learning system features and the performance outcomes obtained from user evaluation and expert validation.

3.1 System output

The AI-based e-learning prototype was successfully developed and implemented in a limited graduate learning context. The system delivered four main functional outputs: (1) adaptive learning recommendations generated from student learning progress and interaction patterns, (2) automatic feedback for quizzes and assignments to accelerate response and guidance, (3) learning analytics dashboards to visualize engagement and performance trends for students and lecturers, and (4) an NLP-powered chatbot to support academic interaction and real-time assistance. These outputs confirm that the prototype achieved the intended intelligent-learning features to support adaptive and data-driven learning in graduate education.

3.2 Quantitative results

Table 2 summarizes the effectiveness and validation outcomes. The system produced high learning gains, indicated by a 58% improvement in learning efficiency and a 65% improvement in feedback response time, demonstrating that AI-supported automation and personalization can enhance learning productivity and reduce delays in instructional support. User evaluation results also showed strong acceptance, with user satisfaction reaching 89% (excellent). Engagement indicators increased notably, as reflected in interactivity improvement (54%) and student motivation improvement (61%), suggesting that adaptive recommendations and chatbot-based assistance contribute to increased participation and learning enthusiasm.

Table 2. Effectiveness and validation results

Indicator	Result (%)	Category
Learning efficiency improvement	58%	High
Feedback response time improvement	65%	Very High
User satisfaction	89%	Excellent
Interactivity improvement	54%	High
Student motivation improvement	61%	Very High
System feasibility (FGD)	92%	Excellent
Pedagogical relevance (FGD)	85%	Very Good

Expert validation confirmed the overall readiness and instructional appropriateness of the system. The system feasibility score reached 92%**,** indicating that the prototype is technically robust and suitable for deployment in a real learning environment. Additionally, pedagogical relevance scored 85%**,** showing that the system aligns well with graduate-level learning needs and curriculum objectives. Overall, these findings demonstrate that the proposed AI-based e-learning system provides measurable benefits in effectiveness, engagement, and implementation feasibility.

3.3 The evaluation indicators

Figure 1 presents a comparative summary of the evaluation indicators. The highest results were observed in system feasibility (92%) and user satisfaction (89%), highlighting strong readiness and user acceptance. Meanwhile, significant improvements were also found in feedback response time (65%), motivation (61%), and learning efficiency (58%), confirming the system's contribution to adaptive and responsive learning processes. The overall distribution across indicators indicates consistent positive performance in both technical and pedagogical dimensions.

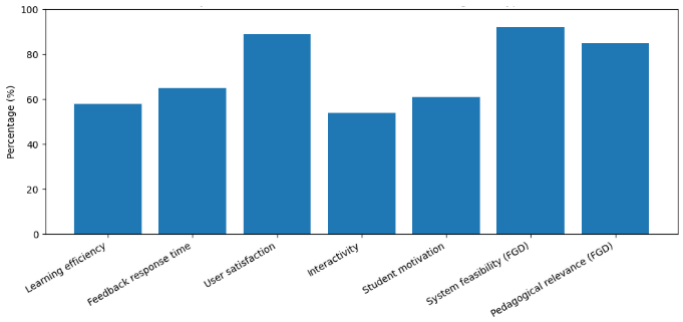

Fig. 1. Comparative summary of the evaluation indicators

3.4 Discussion

The findings confirm that the developed AI-based e-learning system improves graduate learning performance and engagement. The learning efficiency improvement (58%) indicates that students were able to complete learning tasks faster and more effectively due to adaptive recommendations and structured guidance. This result is consistent with prior studies showing that AI-driven personalized learning pathways and tailored content delivery can enhance learning performance while reducing unnecessary learning load by directing students to relevant learning resources [14].

The feedback response time improvement (65%) demonstrates that automated feedback mechanisms can significantly reduce delays commonly found in conventional LMS environments. Timely or immediate feedback plays a crucial role in supporting motivation and learning outcomes, particularly in online learning settings where students depend on fast instructional responses to maintain learning momentum and improve academic performance [15]. Therefore, the integration of AI-supported feedback in this prototype provides an important practical contribution for improving responsiveness in graduate-level learning activities.

User satisfaction reached 89%, indicating strong acceptance of the AI-based prototype. This high satisfaction level is closely linked to system usability, relevance of recommendations, and chatbot support that enhances continuous learning access. Previous research has emphasized that AI-supported tools, including chatbots integrated into LMS environments, can enhance student satisfaction and engagement by providing interactive and personalized learning assistance. Moreover, interactivity (54%) and student motivation (61%) improved substantially, which suggests that AI features encourage more frequent and meaningful learning interactions. This finding aligns with recent evidence that AI-based personalization and adaptive learning

technologies can improve engagement and motivation by supporting learner autonomy and providing more relevant learning experiences [16].

Expert validation results further strengthen the significance of the developed system. Feasibility reached 92%, showing that the platform is technically ready for implementation in real learning environments. Pedagogical relevance scored 85%, indicating that the system aligns well with learning objectives, teaching strategies, and graduate program curriculum structure. These results support the argument that AI in education is increasingly valuable when designed not only from a technical perspective but also aligned with instructional design and learning analytics frameworks to support data-driven learning decisions [17].

Overall, this study confirms that intelligent e-learning systems can foster adaptive learning and enable data-driven decision-making in graduate education. A key contribution of this research is the development of a replicable and scalable AI-based e-learning model that can be adopted by other graduate programs, consistent with trends in AI in education that emphasize adaptive learning systems, learner analytics, and AI-driven student support mechanisms.

4. Conclusion

This research successfully developed an Artificial Intelligence–based e-learning system for graduate education using the ADDIE-based R&D approach. The system integrates adaptive learning recommendations, automated feedback, learning analytics, and an NLP-powered chatbot, supporting adaptive and data-driven learning environments. Empirical evaluation results confirmed major improvements: learning efficiency increased by 58%, feedback response time improved by 65%, user satisfaction achieved 89%, interactivity increased by 54%, and student motivation improved by 61%. Expert validation (FGD) also reported high feasibility (92%) and strong pedagogical relevance (85%). These findings demonstrate that the AI-based e-learning prototype enhances learning personalization, engagement, and decision-making support in higher education. Future research may expand system testing using larger populations, cross-program evaluation, predictive learning models, and integration with institutional academic data warehouses to support broader digital transformation strategies.

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References

[1] Liu M, Yu D. Towards intelligent E-learning systems. *Educ Inf Technol (Dordr)* 2023; 28: 7845–7876.

[2] Mirza J, Borana K. A New Era in E-Learning. *Mobile Cloud Computing, Services and Engineering* 2025; 94–113.

[3] Xavier M, Meneses J, Fiuza PJ. Dropout, stopout, and time challenges in open online higher education: A qualitative study of the first-year student experience. *Open Learning: The Journal of Open, Distance and e-Learning* 2026; 41: 24–40.

[4] Hariyanto, Kristianingsih FXD, Maharani R. Artificial intelligence in adaptive

education: a systematic review of techniques for personalized learning. *Discover Education* 2025; 4: 458.

[5] Strielkowski W, Grebennikova V, Lisovskiy A, et al. AI-driven adaptive learning for sustainable educational transformation. *Sustainable Development* 2025; 33: 1921–1947.

[6] Siswanti T, Chai N, Som R. The Future of Adaptive Learning Systems in Education. *Al-Hijr: JIIET: Journal International Inspire Education Technology*; 4.

[7] Yunita S, Gandamana A, Lubis W, et al. Innovative Learning Strategies by Embedding Design Thinking-based Project Learning in Textbooks for Edupreneurial Impact. *Aptisi Transactions on Technopreneurship (ATT)* 2025; 7: 627–637.

[8] Pankaew K, Chanowan S, Piyakoson S. Design and Development of Innovation towards Contemporary Educational Innovation. *Asian Journal of Education and Training* 2025; 11: 88–95.

[9] Puan OC, Masri KA, Razelan ISM, et al. STATISTICAL ANALYSIS OF RED-LIGHT VIOLATIONS ACROSS DIFFERENT TRAFFIC SIGNAL SYSTEMS AND OPERATING CONDITIONS. *PLANNING MALAYSIA*; 23.

[10] Hu L, Chen Y, Cao E, et al. User experience \& usability of wearable health device: A bibliometric analysis of 2014--2023. *Int J Hum Comput Interact* 2025; 41: 5100–5119.

[11] Chauhan A, Khaliq F, Nayak KR. Assessing Quality of Scenario-Based Multiple-Choice Questions in Physiology: Faculty-Generated vs. ChatGPT-Generated Questions among Phase I Medical Students. *Int J Artif Intell Educ* 2025; 1–30.

[12] Ara J, Sik-Lanyi C, Kelemen A, et al. An inclusive framework for automated web content accessibility evaluation. *Univers Access Inf Soc* 2025; 24: 1581–1607.

[13] As M, Harahap F, Febrian D, et al. Metaverse approach as educational tool in online learning systems. In: *The 10th Annual International Seminar on Trends in Science and Science Education (AISTSSE) 2023*. Sciendo, pp. 560–570.

[14] Singh TM, Reddy CKK, Murthy BVR, et al. Ai and education: Bridging the gap to personalized, efficient, and accessible learning. In: *Internet of behavior-based computational intelligence for smart education systems*. IGI Global, 2025, pp. 131–160.

[15] Maphalala MC, Mkhasibe RG, Mncube DW. Exploring the roles of AI-powered e-tutors in enhancing self-directed learning in open distance e-learning courses. *Interdisciplinary Journal of Education Research* 2025; 7: a12--a12.

[16] As M, Harahap F, Subaedah S, et al. Impact of Virtual Worlds on Student Engagement and Academic Performance: An Analysis of Online Learning Using Second Life Technology. *Journal of Soft Computing and Data Mining* 2024; 5: 70–78.

[17] Sajja R, Sermet Y, Cwiertny D, et al. Integrating AI and learning analytics for data-driven pedagogical decisions and personalized interventions in education. *Technology, knowledge and learning* 2025; 1–31.