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Designing Intelligent Learning Ecosystems: The Role of Artificial Intelligence and Blended Learning in Enhancing Digital Education Quality

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A B S T R A C T

This study presents a model for designing intelligent learning ecosystems that enhance the quality of digital education through the integration of artificial intelligence and blended learning, with Islamic Azad University as the empirical context. The research addresses persistent challenges in e-learning, including limited interaction, unequal access, and the need to respond to diverse learner profiles through technology-enhanced educational design. A mixed-methods approach was employed. In the qualitative phase, semi-structured interviews were conducted with 15 experts in education and educational technology selected through purposive sampling. In the quantitative phase, data were collected from 384 faculty members and university staff using stratified random sampling across regions and academic fields. Qualitative data were analyzed through thematic analysis, while quantitative data were examined using Partial Least Squares Structural Equation Modeling (PLS-SEM), Artificial Neural Networks (ANN), and the MABAC multi-criteria decision-making method. Findings revealed that the proposed ecosystem is built around three core dimensions: blended learning, artificial intelligence capabilities, and digital education quality. Blended learning was defined through flexibility, interaction, personalization, and infrastructure, while AI capabilities included educational data analysis, intelligent recommendation, intelligent support, and automated assessment. The quality of digital education was reflected in learner satisfaction, learning effectiveness, and educational interaction. The model demonstrated strong explanatory power (R^2 = 0.712). ANN results identified learner satisfaction and learning effectiveness as the most influential indicators, and MABAC ranked intelligent support as the highest-priority AI capability. The study concludes that integrating AI-driven support into blended learning environments can provide a practical pathway for strengthening digital education quality and informing future policy and implementation in higher education.

Keywords: *intelligent learning ecosystems, artificial intelligence, blended learning, digital education quality, e-learning, higher education*

1. Introduction

The rapid expansion of digital technologies has reshaped higher education and has made e-learning a central part of university teaching and learning. Although online education has improved access, flexibility, and continuity, concerns about educational quality remain substantial, especially in systems that still face uneven infrastructure, limited personalization, and insufficient interaction. Within this context, blended learning has emerged as an important pedagogical response because it combines the strengths of face-to-face instruction with the flexibility and scalability of digital environments. The literature cited in the thesis shows that blended learning is no longer understood as a simple mixture of classroom and online delivery; rather, it is increasingly viewed as a strategic redesign of teaching and learning in higher education (Graham, 2009; Halverson et al., 2023; Heinze & Procter, 2010; Horn & Staker, 2014; Jones & Ravishankar, 2021). The theoretical basis of blended learning in the thesis emphasizes learner-centeredness, flexibility, active participation, and the purposeful coordination of content, technology, and human interaction. In this view, effective blended learning environments are not defined only by the presence of digital tools, but by their ability to support meaningful engagement, self-regulated learning, and diverse learning preferences. The thesis also highlights major blended learning models, especially those of Graham and Horn and Staker, as useful frameworks for designing integrated learning experiences. These models support the idea that high-quality digital education depends on the alignment of pedagogical design, access to digital resources, and structured opportunities for interaction and feedback. At the same time, artificial intelligence has become an increasingly influential force in digital education. The references listed in the file suggest that AI can enhance learning systems through educational data analysis, adaptive support, intelligent recommendation, automated assessment, and other forms of personalized intervention (Hamadneh et al., 2022; Ilieva et al., 2023; Joseph et al., 2024; Kadhim & Hassan, 2020; Katsamakas et al., 2024). Rather than replacing teachers, AI expands the capacity of educational systems to respond to variation in learner needs, monitor performance, generate timely feedback, and improve decision-making in teaching and assessment. When embedded within blended learning, these capabilities may improve both the efficiency and the responsiveness of digital learning ecosystems. Another central issue addressed in the thesis is the quality of e-learning itself. The file reviews several frameworks for understanding educational quality in digital contexts, including the Sloan-C perspective, the Quality Matters framework, and integrated models of blended learning and e-learning success. Across these models, quality is treated as a multidimensional construct that includes learner satisfaction, learning effectiveness, interaction quality, accessibility, support, and instructional design. This perspective is especially important because it shifts attention away from technology alone and toward the broader educational ecosystem in which technology operates. In other words, digital quality is not achieved merely by introducing platforms or tools; it is achieved when those tools are aligned with teaching goals, learner needs, and institutional capacities (Istenič, 2024; Komsiyah, 2023; Legon & Garrett, 2018). The article argues that this issue is particularly relevant in the context of Iranian higher education and Islamic Azad University. Despite growing interest in e-learning and digital transformation, universities may still face practical barriers such as unequal technological access, insufficient digital readiness, financial limitations, fragmented systems, and resistance to educational change. The extracted text also shows that previous studies have often examined blended learning and artificial intelligence separately, while fewer studies have proposed a comprehensive model that integrates both for the specific purpose of improving e-learning quality. This gap is important because higher education institutions need frameworks that are not only theoretically sound but also operational and context-sensitive. Accordingly, the present study aimed to design and validate a model of blended learning supported by artificial intelligence for improving digital education quality at Islamic Azad University. The study sought to identify the main dimensions of blended learning, determine the most relevant AI capabilities for educational improvement, validate the proposed framework empirically, and prioritize the relative importance of different components. By combining qualitative exploration with quantitative validation, the study contributes to the literature on intelligent learning ecosystems and provides a practical basis for institutional planning, faculty development, and future policy-making in digital higher education.

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2. Methods and Materials

This study employed a mixed-methods design grounded in pragmatism and organized as a sequential exploratory process in which qualitative findings informed quantitative model validation. The research was conducted in the context of Islamic Azad University and focused on designing a blended learning model supported by artificial intelligence to improve the quality of e-learning. The time frame of the study, extended from Bahman 1403 to Shahrivar 1404. In the qualitative phase, semi-structured interviews were conducted with 15 experts in e-learning, blended learning, and artificial intelligence. Participants were selected through purposive sampling, and the interview data were analyzed using thematic analysis. This stage aimed to identify the key concepts, categories, and dimensions relevant to the design of the proposed model. The qualitative analysis led to an initial conceptual framework that included dimensions related to blended learning, AI capabilities, and e-learning quality. In the quantitative phase, a questionnaire developed from the qualitative model was distributed among 384 faculty members and university staff selected through stratified random sampling based on geographical regions and academic disciplines. The quantitative analysis was conducted in three stages. First, Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to assess and validate the proposed model. Second, Artificial Neural Networks (ANN) were employed to determine the optimal weights of key indicators. Third, the MABAC multi-criteria decision-making method was used to rank the identified AI capabilities in terms of their contribution to improving e-learning quality. Overall, the methodology combined qualitative depth with quantitative rigor and allowed the study to move from conceptual identification to empirical validation and prioritization. This design was particularly suitable for a topic that required both contextual understanding and model testing in a real higher education setting.

Figure 1

Proposed intelligent learning ecosystem model

3. Findings and Results

The results of the present study support the proposed model of intelligent learning ecosystems for improving the quality of digital education in higher education settings. As illustrated in Figure 1, the final model is structured around three major dimensions: blended learning, artificial intelligence capabilities, and e-learning quality. The qualitative phase showed that blended learning constitutes the pedagogical core of the model, artificial intelligence provides the enabling technological layer, and e-learning quality represents the ultimate educational outcome of the system.

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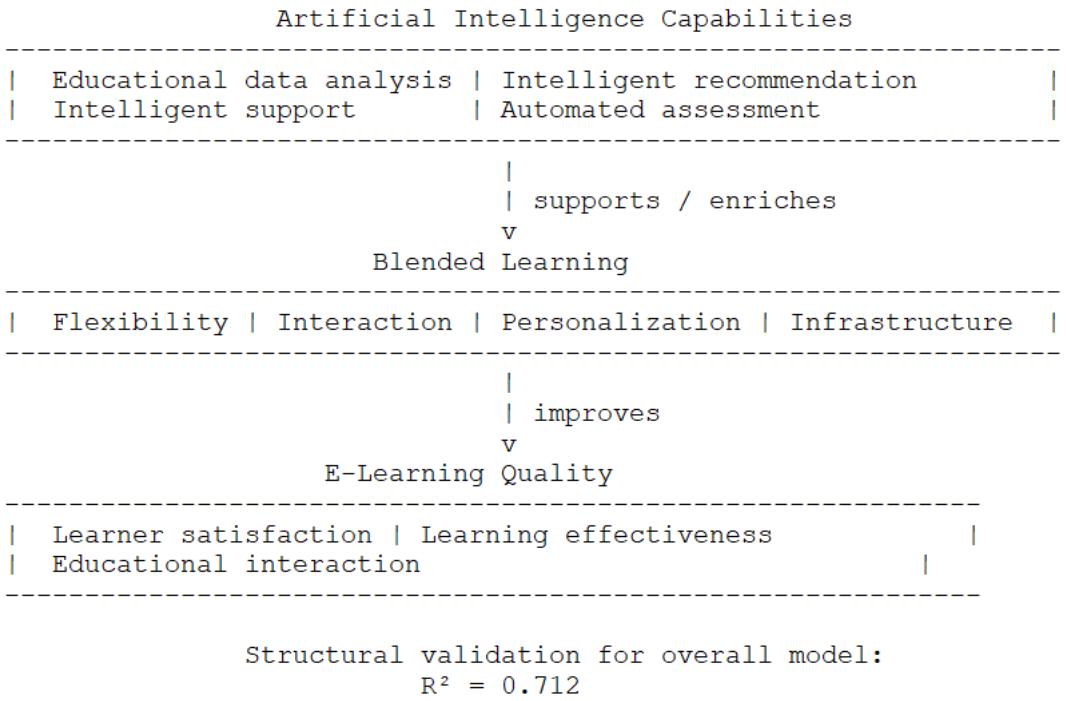

The qualitative findings are summarized in Table 1. The thematic analysis identified 11 subthemes grouped under the three main dimensions. Within the blended learning dimension, the extracted components included flexibility, interaction, personalization, and infrastructure and access. These results indicate that effective blended learning is not limited to combining online and face-to-face delivery modes, but rather depends on the capacity of the learning environment to provide adaptable pathways, active communication, individualized learning opportunities, and sufficient technological support. In this respect, blended learning emerged as the foundational educational mechanism through which digital education quality can be enhanced.

Table 1

Summary of qualitative results and final thematic structure

Main dimension	Sub-dimension / component	Interpretation in the thesis
Blended learning	Flexibility	Ability to adjust learning time and place; includes flipped learning and flexible access to recorded content
Blended learning	Interaction	Active communication among teacher, student, and content
Blended learning	Personalization	Adapting content and learning pathways to learner needs
Blended learning	Infrastructure and access	Technological prerequisites such as stable internet and digital access
AI capabilities	Educational data analysis	Processing educational data to identify patterns and improve learning
AI capabilities	Intelligent recommendation	Providing personalized recommendations based on learner needs
AI capabilities	Intelligent support	Offering automated and interactive support during learning
AI capabilities	Automated assessment	Conducting assessment and feedback processes automatically
E-learning quality	Learner satisfaction	Positive learner perception of the educational experience
E-learning quality	Learning effectiveness	Achievement of educational goals and academic progress
E-learning quality	Educational interaction	Quality of communication and interaction in the digital learning environment

The second main dimension consisted of artificial intelligence capabilities, including educational data analysis, intelligent recommendation, intelligent support, and automated assessment. These findings suggest that

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artificial intelligence contributes to digital education not merely through automation, but through more adaptive, responsive, and data-informed learning processes. Educational data analysis enables monitoring of learner behavior and performance patterns; intelligent recommendation supports personalized content delivery; intelligent support facilitates timely guidance and sustained motivation; and automated assessment improves the efficiency and consistency of feedback and evaluation processes. Together, these capabilities form the technological infrastructure of the proposed ecosystem.

The third dimension, e-learning quality, was represented by learner satisfaction, learning effectiveness, and educational interaction. These indicators frame educational quality as a multidimensional and learner-centered construct. The findings therefore show that the proposed model does not treat technological integration as an end in itself; instead, it emphasizes the improvement of meaningful educational outcomes and experiences.

The quantitative findings further confirmed the validity of the proposed model. As reported in Table 2, the structural model demonstrated acceptable psychometric properties, including satisfactory convergent validity, composite reliability, and discriminant validity. Most importantly, the coefficient of determination for e-learning quality was $R^2 = 0.712$, indicating that the proposed dimensions and indicators explained 71.2% of the variance in e-learning quality. This finding reflects strong explanatory power and provides empirical support for the conceptual framework derived from the qualitative phase.

Table 2

Quantitative validation of the proposed model

Indicator	Reported result	Interpretation
Sample size	384	Quantitative validation sample
Convergent validity	AVE > 0.50	Acceptable
Composite reliability	CR > 0.70	Acceptable
Discriminant validity	HTMT < 0.85	Acceptable
Path significance	$p < 0.05$	Significant structural paths
Coefficient of determination for e-learning quality	$R^2 = 0.712$	The model explains 71.2% of variance in e-learning quality

The ANN analysis, presented in Table 3, clarified the relative importance of the indicators associated with blended learning and e-learning quality. Among all indicators, learner satisfaction obtained the highest optimal weight (0.2772), followed by learning effectiveness (0.1780). These findings indicate that the perceived quality of digital education within the proposed ecosystem depends most strongly on students' positive educational experiences and the extent to which learning outcomes are effectively achieved. The ANN model also showed strong performance, with a reported MSE of 0.0060 and R^2 of 0.9580, suggesting a high level of predictive precision in estimating the importance of the indicators.

Table 3

Optimal weights of e-learning quality and blended learning indicators based on ANN

Rank	Indicator	Weight
1	Learner satisfaction	0.2772
2	Learning effectiveness	0.1780
3	Flexibility	0.1502
4	Interaction	0.1281
5	Educational interaction	0.1264
6	Infrastructure and access	0.0998
7	Personalization	0.0404
ANN performance criterion	Value	
MSE	0.0060	
R^2	0.9580	

Finally, the MABAC ranking of AI capabilities is shown in Table 4. The results ranked intelligent support in the first position, followed by intelligent recommendation, automated assessment, and educational data analysis. This

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ranking indicates that, in the study context, the most influential AI capability for enhancing digital education quality is not merely analytical processing, but supportive and interactive functionality that directly assists learners throughout the learning process. These findings provide practical guidance for universities seeking to prioritize AI investments within blended learning environments.

Table 4

Ranking of AI capabilities using MABAC

Rank	AI capability	Code	Q value
1	Intelligent support	A3	0.2373
2	Intelligent recommendation	A2	0.2343
3	Automated assessment	A4	-0.1234
4	Educational data analysis	A1	-0.1399

4. Discussion and Conclusion

The findings support the central argument that improving digital education quality requires an integrated ecosystem rather than isolated technological interventions. The model designed in this study links pedagogy, technology, and educational quality in a single framework. This is consistent with the literature in the file that presents blended learning as a strategic educational design rather than a simple combination of modalities (Graham, 2009; Heinze & Procter, 2010; Horn & Staker, 2014; Istenič, 2024). The present findings extend that perspective by showing that blended learning becomes more effective when it is strengthened by AI capabilities that respond to learner needs in a targeted and adaptive manner. The prominence of flexibility, interaction, personalization, and infrastructure in the blended learning dimension suggests that quality digital education depends on both pedagogical design and institutional readiness. This aligns with the quality frameworks reviewed, including the Sloan-C approach and Quality Matters, both of which emphasize that successful online learning requires coherent design, support services, interaction, and accessibility. In the present study, these elements were not peripheral concerns; they formed the foundation upon which AI could operate meaningfully. Without adequate infrastructure and interaction, the benefits of intelligent systems would likely remain limited. The AI-related findings are also theoretically important. The ranking of intelligent support as the highest-priority capability suggests that the most valuable contribution of AI in higher education may be relational and facilitative rather than purely computational. This interpretation is compatible with the references in the file that discuss AI in terms of personalized assistance, adaptive learning, and enhanced student engagement (Hamadneh et al., 2022; Joseph et al., 2024; Kadhim & Hassan, 2020; Katsamakas et al., 2024). In other words, the study implies that AI is most educationally effective when it helps institutions humanize digital learning rather than merely automate it. This is a valuable insight for universities that may otherwise focus too heavily on analytics or administrative efficiency. The strong importance of learner satisfaction and learning effectiveness further reinforces the view that digital quality should be evaluated through both experiential and substantive outcomes. Satisfaction had the highest ANN weight, but it did not stand alone; it was closely followed by learning effectiveness, showing that a high-quality intelligent learning ecosystem must be both supportive and educationally productive. This result resonates with the quality models discussed, where learner experience, instructional effectiveness, and interaction are treated as interdependent dimensions. It also indicates that universities should avoid implementing AI merely as a technical innovation; instead, AI initiatives should be judged by whether they improve the real learning experience and outcomes of students. From an applied perspective, the study offers a practical roadmap for higher education institutions, especially Islamic Azad University. The research recommends investment in infrastructure development and faculty training, and the present findings make that recommendation even more compelling. Intelligent learning ecosystems require not only software and data, but also academic staff who can interpret, use, and integrate these tools into sound pedagogical practice. The findings therefore suggest that institutional strategy should begin with capacity-building, learner support systems, and coherent blended course design, while gradually expanding into more advanced AI-supported functions such as recommendation and automated

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assessment. At the same time, the discussion should acknowledge the limits of the study. The result itself indicates that the research was cross-sectional, which means that the model was validated at one point in time rather than across multiple stages of implementation. As a result, the findings provide a strong conceptual and empirical starting point, but further longitudinal and comparative studies would be helpful to examine how intelligent learning ecosystems evolve in practice. Even so, the present study makes an important contribution by offering a validated and context-sensitive framework that links blended learning, AI capabilities, and digital education quality in a way that is both theoretically meaningful and operationally useful.

Authors' Contributions

Fatemeh Akbari Markhali contributed to conceptualization, investigation, data collection, formal analysis, and original drafting of the manuscript. Mehdi Keramatpour contributed to supervision, methodology development, validation of the analytical framework, critical revision of the manuscript, and final approval of the version to be published. Both authors approved the final manuscript and agreed to be accountable for all aspects of the work.

Declaration

The authors declare that artificial intelligence tools were used only to assist with language editing, translation, and improvement of the manuscript's readability. All conceptualization, study design, data collection, data analysis, interpretation of findings, and final approval of the manuscript were performed by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

Transparency Statement

The data supporting the findings of this study are derived from the doctoral thesis conducted at Islamic Azad University. Because the study includes interview materials and institutional survey responses, the data are not publicly available in full form but may be made available by the corresponding author upon reasonable academic request and in accordance with confidentiality requirements.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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