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Identification and Prioritization of Factors Affecting E-Learner Satisfaction in Mathematics Based on the Fuzzy Analytic Hierarchy Process (Case Study: Farhangian University of Mazandaran)

Morteza. Gorzinnezhad[1*], Davood. Darvishi Salookolaei[2], Mohammad. Dehghandar[Error! Reference source not found.]

[1] Department of Basic Sciences, Farhangian University, Tehran, Iran.
[2] Assistant Professor, Department of Mathematics, Payame Noor University, Tehran, Iran.

*** Corresponding author email address**: mgorzinnezhad95@gmail.com

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ABSTRACT

The purpose of this study was to evaluate the factors influencing the satisfaction of mathematics students in an e-learning environment. To achieve this goal, a library-based and descriptive research method was employed. The statistical population consisted of experts, mathematics specialists, and e-learning curriculum planners at Farhangian University of Mazandaran. The sample included seven experts who were purposively selected based on the research objectives and questions. Based on the theoretical literature and in consultation with experts and specialists, the factors and criteria of e-learning environment quality were categorized into four main dimensions—technical system and technology infrastructure quality, educational quality, information and content quality, and service quality—comprising a total of 24 criteria. The weight of each of these indicators within the studied population was determined using an expert questionnaire and the Fuzzy Analytic Hierarchy Process (FAHP). Data analysis was performed using the Super Decisions software. The findings revealed that, in terms of importance, the factors related to technical systems and technology infrastructure, technology and instructional design, content development, and support services were evaluated and ranked, respectively, as the key determinants of e-learning environment quality.

Keywords: *ranking, e-learning, satisfaction, Analytic Hierarchy Process (AHP), fuzzy numbers.*

1. Introduction

The rapid growth of e-learning in the past two decades has transformed the educational landscape and created new opportunities for accessible, flexible, and cost-effective instruction across disciplines, including mathematics education. However, despite significant technological advances, many e-learning initiatives fail to achieve their intended outcomes due to low learner satisfaction and insufficient alignment between instructional design, system usability, and learners' needs (Cheawjindakarn et al., 2013; Seraji & Attaran, 2012). Learner satisfaction is widely recognized as a critical success factor for sustaining engagement, improving performance, and ensuring the effectiveness of digital learning systems (Maria de Lourdes et al., 2011; Mohammadi, 2015). In mathematics education, where abstract concepts and problem-solving skills dominate, dissatisfaction can lead to disengagement and poor achievement (Jafarabadi Ashtiani & Nomanov, 2021; Ragib, 2023).

Advances in e-learning technology have produced diverse systems, but their success depends on the interplay of technical infrastructure, instructional quality, content design, and support services (Asgari et al., 2023; Yakubu & Dasuki, 2018). Technical aspects such as system interactivity, security, accessibility, and user-friendly design influence perceived ease of use and satisfaction (Gorzin Nezhad et al., 2020; Karimzadganmoghadam et al., 2012). Instructional quality—including clear objectives, adaptive learning paths, and collaborative opportunities—is equally essential for sustaining motivation and promoting meaningful learning (Pei-Chen & Hsing Kenny, 2025; Poorasghar et al., 2015). Furthermore, the quality and relevance of content significantly impact learners' trust and engagement (Chen & Young Tat Yao, 2016; Filippova, 2015). Service-related factors such as timely support, responsiveness, and effective feedback channels further shape students' perceptions of the e-learning environment (Elahi et al., 2015; Maria de Lourdes et al., 2011).

Despite the theoretical recognition of these variables, a systematic and context-sensitive framework for evaluating e-learning success in mathematics remains underdeveloped, particularly in non-Western settings such as Iran. Previous studies have highlighted cultural and contextual differences in technology acceptance, learning styles, and system usability (Chen & Tseng, 2012; Narenji Thani et al., 2021). While research on the Technology Acceptance Model (TAM) and Information Systems (IS) success model provides valuable foundations (Mohammadi, 2015; Yakubu & Dasuki, 2018), localized studies show the need to adapt these frameworks to learners' expectations, institutional resources, and discipline-specific requirements (Faraj Elahi et al., 2020; Zare et al., 2024).

The evolution of e-learning also brings new pedagogical and technological complexities. Modern e-learning increasingly integrates multimedia resources, interactive simulations, and gamification elements to improve engagement and cognitive performance (Pei-Chen & Hsing Kenny, 2025; Sadeghi, 2024). For mathematics education, these tools can help visualize abstract concepts and support self-paced exploration (Ragib, 2023; Zare et al., 2023). Yet the effectiveness of such innovations depends on their alignment with learners' cognitive preferences and institutional readiness (Fazeli et al., 2021; Oulamine et al., 2025). Research shows that poorly designed interfaces, irrelevant multimedia, or weak instructional scaffolding can increase cognitive load and reduce satisfaction (Chen & Young Tat Yao, 2016; Farhadi, 2015).

Furthermore, ensuring high-quality content remains a persistent challenge. Content must be accurate, comprehensive, current, and aligned with learning objectives to foster trust and satisfaction (Farhadi, 2015; Filippova, 2015). In mathematics, the clarity and sequence of topics, the availability of examples, and the adaptability of materials to diverse learning styles are essential (Jafarabadi Ashtiani & Nomanov, 2021; Zare et al., 2024). Active teaching strategies in e-learning, such as interactive problem-solving, adaptive feedback, and collaborative group work, have been shown to increase motivation and understanding (Fazeli et al., 2021; Sadeghi, 2024).

Service quality, though sometimes overlooked, is equally crucial. Effective guidance and responsive technical support reduce frustration and build trust in digital platforms (Elahi et al., 2015; Maria de Lourdes et al., 2011). Research indicates that the speed of service delivery, the ability to address technical challenges, and the responsiveness to learner feedback directly affect satisfaction and retention (Dehghandar et al., 2020; Faraj Elahi et al., 2020). Additionally, user-driven improvements, such as integrating students' suggestions into system design and course management, can enhance perceived system value (Asgari et al., 2023; Karimzadganmoghadam et al., 2012).

Given the multidimensional nature of learner satisfaction, robust methodologies are required to evaluate and prioritize influencing factors. The Fuzzy Analytic Hierarchy Process (FAHP) has been proposed as an effective approach to address uncertainty in expert judgment and handle the complexity of multi-criteria decision-making (Babakordi, 2020; Dehghandar, Pabasteh, et al., 2021). Fuzzy logic enables decision-makers to express imprecise preferences while maintaining analytical rigor (Babakordi, 2020; Elahi et al., 2015). Studies applying FAHP in educational technology contexts have successfully ranked key success criteria, offering actionable insights for institutional policy and system design (Dehghandar et al., 2020; Gorzin Nezhad et al., 2020).

In the Iranian higher education context, research on e-learning system evaluation is expanding but remains fragmented. Some studies have explored the success of learning management systems (LMS) and usability frameworks (Asgari et al., 2023; Zare et al., 2023), while others have examined learners' competencies and readiness (Narenji Thani et al., 2021). Still, there is limited focus on discipline-specific factors, especially for mathematics, where cognitive load, problem-solving demands, and conceptual abstraction are unique challenges (Jafarabadi Ashtiani & Nomanov, 2021; Ragib, 2023). Moreover, earlier frameworks often fail to consider emerging trends such as artificial intelligence and adaptive learning analytics that can influence satisfaction and learning outcomes (Oulamine et al., 2025; Reis et al., 2024).

Understanding these complexities is not merely theoretical but has direct implications for policy and practice. Universities investing in digital education require actionable models to optimize technical infrastructure, instructional design, and support systems (Cheawjindakarn et al., 2013; Pei-Chen & Hsing Kenny, 2025). With the increasing use of blended and fully online programs in Iranian teacher training universities (Faraj Elahi et al., 2020; Zare et al., 2024), identifying and ranking satisfaction factors helps administrators allocate resources strategically. For mathematics teacher training in particular, such frameworks guide the development of adaptive content, interactive assessments, and supportive digital ecosystems (Jafarabadi Ashtiani & Nomanov, 2021; Poorasghar et al., 2015).

Additionally, the COVID-19 pandemic accelerated digital adoption but exposed weaknesses in e-learning preparedness, such as uneven infrastructure, unstandardized content, and insufficient training for educators (Dehghandar, Ahmadi, et al., 2021; Fazeli et al., 2021). Addressing these gaps requires integrating user satisfaction metrics with technological and pedagogical strategies (Farhadi, 2015; Seraji & Attaran, 2012). As institutions move toward sustainable digital transformation, frameworks rooted in both global best practices and local context are essential (Oulamine et al., 2025; Yakubu & Dasuki, 2018).

Therefore, this study aims to provide a systematic and evidence-based model for evaluating and prioritizing the factors influencing mathematics e-learners' satisfaction in higher education. By integrating expert knowledge with FAHP methodology, it extends the existing literature on e-learning success models and adapts them to the specific requirements of mathematics education (Dehghandar et al., 2020; Gorzin Nezhad et al., 2020). Unlike generic e-learning evaluations, this research accounts for both cognitive and technological complexities, offering a more discipline-sensitive approach.

Furthermore, the research builds on prior efforts to combine technical, pedagogical, and service quality indicators into a single hierarchical model (Asgari et al., 2023; Cheawjindakarn et al., 2013). It also incorporates new theoretical perspectives on multimedia design and gamified environments (Pei-Chen & Hsing Kenny, 2025; Sadeghi, 2024), ensuring relevance to the contemporary digital learning landscape. By focusing on user-centered analysis, it bridges the gap between system designers and learners, offering actionable recommendations for improving satisfaction and academic performance (Maria de Lourdes et al., 2011; Mohammadi, 2015).

In summary, the increasing reliance on e-learning for mathematics education calls for a comprehensive understanding of satisfaction drivers. This study responds to that need by synthesizing the multi-dimensional factors identified in the literature and localizing them for the Iranian higher education system. It leverages the FAHP method to systematically rank these factors, addressing uncertainty in expert evaluations while producing practical insights for institutional decision-making

2. Methods and Materials

This research is applied–developmental and descriptive in purpose, correlational in type, and survey-based in strategy. The method of collecting the required information during the literature review stage involved library research, including the study of articles, books, journals, theses, and other valid scientific databases.

The thematic scope of this research relates to the concepts and components of measuring the success of e-learning systems. The geographical scope of this study is Farhangian University of Mazandaran. This research, after exploratory studies, formally began in the summer of 2019 and ended in the summer of 2020. Its data were collected during the 2019–2020 academic year.

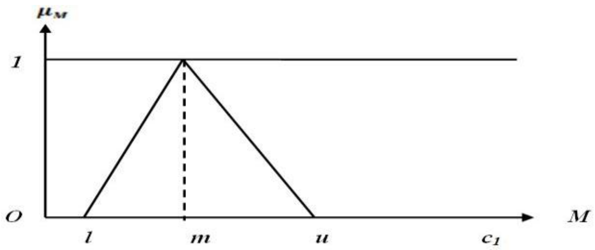
For collecting field data, a questionnaire was used to prioritize the factors influencing the success of e-learning systems in universities based on pairwise comparisons. The statistical population included all professors, experts, specialists, and practitioners active in e-learning at

Farhangian University of Mazandaran. A total of seven experts were purposively selected, each with at least 10 years of university-level mathematics teaching experience, teaching experience in e-learning environments, experience conducting in-service e-learning courses, and published articles on e-learning, aligned with the objectives and questions of this research.

Individuals' judgments about priorities are often not sufficiently clear for precise numerical estimation; however, fuzzy logic is useful for addressing problems characterized by ambiguity and uncertainty. The fuzzy theory was first introduced by Lotfi Zadeh (1965) to handle the uncertainty inherent in human perception. A triangular fuzzy number is shown in Figure 3.

Figure 1

Representation of a Triangular Fuzzy Number



Triangular fuzzy numbers are presented as (l, m, u), where the parameters *l*, *m*, and *u* represent, respectively, the smallest possible expected value, the most likely expected value, and the largest possible expected value.

A triangular fuzzy number is defined as:

$$\mu(x/M) = \begin{cases} 0 & x < l \\ (x - l) / (m - l) & l \le x \le m \\ (u - x) / (u - m) & m \le x \le u \\ 0 & x > u \end{cases}$$

Arithmetic operations on triangular fuzzy numbers are given below:

Addition of fuzzy numbers:

$(L_1, M_1, U_1) \oplus (L_2, M_2, U_2) = (L_1 + L_2, M_1 + M_2, U_1 + U_2)$

Multiplication of fuzzy numbers:

$(L_1, M_1, U_1) \otimes (L_2, M_2, U_2) = (L_1L_2, M_1M_2, U_1U_2)$

For any real number *k*:

$k(L_1, M_1, U_1) = (kL_1, kM_1, kU_1)$

Subtraction of fuzzy numbers:

$(L_1, M_1, U_1) \ominus (L_2, M_2, U_2) = (L_1 - U_2, M_1 - M_2, U_2 - L_1)$

Division of fuzzy numbers:

$(L_1, M_1, U_1) \div (L_2, M_2, U_2) = (L_1 / U_2, M_1 / M_2, U_2 / L_1)$

Inverse of a triangular fuzzy number:

$(L_1, M_1, U_1)^{-1} = (1 / U_1, 1 / M_1, 1 / L_1)$

In this study, Buckley's geometric mean method was used to calculate the relative weights in pairwise comparisons (Buckley, 1985). Suppose $\tilde{P}_{ij}$ represents the set of preferences of decision-makers regarding one criterion compared to another. The pairwise comparison matrix is formed as:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{P}_{12} & \dots & \tilde{P}_{1n} \\ \tilde{P}_{21} & 1 & \dots & \tilde{P}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{P}_{n1} & \tilde{P}_{n2} & \dots & 1 \end{bmatrix}$$

where *n* is the number of related elements in each row. The fuzzy weights of each criterion in the pairwise comparison matrix are obtained using Buckley's geometric mean method. The geometric mean of the fuzzy comparisons of criterion *i* with respect to each other criterion is calculated as:

$\tilde{r}_i = (\prod_{j=1}^{n} \tilde{P}_{ij})^{\wedge}(1/n) \quad \text{for } i = 1, 2, 3, \dots, n$

The fuzzy weight of the *i*-th criterion is represented by a triangular fuzzy number:

$w_i = r_i \otimes (r_1 \oplus r_2 \oplus \dots \oplus r_m)^{-1}$

After computing the fuzzy weight factors, the weights are defuzzified and then normalized using the following formula:

$w\_crisp = (l + 2m + u) / 4$

In this study, to assign weights in the pairwise comparisons, the linguistic terms and triangular fuzzy numbers presented in Table 2 were used.

Table 1

Linguistic Terms and Triangular Fuzzy Numbers for Weighting Criteria

Code	Importance Level	Lower Bound (L)	Middle Bound (m)	Upper Bound (u)
1	Equal importance	1	1	1
2	Equal to moderately more important	1	2	3
3	Moderately more important	2	3	4
4	Moderately to strongly more important	3	4	5
5	Strongly more important	4	5	6
6	Strongly to very strongly more important	5	6	7
7	Very strongly more important	6	7	8
8	Very strongly to extremely more important	7	8	9
9	Extremely more important	8	9	10

3. Findings and Results

Based on the review of the literature and previous studies, as well as the opinions of experts, 24 indicators affecting the evaluation of success factors for mathematics e-learners were identified and extracted in four dimensions, as presented in Table 3.

Table 2

Introduction of Research Factors

Row	Main Criterion	Sub-Criterion	Code
1	Technical System Quality	System interactivity	C11
		Ease of access to online resources	C12
		Ease of system use	C13
		System user-friendliness	C14
		Degree of system personalization	C15
		System security assessment	C16
		System flexibility	C17
		Structured design	C18
		Possibility of communication with students	C19
2	Educational Quality	Organizational vision for funding and infrastructure provision	C21
		Compatibility of the e-learning system with different learning styles	C22
		Capability for performance and learning assessment	C23
		Potential for collaborative learning	C24
		Needs assessment and instructional design aligned with course objectives	C25
3	Information and Content Quality	Completeness and comprehensiveness of information and content	C31
		Up-to-dateness of information and content	C32
		Understandability of information and content	C33
		Accuracy of information and content	C34
		Relevance of information and content	C35
4	Service Quality	Provision of guidance services	C41
		Timely responsiveness	C42
		Speed of service delivery	C43
		Course management	C44
		Reflection of user feedback	C45

Initially, all criteria in each layer were compared to the criteria in the layer above, and these pairwise comparisons were placed in a matrix called the pairwise comparison matrix. To create these matrices, the mean of the fuzzy numbers obtained from the questionnaires was used. Pairwise comparison matrices were constructed for the criteria of technical system quality, educational quality, information and content quality, and service quality.

The pairwise comparison matrix for the main criteria is presented below, where the rows and columns correspond, respectively, to Technical Quality (C1), Educational Quality (C2), Information and Content Quality (C3), and Service Quality (C4).

Table 3

Pairwise Comparison Matrix of Main Criteria

	C1	C2	C3	C4
C1	(1,1,1)	(1.12,1.35,1.51)	(1.15,1.47,1.7)	(1.23,1.61,1.96)
C2	(0.66,0.74,0.89)	(1,1,1)	(1,1,1)	(1.06,1.39,1.61)
C3	(0.59,0.68,0.87)	(1,1,1)	(1,1,1)	(1.02,1.35,1.67)
C4	(0.51,0.62,0.81)	(0.62,0.72,0.94)	(0.6,0.74,0.98)	(1,1,1)

To calculate the inconsistency ratio, the fuzzy matrix in Table 4 was first converted into a crisp matrix using the formula:

w_crisp = (l + 2m + u) / 4

Then, using the Super Decisions software, the inconsistency ratio was computed, as illustrated in Figure 4.

The results show that the inconsistency ratio equals 0.001, which is less than 0.1, indicating an acceptable level of consistency.

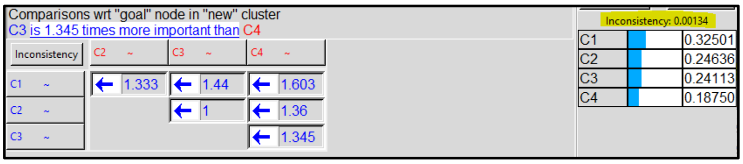
Table 4

Calculation of the Inconsistency Ratio

Crisp	C1	C2	C3	C4
C1		1.333	1.44	1.603
C2			1	1.36
C3				1.345
C4				

Figure 2

Inconsistency Ratio of Main Criteria



The weights of the main criteria were calculated as follows: Technical System Quality and Infrastructure = 0.324 (ranked first), Educational Quality = 0.245 (ranked second), Information and Content Quality = 0.240 (ranked third), and Service Quality = 0.191 (ranked fourth). In the same way, the weights and rankings of all criteria were determined.

4. Discussion and Conclusion

The present study aimed to identify and prioritize the factors influencing the satisfaction of mathematics e-learners in higher education by applying the Fuzzy Analytic Hierarchy Process (FAHP). The results revealed that *Technical System Quality and Infrastructure* received the highest weight (0.324), followed by *Educational Quality* (0.245), *Information and Content Quality* (0.240), and *Service Quality* (0.191). Within these dimensions, indicators such as system interactivity, user-friendliness, accessibility of online resources, and structural design were most critical for fostering a satisfying learning experience. These findings highlight the pivotal role of robust technical foundations and adaptive system functionalities in shaping learners' perceptions and overall engagement in mathematics e-learning.

This emphasis on technical quality is consistent with earlier works that underscore the importance of system usability and infrastructure reliability for successful digital education (Cheawjindakarn et al., 2013; Karimzadganmoghadam et al., 2012; Yakubu & Dasuki, 2018). In particular, the weight assigned to system interactivity and user-friendliness aligns with evidence that intuitive interfaces reduce cognitive load and increase the sense of control among learners (Maria de Lourdes et al., 2011; Mohammadi, 2015). In mathematics, where students frequently engage in problem-solving and conceptual modeling, an interactive and stable platform supports dynamic content delivery and immediate feedback, improving satisfaction and performance (Jafarabadi Ashtiani & Nomanov, 2021; Ragib, 2023). Our findings also corroborate studies that argue technical barriers—such as difficulty accessing resources or insecure platforms—negatively affect learners' trust and willingness to continue in online programs (Asgari et al., 2023; Chen & Tseng, 2012).

The second dimension, *Educational Quality*, highlights the importance of instructional design, adaptability to diverse learning styles, performance evaluation, and collaborative opportunities. Our results show that structured instructional planning and needs analysis significantly contribute to satisfaction. This is consistent with research showing that active teaching strategies and alignment of learning outcomes with course design strengthen learners' cognitive engagement (Fazeli et al., 2021; Sadeghi, 2024). In mathematics e-learning, personalized instructional design and adaptable pathways can help address diverse learning speeds and conceptual understanding (Poorasghar et al., 2015; Zare et al., 2024). Moreover, the inclusion of performance assessment tools within the platform enables students to monitor their progress, reinforcing self-regulated learning strategies—a factor previously identified as a predictor of success in distance education (Cheawjindakarn et al., 2013; Poorasghar et al., 2015).

The findings also confirm the growing relevance of interactive and multimedia-rich instructional strategies, particularly in mathematics. Platforms incorporating gamification, simulations, and visual representations of complex problems have shown to significantly enhance motivation and comprehension (Pei-Chen & Hsing Kenny, 2025; Sadeghi, 2024). Our ranking of educational quality indicators underscores this shift toward technology-enhanced pedagogy, supporting global research advocating for the integration of innovative digital tools that align with cognitive needs (Oulamine et al., 2025; Reis et al., 2024).

Information and Content Quality emerged as the third key dimension but with nearly equal weight to educational quality, indicating that while technology and pedagogy are vital, content remains central to learner satisfaction. The priority given to up-to-date, accurate, and relevant content reinforces long-standing claims in the literature that content credibility drives learners' trust and engagement (Farhadi, 2015; Filippova, 2015). In mathematics, content clarity and comprehensiveness are particularly important as learners rely on step-by-step explanations, worked examples, and problem sets to internalize abstract concepts (Jafarabadi Ashtiani & Nomanov, 2021; Ragib, 2023). Previous Iranian research has similarly emphasized the impact of high-quality content on learners' satisfaction and performance (Faraj Elahi et al., 2020; Gorzin Nezhad et al., 2020). Our findings add further evidence by quantifying this relationship and ranking content-related indicators alongside other key factors.

The comparatively lower weight assigned to *Service Quality* may seem surprising but is consistent with some prior findings in contexts where technical and instructional quality dominate learner perceptions (Elahi et al., 2015; Maria de Lourdes et al., 2011). However, it is important to note that while service-related factors rank lower, they remain crucial for sustaining long-term engagement and addressing learners' difficulties. Prompt technical support, effective user feedback channels, and timely responsiveness can prevent dropout and frustration (Dehghandar et al., 2020; Faraj Elahi et al., 2020). Our findings suggest that although learners may initially focus on system design and content, their continued satisfaction and loyalty depend on reliable support mechanisms—a conclusion aligning with user-centered models of e-learning adoption (Asgari et al., 2023; Mohammadi, 2015).

Another significant contribution of this study is methodological. The use of FAHP allowed for a nuanced assessment of expert judgments, accommodating uncertainty and ambiguity in evaluating qualitative aspects of e-learning systems (Babakordi, 2020; Dehghandar, Pabasteh, et al., 2021). Traditional evaluation models often rely on crisp values, which may not capture the complexities of expert reasoning (Elahi et al., 2015). By integrating fuzzy logic with hierarchical analysis, this study produced robust, context-sensitive priorities that can guide educational institutions in strategic planning and resource allocation. Similar approaches in other Iranian contexts have demonstrated the usefulness of FAHP for ranking success factors in educational technology and system quality (Dehghandar et al., 2020; Gorzin Nezhad et al., 2020).

Furthermore, our results contribute to the ongoing discourse about localized frameworks for e-learning success. While global models such as the DeLone and McLean IS Success Model (Yakubu & Dasuki, 2018) and TAM (Mohammadi, 2015) provide foundational insights, their application in non-Western higher education requires adaptation to cultural and infrastructural realities. Our findings echo calls from recent research urging for the integration of local user expectations and institutional constraints into evaluation models (Asgari et al., 2023; Narenji Thani et al., 2021). In Iran, where universities like Farhangian are scaling up digital teacher training, attention to both global standards and local learning contexts is essential (Faraj Elahi et al., 2020; Zare et al., 2024).

Importantly, this study reinforces the interconnectedness of the four dimensions rather than viewing them in isolation. Although technical system quality ranked highest, it is not sufficient alone; effective educational design, high-quality content, and supportive services together create a coherent learning ecosystem. This holistic perspective aligns with recent meta-syntheses emphasizing integrated frameworks for LMS usability and success (Asgari et al., 2023). For mathematics e-learning specifically, where cognitive demands are high, synergy among technology, pedagogy, and support becomes indispensable.

The findings also have implications for emerging digital learning trends. Artificial intelligence and machine learning are increasingly integrated into e-learning to personalize experiences and predict learning performance (Reis et al., 2024). However, our results suggest that for these technologies to impact satisfaction positively, they must be embedded within robust, user-friendly systems and paired with adaptive instructional strategies. Similarly, the growing interest in gamification and multimedia tools (Pei-Chen & Hsing Kenny, 2025; Sadeghi, 2024) requires balancing novelty with content quality and pedagogical coherence to avoid cognitive overload.

Finally, the study confirms the value of expert-driven evaluation when designing and refining e-learning systems. Engaging domain experts ensures that ranking criteria remain aligned with learners' actual cognitive and motivational needs (Cheawjindakarn et al., 2013; Karimzadganmoghadam et al., 2012). This participatory approach may be particularly effective in mathematics, where disciplinary insights are critical to shaping meaningful digital learning environments.

Despite its contributions, the study has several limitations. First, the sample size of experts was relatively small and context-specific, focusing on mathematics specialists and e-learning planners at a single teacher training university. Although purposive sampling ensured relevant expertise, the findings may not fully capture the perspectives of broader learner populations or other academic disciplines. Second, the study relied on expert judgments rather than direct learner feedback to identify and rank satisfaction factors. While this approach provides theoretical rigor and informed prioritization, incorporating students' lived experiences might yield additional insights into usability and motivation. Third, the study's scope was geographically limited to Iranian higher education, specifically Farhangian University in Mazandaran. Cultural, institutional, and infrastructural differences could influence the generalizability of the results to other national or international contexts. Finally, although FAHP effectively addressed uncertainty in expert judgments, the method still depends on the subjective interpretation of linguistic variables, which may introduce bias despite its mathematical robustness.

Future studies could build on these findings by adopting mixed-method approaches that combine expert analysis with direct learner surveys and interviews. Integrating students' perspectives may reveal additional satisfaction drivers, particularly related to emotional engagement and self-efficacy. Expanding the sample to include multiple universities and diverse educational contexts could improve the external validity of the results and allow comparative analysis across regions and disciplines. Moreover, researchers could explore the dynamic nature of e-learning satisfaction by conducting longitudinal studies to track changes in learner expectations as technologies and pedagogies evolve. Advanced analytics and learning management system data could also be integrated to validate expert-identified factors with actual learner behavior and performance outcomes. Additionally, future work might investigate the role of emerging technologies, such as adaptive learning systems, artificial intelligence-based tutoring, and immersive virtual environments, to refine satisfaction frameworks for next-generation digital learning.

For educational administrators and instructional designers, the study offers actionable guidance for developing more effective e-learning systems in mathematics. Prioritizing technical system quality—such as platform stability, interactivity, security, and user-friendly design—should be a foundational step before implementing advanced pedagogical features. Institutions should invest in instructional design that accommodates diverse learning styles, provides clear performance evaluation mechanisms, and fosters collaborative opportunities to maintain engagement. Regular updating and quality control of content are essential to sustain learners' trust and comprehension. Finally, although service quality ranked lower, establishing responsive support channels, timely assistance, and mechanisms for learner feedback can enhance long-term satisfaction and retention. Adopting structured multi-criteria evaluation frameworks like FAHP can help universities allocate resources efficiently and continuously monitor the success of their e-learning initiatives.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

References

Asgari, M., Abdoli, S., Nili Ahmadabadi, M., & Fardanesh, H. (2023). Meta-Synthesis of a Comprehensive Framework of Factors Affecting the Usability of Learning Management Systems. *Technology of Education Journal*, *17*(4), 849-868. https://jte.sru.ac.ir/article_1962.html

Babakordi, F. (2020). Familiarity with Hesitant Fuzzy Sets and Their Types. *Journal of Operations Decision Making*, *4*(4), 361-353. https://civilica.com

Cheawjindakarn, B., Suwannatthachote, P., & Theeraroungchaisri, A. (2013). Critical Success Factors for Online Distance Learning in Higher Education: A Review of the Literature. *Creative Education*, *3*(8), 61. https://doi.org/10.4236/ce.2012.38B014

Chen, R., & Tseng, H. (2012). Factors That Influence Acceptance of Web-Based E-learning System for the In-Service Education of Junior High School Teachers in Taiwan. *Evaluation and Program Planning*, *35*(4), 398-406. https://doi.org/10.1016/j.evalprogplan.2011.11.007

Chen, S., & Young Tat Yao, A. (2016). An Empirical Evaluation of Critical Factors Influencing Learner Satisfaction in Blended Learning: A Pilot Study. *Universal Journal of Educational Research*, *4*(7), 1667-1671. https://doi.org/10.13189/ujer.2016.040719

Dehghandar, M., Ahmadi, G., & Aghebatbeen Monfared, H. (2021). Designing a Fuzzy Expert System for Diagnosis and Prediction of Metabolic Syndrome in Children and Adolescents. *Health Management & Information Science*, *8*(2), 79-89. https://jhmi.sums.ac.ir

Dehghandar, M., Chegini, P., & Hashemnia, S. H. (2020). Ranking of Factors Affecting Educational Quality in Payame Noor University of Karaj by AHP Method. *Journal of Research in Psychology and Education*, *4*(17), 277-290. https://www.noormags.ir

Dehghandar, M., Pabasteh, M., & Heydari, R. (2021). Diagnosis of COVID-19 Disease by the Fuzzy Expert System Designed Based on Input-Output. *Journal of Control*, *14*(5), 71-78. https://doi.org/10.52547/joc.14.5.71

Elahi, S., Rashidi, M., & Sadeghi, M. (2015). Designing a Fuzzy Expert News System for the CEO of Privacy in Electronic Government and Business Exchange. *Journal of Information Technology Management*, *7*(3), 511-530. https://journals.ut.ac.ir

Faraj Elahi, M., Pahlevani Nejad, D., Musa Kazemi, A., & Shabiri, S. M. (2020). Quality Assessment with Students' Satisfaction in E-learning, Tehran Universities. *Bi-Quarterly Journal of Educational Studies and Planning*. https://elmnet.ir/

Farhadi, R. (2015). E-learning New Paradigm in the Information Age. *Journal of Science and Technology*, *21*(1), 49-66. https://jipm.irandoc.ac.ir/article-1-116-fa.html

Fazeli, Z., Vahedi, M., & Rahimi, Z. (2021). Active Teaching in E-learning from the Perspective of Elementary School Teachers: Methods, Consequences and Challenges. *Journal of Training & Learning Researches*, *18*(1), 87-100. https://tlr.shahed.ac.ir/article_3575.html?lang=en

Filippova, T. (2015). Priority Fields of E-learning Development in Russia. *Procedia and Behavioral Sciences*, *20*(6), 348-353. https://doi.org/10.1016/j.sbspro.2015.10.063

Gorzin Nezhad, M., Darvishi Salookolaei, D., & Dehghandar, M. (2020). Evaluation and Ranking of Factors Affecting the Satisfaction of Electronic Mathematics Learners Using the Fuzzy Hierarchical Analysis Process Technique. *Quarterly Journal of Education in Basic Sciences Farhangian University*, *6*(2), 63-78. https://ensani.ir/fa/article/458154

Jafarabadi Ashtiani, M., & Nomanov, M. (2021). Mathematical e-learning based on problem solving by designing new software and investigating its effect on math performance of secondary school students. *Scientific Publications Management System*, *15*(2), 222-207.

Karimzadganmoghadam, D., Khodaparast, M., & Vahdat, D. (2012). Evaluation of Effective Factors on E-learner Satisfaction. *Iranian Journal of Information Processing & Management*, *27*(2), 461-478. https://doi.org/10.29252/acadpub.ijipm.27.2.461

Maria de Lourdes, M., Machado Virgilio Meira, B., Brites, R., Soares, J. B., & Ferreira Gouveia, O. M. R. (2011). A Look to Academic Satisfaction and Motivation in Portuguese Higher Education Institutions. *Social and Behavioral Sciences*, *29*, 1715-1724. https://doi.org/10.1016/j.sbspro.2011.11.417

Mohammadi, H. (2015). Investigating Users' Perspectives on E-learning: An Integration of TAM and IS Success Model. *Computers in human Behavior*, *45*, 359-374. https://doi.org/10.1016/j.chb.2014.07.044

Narenji Thani, F., Pourkarimi, J., & Tizhoosh Jalali, F. (2021). Identifying and Examining the E-learning Competencies for Students in Higher Education. *Journal of New Approaches in Educational Administration*, *12*(2), 1-22. http://jedu.miau.ac.ir/article_4778.html

Oulamine, A., El Gareh, F., Hattabou, & Elmenssouri, A. (2025). The evolution of e-learning and its challenges in higher education: A theoretical review. *African Scientific Journal*, *3*(28), 174-196. http://africanscientificjournal.com

Pei-Chen, S., & Hsing Kenny, C. (2025). The design of instructional multimedia in e-learning: A media richness theory-based approach. *http://i-learn.uitm.edu.my/resources/journal/j3.pdf*. https://www.researchgate.net/publication/222414548

Poorasghar, N., Kiamanesh, A., & Sarmadi, M. R. (2015). Model for Predicting Academic Performance of Distance Education Students Based on Individual Variables, Motivational Beliefs and Self-Regulated Learning Strategies. *Quarterly Journal of Research in School and Virtual Learning*, *4*(2), 7-22. http://ensani.ir

Ragib, M. (2023). Fundamentals of e-learning in mathematics teaching: future perspectives. https://doi.org/10.51582/interconf.19-20.11.2023.015

Reis, F. J., Alaiti, R. K., Vallio, C. S., & Hespanhol, L. (2024). Artificial intelligence and machine-learning approaches in sports: Concepts, applications, challenges, and future perspectives. *Brazilian Journal of Physical Therapy*, 101083. https://doi.org/10.1016/j.bjpt.2024.101083

Sadeghi, S. H. (2024). The effect of gamified e-learning on marine ecology education: insights from Iranian maritime students. *Environmental Education Research*, 1-18. https://doi.org/10.1080/13504622.2024.2415944

Seraji, F., & Attaran, M. (2012). *E-learning: Basics, Design, Implementation and Evaluation*. Bu Ali Sina University Press. https://www.gisoom.com

Yakubu, M. N., & Dasuki, S. I. (2018). Assessing E-learning Systems Success in Nigeria: An Application of the DeLone and McLean Information Systems Success Model. *Journal of Information Technology Education: Research*, *17*, 182-202. https://doi.org/10.28945/4077

Zare, M., Nili, M. R., Ali Abadi, K., Zarei Zavarki, E., & Asgari, M. (2024). The effectiveness of a blended e-learning design model on academic performance of Farhangian University students. *Educational and Instructional Studies*(40), 126-136. https://pma.cfu.ac.ir/article_3895.html?lang=en

Zare, Z., Salehi, K., & Javadipour, M. (2023). Designing an Indicators System for Evaluation of the Performance of Teachers in E-learning Environments. *Journal of Training & Learning Researches*, *20*(1), 64-78. https://tlr.shahed.ac.ir/article_4258_05297d842c1dfebcd86ecdf020df3a1b.pdf