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Research AI: integrating AI and gamification in higher education for e-learning optimization and soft skills assessment through a cross-study synthesis

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Introduction: The integration of Artificial Intelligence (AI) and gamification into higher education is reshaping educational practices by personalizing learning and fostering essential workforce skills. This study critically examines the effectiveness of these technologies, their impact on student engagement, and the factors influencing students' acceptance.
Methods: A systematic literature review complemented by Topic Modeling using Latent Dirichlet Allocation (LDA) identified key research themes. Subsequently, predictive modeling with machine learning algorithms, hyperparameter optimization, and Local Interpretable Model-Agnostic Explanations (LIME) were applied to classify academic documents and interpret influential factors.
Results: Findings indicate that AI effectively customizes educational pathways, enhancing engagement and academic performance. Gamification notably supports soft skill development, providing more interactive assessments than traditional approaches. However, challenges related to data privacy and technological accessibility remain significant, particularly affecting international students and institutions with limited resources.
Discussion: AI and gamification demonstrate considerable potential for transforming higher education through personalized learning and interactive skill assessments. Nevertheless, widespread adoption depends on addressing data privacy concerns and ensuring technological equity. Future research should investigate the long-term implications of these technologies in developing students' adaptability within a dynamic global workforce.

KEYWORDS
artificial intelligence, gamification, E-learning, adaptive learning, higher education

1 Introduction

In a rapidly evolving higher education landscape, Artificial Intelligence (AI) and gamification are redefining the way learning is personalized, and soft skills are assessed (Karimi and Pina, 2021). The integration of AI, serious games, and adaptive learning strategies is opening new educational frontiers (Marengo et al., 2023; Pagano and Marengo, 2021), particularly following the COVID-19 pandemic, which accelerated the shift to resilient digital models (Barletta et al., 2022). This study responds to the need for innovative teaching approaches by reanalyzing data from recent literature (Marengo and Pagano, 2020). Soft skills such as emotional intelligence, critical thinking, and adaptability are now seen as essential for professional success and educational systems must be equipped to both cultivate and assess them effectively (Kirikkanat, 2023; Sony and Mekoth, 2016). AI-supported e-learning platforms have demonstrated their value in supporting international students and strengthening learning flexibility (Wang et al., 2023). Traditional assessments often fall short in capturing the complexity of soft skills, whereas AI and gamified environments provide more realistic and dynamic evaluation tools (Rapp, 2018; Minn, 2022). AI has shown transformative potential in teaching and learning through intelligent tutoring, adaptive feedback, and personalized student modeling (Popenici and Kerr, 2017; Akinwalere and Ivanov, 2022; Hannan, 2021; Slimi, 2022), enhancing teaching effectiveness, engagement, and student outcomes (Singh and Hiran, 2022; Rowe and Lester, 2020; Sadiku et al., 2021). For international students, AI can influence institutional choices and educational adaptation, especially in the post-pandemic context (Akgün and Greenhow, 2021; Kanwar and Carr, 2020), although limited research exists on their acceptance of AI tools (Watanabe, 2023; Kansal et al., 2022). Gamification also plays a significant role in increasing motivation, autonomy, and critical thinking, particularly in vocational and higher education settings (Adhiatma et al., 2019; Cheng et al., 2022; James et al., 2023; Zhang et al., 2021; Ahmed and Asiksoy, 2021; Alfaiz et al., 2021; Helvaci and Yörük, 2021; Reiners and Wood, 2015; Zakaria and Binti Rosli, 2019). Traditional pedagogical methods, though foundational, struggle to support the development of soft skills due to their rigid structure (Firat, 2023; Joie-La Marle et al., 2023; Andrews-Todd et al., 2022; Martín-Núñez et al., 2023). In contrast, AI and gamification enable adaptive, engaging, and personalized learning that responds to students' diverse needs (Siddiky, 2020; Devare, 2022; Jitsupa et al., 2022; Zhumasheva et al., 2022). As highlighted by Bao, the pandemic marked a paradigm shift in education (Bao, 2020), and the concept of emergency remote teaching further underscored this change, as noted by Hodges and colleagues (Hodges et al., 2020). Despite these advancements, the literature reveals critical gaps (Tolks et al., 2024). This study investigates the lasting impact of AI and gamification in higher education by exploring five key research questions: personalized learning (RQ1), soft skills assessment (RQ2), post-pandemic adaptive strategies (RQ3), international student perspectives (RQ4), and workforce readiness (RQ5), using diverse data sources to uncover transformative educational trends. The article is structured as follows: Section 2 details the methodology adopted for the systematic literature review, topic modeling, and predictive analysis. Section 3 presents the main findings of the review, while Section 4 discusses the implementation of the deep learning extension and its interpretability through LIME. Finally, Section 5 offers concluding remarks and outlines future research directions.

2 Materials and methods

To answer the research questions, this study adopted a systematic literature review approach structured in several sequential phases, including the definition of the research strategy, the application of inclusion and exclusion criteria, the selection and screening of relevant studies, and the final data extraction and analysis, all conducted in accordance with established methodological standards to ensure transparency and reproducibility. A comprehensive search was carried out across four major academic databases—ScienceDirect, Scopus, PubMed, and Emerald—focusing on peer-reviewed publications from 2019 to 2024, a period marked by the accelerated evolution of e-learning systems due to global health emergencies. The selected databases were chosen based on their disciplinary relevance, indexed coverage of peer-reviewed literature, and the availability of advanced search and filtering tools. These sources proved particularly suitable for identifying studies related to artificial intelligence in education, computer science, and educational technology, ensuring methodological rigor, traceability, and reproducibility. The search strategy employed Boolean operators (AND, OR) to combine keywords such as "Artificial Intelligence," "Gamification," and "Adaptive Learning," applied to titles, abstracts, and keywords to ensure broad and targeted retrieval of relevant literature.

Inclusion criteria required that articles be written in English, present empirical findings on AI and gamification in the context of adaptive learning within higher education and be published in peer-reviewed scientific journals or recognized conference proceedings. Both open-access and institutionally accessible publications were considered. Studies not meeting these criteria, particularly those unrelated to the technological adoption processes relevant to the research scope, were excluded.

Duplicates were removed initially using Orange Data Mining software and verified manually. From an initial pool of 1,200 records, 1,030 were excluded based on the defined criteria, and 2 were removed as duplicates. The remaining 168 articles, together with 5 additional relevant studies identified during the process, underwent full-text screening. To further refine the selection, an advanced Topic Modeling technique was applied. Specifically, Latent Dirichlet Allocation (LDA), an unsupervised machine learning method, was used to uncover hidden thematic structures within the text corpus. In LDA, each document d is represented by a topic distribution θ_d sampled from a Dirichlet distribution with hyperparameter α as described in Equation 1:

$$\theta_d \sim Dirichlet(\alpha) \tag{1}$$

Each word w_n in document d, a topic z_n is chosen from a multinomial distribution as shown in Equation 2:

$$z_n \sim Multinomial(\theta_d) \tag{2}$$

Words themselves are drawn from a topic-specific word distribution β_{zn} as shown in Equation 3:

$$w_n \sim Multinomial(\beta_{zn}) \tag{3}$$

where β is also drawn from a Dirichlet distribution with parameter η as shown in Equation 4:

$$\beta \sim Dirichlet(\eta) \tag{4}$$

The corpus, combining titles and abstracts, underwent preprocessing (lowercasing, removing special characters/stopwords, lemmatization) via Python's NLTK library, and was vectorized using CountVectorizer. The final probability distribution of words per document was estimated according to Equation 5:

$$p(\omega_n|d) = \sum_{z=1}^{K} p(\omega_n|z)\, p(z|d) \tag{5}$$

where K is the total number of topics. The LDA model identified five main topics and labeled each document accordingly. Specifically, the extracted topics are: Topic 1 – Big Data & Security, focused on big data, web systems, and security-related challenges; Topic 2 – Gamification, centered on gamification strategies, student engagement, and instructional design; Topic 3 – AI in Education, addressing the use of artificial intelligence to enhance learning, personalization, and educational technologies; Topic 4 – Digital Learning, covering digital approaches and game design for adaptive and online learning; and Topic 5 – AI/Gamification Impact, which explores the combined effects of AI and gamification on learning outcomes and job market preparation. To enhance interpretability, top keywords per topic were extracted. Topic Modeling also functioned as a screening tool: 9 articles from Topic 1 were excluded for irrelevance, and a subsequent manual review removed 96 more, resulting in 59 final studies. Data extraction focused on how AI and gamification were applied, adoption factors, and reported outcomes. Studies were grouped thematically and prioritized for recency and methodological rigor, covering various educational contexts. Both qualitative (e.g., user perceptions) and quantitative data (e.g., engagement metrics) were included. Quantitative data were reanalyzed using Orange Data Mining; thematic analysis in Python was applied to qualitative data. Meta-analytic techniques assessed effect sizes where applicable. The PRISMA diagram (Supplementary Figure 1) outlines the review process, from 1,200 initial records to 59 included studies after screening and Topic Modeling. For topic validation, a Neural Network classified documents into four categories—Gamification, AI in Education, Digital Learning, and AI/Gamification Impact—using TF-IDF features.

The general Equation 6 for calculating the posterior probability in a Neural Network, considering classification into 4 topics, is:

$$\mathrm{P}(\mathrm{y_i}|\mathrm{x}) = \mathrm{f}\left(\sum\nolimits_{j=1}^{n} \omega_j x_j + b_i\right) \tag{6}$$

Where $\mathrm{P}(\mathrm{y_i}|\mathrm{x})$ represents the predicted probability that a document belongs to topic i, given the input x, with i =1,2,3,4 corresponding to the 4 topics; ù $_j$ are the weights learned by the model for each input x_j; b_i is the bias for class i; f is the activation function applied, such as Softmax for multi-class classification. The Softmax activation function, used to convert the model's output into probabilities for each of the 4 classes, is defined in Equation 7:

$$\mathrm{f}(\mathrm{z_i}) = \frac{e^{z_i}}{\sum_{k=1}^{4} e^{z_k}} \tag{7}$$

where z_i is the output of the neuron for class i among 4 total classes (k = 1, 2, 3, 4). This formula enables the Neural Network to estimate the probability of a document being classified into one of the four topics, based on extracted features (e.g., TF-IDF). The model's performance was evaluated using macro-averaged AUC-ROC, accuracy, precision, recall, F1 score, and Matthews Correlation Coefficient (MCC). Macro AUC-ROC measures classification accuracy independent of decision thresholds by averaging the AUC for each class. Accuracy is the proportion of correct predictions. Precision is the ratio of true positives to total predicted positives; recall reflects the proportion of actual positives correctly identified. The F1 score balances precision and recall as their harmonic mean. MCC, ranging from −1 (total error) to +1 (perfect accuracy), evaluates prediction quality considering all confusion matrix components (true/false positives/negatives). Metrics derive from the confusion matrix, where rows are actual classes and columns predicted ones, offering insight into classification effectiveness.

3 Results and discussion

The Latent Dirichlet Allocation (LDA) analysis identified five dominant topics across the document corpus, each defined by prevalent keywords and document frequency, as shown in Supplementary Table 1. Topic 1, "Big Data & Security," focused on large-scale cyberattacks against web systems using models and expert systems but represented only 5.20% of documents (n = 9) and was excluded due to limited relevance to the study's educational focus. Topic 2, "Gamification" (29.48%, n = 51), emphasized student engagement and learning innovation through game-based methods. Topic 3, "AI in Education" (31.21%, n = 54), addressed AI's integration into educational systems to personalize experiences and improve outcomes. Topic 4, "Digital Learning" (12.72%, n = 22), dealt with interactive approaches and user-centered design in online education. Topic 5, "AI/Gamification Impact" (21.39%, n = 37), explored cross-sector applications of AI and gamification in education and tourism. Their thematic relevance to the research questions (RQ) is presented in Supplementary Table 2: Topic 3 aligns with RQ1 and RQ4 on AI's role in personalization and international students' perceptions; Topic 2 with RQ2 on gamified assessment for soft skills; Topic 4 with RQ3 on post-COVID adaptive strategies; and Topic 5 with RQ5 on long-term impacts. A second review phase excluded 96 additional articles, resulting in 59 final studies, with distribution detailed in Supplementary Table 3, and "Gamification" and "AI in Education" comprising over 70% of the included literature.

As highlighted in the detailed analysis of Supplementary Table 4, the gamified approach offers a global and temporal perspective on the dynamics emerging from the 23 studies analyzed under Topic Gamification. Gamified assessments are increasingly recognized as one of the most effective methods for measuring and developing soft skills, outperforming traditional evaluation techniques. Recommendation systems integrated with emerging technologies foster continuous interaction between students and educational content, enhancing key skills such as communication and collaboration through personalized learning paths (Harrathi and Braham, 2021). The learning environment, combined with teacher expertise and technological resources, has proven essential for stimulating abilities like time management and problem-solving (Hanaysha et al., 2023). Intelligent virtual assistants, such as Alexa, illustrate how audio-based techniques can support task management and real-time problem-solving (Bräuer and Mazarakis, 2022). Immersive technologies like extended reality (XR) enable dynamic assessments, significantly improving collaboration in simulated real-world settings (Zolezzi et al., 2024). Adaptive systems like AGE-Learn promote self-regulation and autonomous task management (Bennani et al., 2020), while gamification in professional training enhances leadership and decision-making through structured feedback (Jahn et al., 2021). The integration of the metaverse strengthens the evaluation of collaboration and creativity, despite challenges related to cost and privacy (De Felice et al., 2023; Miller et al., 2024). Immersive environments and serious games foster environmental awareness and complex decision-making (Negi, 2024; Pistono et al., 2022), while NLP tools like ChatGPT allow real-time tracking of communication and problem-solving skills (Ho et al., 2024). Augmented reality and adaptive learning improve linguistic collaboration, leadership, and stress management (Haoming and Wei, 2024; Walentek and Ziora, 2023; Audrito et al., 2024; Mirza et al., 2024). Finally, machine learning algorithms and adaptive social comparison dynamics help predict and enhance soft skills development (Rodríguez et al., 2018; Tenório et al., 2020; Barata et al., 2016; Sosnovsky et al., 2020; Stanescu et al., 2016; Tenório et al., 2020; Neerupa et al., 2024), confirming the effectiveness of gamified methods even during critical contexts such as the pandemic (Barletta et al., 2022).

Exploring the transformative role of artificial intelligence (AI) in e-learning, Supplementary Table 5 highlights how AI is reshaping personalized learning, enhancing student engagement, and opening new educational frontiers. AI's ability to analyze vast student data allows for the prediction of learning gaps and the creation of tailored pathways. Systems like the Intelligent Quality Management System (IQMS) have improved performance by identifying weaknesses and suggesting corrective actions (Somasundaram et al., 2020), while platforms such as Knowledge Navigator adapt learning content to individual needs across disciplines (Yadav et al., 2024). Chatbots are increasingly used as educational support tools, offering rapid, personalized responses that reduce teachers' workload and enhance communication. Their use in Data Mining and Text Analytics courses has boosted the quality of responses (Alsafari et al., 2024), and in language learning, they facilitate multitasking and adaptability (Dokukina and Gumanova, 2020). AI technologies also support emotional engagement through social–emotional learning (SEL), promoting empathy and stress management (Sethi and Jain, 2024). Platforms like QLearn enable students to monitor progress autonomously (Şerban and Ioan, 2020). For international students, AI tools help overcome cultural and linguistic barriers, though concerns about data privacy and cultural acceptance persist (Wang et al., 2023). Immersive AI platforms like LearningverseVR use generative AI and VR to create interactive learning with dynamic, non-scripted dialogues (Song et al., 2024). These environments foster digital literacy and cognitive skills (Gejendhiran et al., 2020), such as those developed via interactive web applications for computer science (Vishtak et al., 2022), or AI-supported creativity and problem-solving tools (Benvenuti et al., 2023). AI's benefits also extend to emotionally sensitive and individualized contexts (Haefner et al., 2021) and to the development of sustainable educational models in smart cities (Embarak, 2021). Cognitive computing, including platforms like IBM Watson, supports adaptive learning environments (Bahassi et al., 2024). Technologies like the Internet of Behaviors (IoB) and explainable AI enable real-time personalized feedback (Embarak, 2022). AI-based gamification enhances intrinsic motivation and assessment effectiveness (Bezzina et al., 2021), as seen in simulation games for advanced analytics (Geisthardt et al., 2023). During the pandemic, flexible pedagogies powered by AI proved essential in Latin America (Useche et al., 2022), and platforms like MathE and AI-integrated Open Educational Practices (OEP) offered new sustainable and innovative models for higher education (Azevedo et al., 2024; Halder Adhya et al., 2024; Kant et al., 2021).

The COVID-19 pandemic accelerated the evolution of adaptive learning strategies, as detailed in Supplementary Table 6, prompting the use of immersive technologies like Virtual Reality to sustain engagement during isolation (Ferreira et al., 2024). Gamified tools such as CEBT proved effective in remote settings (Mittal et al., 2021), while the crisis exposed the digital literacy gap, challenging the "digital native" myth (Mertala et al., 2024). Adaptive methods supported international students through flexible approaches (Nguyen et al., 2024). AI-driven educational systems improved responsiveness to emergencies (Marengo et al., 2023), and gamification optimized learning (Marengo and Pagano, 2020). These strategies reshaped higher education, enhancing resilience, personalization, and adaptability for a diverse global student population (Pagano and Marengo, 2021).

Artificial intelligence and gamification are reshaping education and equipping students for the demands of the modern workforce, as detailed in Supplementary Table 7. AI-enhanced systems like Radial Basis Function (RBF) models provide data-driven feedback, enabling personalized learning experiences crucial for data-intensive roles (Wu et al., 2024). Gamified environments improve engagement and transferable skills (Blas et al., 2024), while fostering creativity, critical thinking, and adaptability aligned with industry needs (Bucchiarone, 2022). AI-driven learning systems promote autonomy (Haderer and Ciolacu, 2022), and game-based models enhance collaboration and problem-solving (Udjaja et al., 2019). Sentiment analysis confirms high student motivation toward these tools (Stracqualursi and Agati, 2024), and ontology-based models offer structured, individualized learning paths (Dermeval et al., 2019), reinforcing the relevance of AI and gamification in future-ready education (Ramírez-Montoya and Portuguez-Castro, 2024).

4 Experimental extension: development and evaluation of a predictive model

To enhance textual data analysis, an experimental Deep Neural Network was implemented for automatic classification of academic documents based on identified topics. This AI approach, previously validated in medical domains was adapted to academic contexts. The dataset underwent preprocessing with stopword removal, lemmatization, and TF-IDF (Term Frequency-Inverse Document Frequency), a weighting approach assigning scores based on term frequency (TF) within documents and rarity (IDF) across the corpus, implemented via Python libraries such as NLTK and Scikit-learn. Predictive modeling compared Gradient Boosting, Random Forest, Logistic Regression, and Neural Networks due to their varied capabilities in capturing data complexities. Target variables represented four identified topics, and features included TF-IDF vectors alongside additional extraction metrics. Model validation involved external testing using 59 articles out of 164, supplemented by stratified 10-fold cross-validation to ensure robust estimation. Hyperparameters were optimized through Grid Search, tuning parameters including tree count and depth for Random Forest (n_estimators:100–500; max_depth:10–50), learning rate and subsampling for Gradient Boosting (learning_rate:0.01–0.1; max_depth:3–10), regularization for Logistic Regression (C:0.001–10), and network complexity for Neural Networks (neurons:64–512; learning_rate:0.001–0.01; dropout:0.2–0.5). Model selection relied on AUC (Area Under the Curve), an effective metric for imbalanced datasets assessing classification capability independently of decision thresholds. The Neural Network exhibited superior performance with an AUC of 0.830, detailed in Supplementary Table 8. ROC curve and Confusion Matrix analyses (Supplementary Figure 2) indicated particularly strong performance in classifying AI in Education (accuracy 80.95%) and Gamification (56.52%), with lower accuracy observed for Digital Learning and AI/Gamification Impact.

For model interpretability, LIME (Local Interpretable Model-agnostic Explanations) was employed, implemented in Python using TensorFlow and LIME (Iacoviello et al., 2025). Supplementary Figures 3–6 show how specific terms influenced topic classification. The integration of LIME results with the systematic review provides a comprehensive understanding of emerging technologies in education, highlighting data trends and insights behind the model's predictions, directly addressing the research questions (RQ). Regarding gamification (RQ2), the review confirms that gamified assessments effectively develop students' soft skills compared to traditional methods. Personalized recommendation systems, combined with technologies like extended reality (XR), enable tailored learning experiences, enhancing communication, collaboration, and transversal skills (Bao, 2020). Gamification fosters time management, leadership, and problem-solving within engaging contexts, surpassing traditional static assessments (Devare, 2022; Harratcahi and Braham, 2021). LIME supports this by identifying positively influencing terms like gamification (0.057), individual (0.026), and performance (0.019), while negatively weighted terms such as technology (−0.034) and personalized (−0.029) suggest human interaction and game dynamics outweigh technology alone. For AI in education (RQ1, RQ4), systems like IQMS and Knowledge Navigator personalize learning, improving academic outcomes through targeted interventions (Bezzina et al., 2021; Pistono et al., 2022). Educational chatbots and virtual assistants reduce teacher workloads and provide immediate student support (Kirikkanat, 2023). For international students, AI addresses cultural and language barriers, though privacy and data concerns may limit acceptance (Udjaja et al., 2019). LIME confirms this, positively associating technology (0.081), personalized (0.058), and adaptive (0.047), while terms like education (−0.056) and data (−0.022) negatively influence classification, emphasizing transparent data management. Regarding digital learning (RQ3), COVID-19 accelerated adaptive strategies using technologies like virtual reality (VR), ensuring educational continuity and student engagement (Helvaci and Yörük, 2021; Sosnovsky et al., 2020), yet highlighting the need to address digital inequalities (Mirza et al., 2024). LIME highlights positive influences from digital (0.072) and strategy (0.012), but negative impacts from technology (−0.061) and learning (−0.054), emphasizing that technological adoption must accompany strong pedagogical frameworks.

On long-term impacts of AI and gamification (RQ5), both technologies effectively prepare students for the workforce. AI-supported systems, such as RBF models, enhance predictive accuracy and personalized feedback (Dermeval et al., 2019), while gamification combined with AI promotes transferable skills (Akgün and Greenhow, 2021). LIME indicates education (0.074) and game (0.046) positively impact classification, whereas digital (−0.068) and gamification (−0.050) negatively influence, suggesting gamification alone, without technological integration, is insufficient. Thus, effective long-term preparation requires innovative educational strategies combined with robust technological support.

5 Conclusion

The study highlights the transformative potential of integrating artificial intelligence (AI) and gamification into higher education, demonstrating their ability to enhance personalized learning, boost student engagement, and innovatively assess essential soft skills such as collaboration, problem-solving, and leadership. AI's capacity to analyze large data volumes enables customized learning pathways, while gamified assessments create adaptive, interactive educational experiences.

Limitations include limited longitudinal data on sustained impacts, especially regarding career readiness and adaptability. Rapid technological advancements also challenge educators, as frequent system updates can surpass their ability to integrate new tools effectively. Furthermore, findings primarily originate from well-resourced, technologically advanced environments, limiting generalizability to lower-resourced or culturally diverse contexts.

Future research should investigate long-term effects on professional outcomes and soft skills development, address technological barriers in under-resourced settings, and explore ethical concerns around data privacy and AI biases, crucial for fostering trust among students and institutions to maximize these technologies' educational impact.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AM: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. AP: Writing – original draft, Writing – review & editing. BL: Writing – original draft, Writing – review & editing. VS: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomp.2025.1587040/full#supplementary-material

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