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A Systematic Review of AI-Driven Game Design and User Experience Research

Qiwen Lao[1]

[1] Faculty of Innovation and Design, City University of Macau, Macau

Correspondence: Qiwen Lao, Faculty of Innovation and Design, City University of Macau, Macau

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Abstract

In recent years, artificial intelligence (AI) has been increasingly integrated into game design, driving innovation that extend from development efficiency to user experience. This study systematically reviewed the research on user experience in AI-driven game design published between 2020 to April 2025, analyzing 74 studies retrieved ACM Digital Library, IEEE Xplore and Web of Science. Findings indicate that AI has been incorporated into all stages of game design, enabling collaborative development and facilitating personalized content adaptation and real-time player interaction through dynamic difficulty adjustment, affective computing, and generative technologies. The integration of multimodal technologies further enhances immersion and engagement. In cross-domain applications, AI-driven serious games demonstrate strong potential in fileds such as education and healthcare. Nevertheless, challenges remain in terms of technology integration complexity and insufficient interdisciplinary validation. Future research should establish standardized evaluation frameworks to advance game design from entertainment-focused application toward broader social demands including education and health care.

Keywords: artificial intelligence, game design, user experience, dynamic adjustment, personalization

1. Introduction

The digital gaming industry is undergoing rapid expansion, encompassing a broad range of sectors including game development, publishing and operations, platform services, emerging technology innovation, esports, and derivative content industries. Notably, esports was officially included as a competitive event at the 19th Asian Games held in Hangzhou in 2023(Hangzhou Asian Games Organising Committee, 2022), and the first Esports Olympics is scheduled to take place in Saudi Arabia in 2027(International Olympic Committee, n.d.) . In the realm of game development and design, artificial intelligence (AI) is increasingly integrated into various aspects of the creative and operational process, enhancing both gameplay and user experience (Kawai, 2024). For instance, the powerful language modeling and generation capabilities of GPT have proven effective in areas such as game text generation, code assistance, and player feedback or guidance (Yang et al., 2025). Furthermore, AI is being combined with other emerging technologies such as augmented reality (AR), virtual reality (VR), and mixed reality (MR) in innovative gaming applications, educational games, and even healthcare-related contexts (Berthault et al., 2023; Delgado et al., 2024; Li et al., 2023; Ye et al., 2023). These developments not only enhanced the efficiency of game production but are also reshaping user interaction and immersive experience paradigms.

Prior to the advent of AI, user experience (UX) testing and optimization relied heavily on designers' intuition, internal testing, and post-launch player feedback, resulting in uniform content delivery to all users. However, with increasingly diverse user needs, UX has become central to game design, emphasizing systems that respond in real-time to players' emotions, behaviors, and cognitive states (Carbone et al., 2020; Villareale et al., 2023). The introduction of AI has endowed games with greater adaptability and intelligence, enabling features such as personalized content adjustments, dynamic difficulty scaling, and emotion-aware interaction—thus allowing players to truly become the protagonists of their own gameplay experience and enhancing immersion (Alvarez et al., 2021; Cui et al., 2020; Moon et al., 2022; Rathnayake et al., 2020).

While prior literature reviews have addressed the application of AI in game development, these studies have predominantly focused on technical analysis of AI models, content generation capabilities, and implementation frameworks (Frutos-Pascual & Zapirain, 2017; Singh et al., 2024; Yang et al., 2025). Less attention has been paid to how AI influences user experience across various design dimensions. This paper aims to fill that gap by constructing a review framework centered on "user experience." It systematically analyzed literature published

between 2020 and April 2025 to classify and synthesize current findings, identify emerging trends, highlight research gaps, and propose future directions.

2. Literature Retrieval and Analysis

2.1 Databases and Search Strategy

A systematic search was conducted across three major academic databases—ACM Digital Library, IEEE Xplore, and Web of Science—using the keywords "AI" AND "Game Design" AND "User Experience" within the abstract field. The search covered the period from 2020 to April 2025. These databases are widely recognized in the fields of computer science and AI research. Given the technical and data-driven nature of early AI research in games, these sources are particularly suited for identifying relevant literature (Guha et al., 2013). The initial search yielded 71, 29, and 72 articles from ACM, IEEE, and Web of Science, respectively. After removing non-research materials such as posters, abstracts, tutorials, presentations, and work-in-progress papers, the remaining articles numbered 49, 29, and 72, respectively. After eliminating duplicates, 121 unique papers were identified (Table 1).

Subsequent screening was conducted based on the following inclusion criteria:

1) Explicit application of AI technologies;

2) Involvement of digital or simulated game systems, including either design/development or player interaction;

3) Relevance to user experience research, encompassing behavioral analysis, emotional response, feedback mechanisms, and experience evaluation.

Following a review of titles and abstracts, 74 articles were ultimately deemed relevant and included in this literature review.

Table 1. Types and quantities of initially retrieved articles

Database	Conference Papers	Research Papers	Reviews	Total (Excluding Duplicates)
ACM Digital Library	43	4	2	121
IEEE Xplore	21	6	2	
Web of Science	37	37	5	

2.2 Coding and Classification Methods

To analyze the various patterns through which AI influences user experience in games, this study employed an open coding approach. The content of each selected paper was summarized and tagged, and an initial categorization was made based on three primary domains: design, education, and healthcare. Given that most studies involved design-related or interdisciplinary topics, the design domain was further refined using additional dimensions such as types of AI, stage of application, and mode of interaction.

Ultimately, the coding results were clustered into the following six thematic categories:

1) AI collaborative design: AI assists designers in completing creative tasks such as stories and scenes in different links;

2) Personalization and dynamic adjustment: Real-time adjustment of content and feedback according to players' behavior and state;

3) Multimodal technology integration: AI combines voice, image, VR, AR, etc., to realize multi-sensory interaction;

4) AI technical mechanisms: Focusing on behavior trees, algorithm frameworks, model structures, etc., behind AI technologies;

5) Healthcare application: Experience optimization of AI in gamified therapy and rehabilitation training;

6) Educational application: Teaching guidance and feedback mechanism design of AI in learning games.

Each literature can correspond to multiple labels to ensure interdisciplinary research.

2.3 Literature Analysis

Due to the limited data available for 2025 (only covering the first four months), the temporal comparison in this study focused on the period from 2020 to 2024. An analysis of the 74 selected publications revealed a clear upward

trend in the annual number of studies. The number of papers increased significantly from 8 in 2022 to 19 in 2023, peaking at 30 in 2024 (Figure 1). This trend might indicate that research on AI-driven game design and user experience has increasingly become a focal point within the academic community. The continued growth over the past two years reflected growing scholarly enthusiasm and attention toward the role of AI in enhancing gameplay experiences.

When examining trends across thematic categories, a sharp increase in publication volume was observed from 2023 onward across all major topics (Figure 2). This surge can be largely attributed to the public release of GPT-3 and GPT-3.5, which significantly expanded the user base of generative AI technologies and, in turn, stimulated academic interest in AI applications in game development (Yang et al., 2025).

A closer analysis of individual themes revealed that AI collaborative design is the most widely studied topic, with a consistently increasing number of studies each year. In 2024, the number of publications under this theme reached 12, making it the most prominent area of inquiry. These studies primarily focued on how AI can support game designers in tasks such as content generation, level design, and narrative planning, thereby enhancing development efficiency and creative diversity (Barthet et al., 2022; Charity et al., 2024; Gao et al., 2024; Lankes & Stöckl, 2023).

The theme of personalization and dynamic adjustment has also seen steady growth, with research concentrating on how AI dynamically adjusts gameplay elements—such as difficulty and interactivity—based on player behavior, interests, and skill levels to improve immersion (Vijaya et al., 2024; Wang et al., 2023; Zhu & Ontañón, 2020).

Interest in multimodal technology integration rose sharply starting in 2023, with 8 publications in 2024. These studies explore how AI can incorporate various sensory modalities—such as voice, image, gesture, and VR—to enhance the realism and expressiveness of games (Berthault et al., 2023; Hassan et al., 2022; Hong & Ge, 2022; T & Thomas, 2024; Woodward et al., 2021; Ye et al., 2023; Zhao et al., 2024).

The AI technical mechanism's theme, an early area of focus, included 4 publications as early as 2020. However, its growth has been relatively modest, stabilizing at around 4 papers in 2024. This suggests that foundational technical research in this area is reaching maturity and transitioning toward application-driven studies (Ana et al., 2023; Carbone et al., 2020; Gupta et al., 2024; Raut et al., 2024; Shacklett et al., 2023).

Research on educational applications ranks second in volume after collaborative design, rising from just 1 paper in 2020 to 10 in 2024. These studies primarily investigate adaptive learning systems and feedback mechanisms in game-based learning environments, underscoring the strong momentum of AI-enhanced education (Barmpakas & Xinogalos, 2023; X. Liu et al., 2023; Rodríguez-Rivera et al., 2025; Xu et al., 2025).

In contrast, the volume of research in the medical domain remains relatively low, with only 2 publications recorded in 2024. This suggests that AI applications in healthcare-oriented game design are still in an exploratory phase, with significant room for further development in both theoretical and practical dimensions.

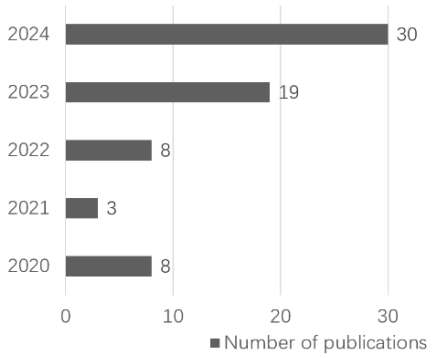

Figure 1. Research trends of AI-driven game design and user experience

(Drawn by the researcher)

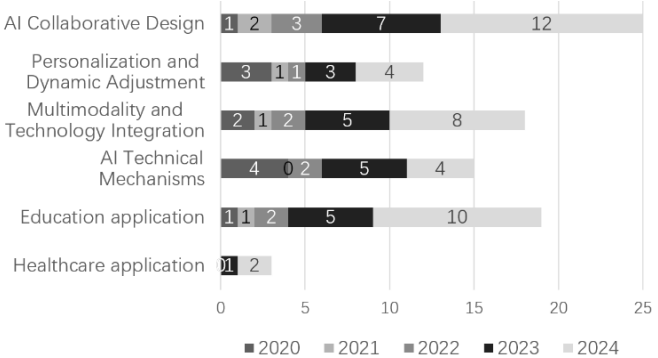

Figure 2. Overall trends of each category

(Drawn by the researcher)

3. Design Perspective: The Role of AI in Game Experience Design

3.1 AI Collaborative Design

Artificial intelligence is increasingly emerging as a transformative force in game design, enabling richer player experiences and innovative gameplay mechanisms. This section summarizes the various ways in which AI participates in collaborative game design, particularly in the domains of text generation, level design, and user experience optimization.

In the area of text generation, AI is primarily involved in narrative development. It not only attends to linguistic style and worldbuilding but can also adapt its storytelling dynamically based on player input and in-game context. For example, Mieschke and Radicke (2023) developed a generative broadcast system using GPT-3.5, which creates news reports, stories, advertisements, and interviews in real time by combining player actions with a general in-game knowledge base (e.g., character histories and story background).

In terms of level design, H. Liu et al., (2023) studied how to use AI to synthesize game levels specially customized for collaborative games in a virtual environment. The researchers synthesized low, medium, and high-level collaborative game levels and recruited participant groups to play the game levels. It was verified that AI virtual agents did provide sufficient data to describe players' collaborative behaviors in each game level block, proving that artificial intelligence can significantly simplify the level creation process. Game developers can consider using AI virtual agents as an alternative method to evaluate the degree of collaboration required to complete game levels, which not only speeds up the game development cycle but also ensures that players can obtain a more suitable game experience.

In the visual design of game design, Su and He (2024) pointed out that generative AI can be used to improve the graphic art style, enabling developers to quickly evaluate various aesthetic changes that meet players' preferences. AI not only significantly improves the efficiency of game design but also allows for innovative graphics and element design. This capability enables designers to more closely align artistic choices with the expectations of the target audience, thereby enhancing player engagement and immersion.

In creating game experiences, Sidji et al. (2024) explored the dynamics of human interaction with AI assistants in the cooperative game "Codenames" and found that AI assistants can enhance player strategies, increase social interaction and connections between teams, and ultimately improve cognitive engagement. However, they can also interfere with the formation of team mental models and challenge many players' understanding of the "spirit of the game". Their research emphasizes the impact of artificial intelligence on social dynamics, indicating that when human players collaborate with artificial intelligence-driven guides, players can obtain a higher level of understanding and enjoyment, and AI can support strategic decision-making by processing situational clues, thereby enriching players' experiences.

Villareale et al.'s (2023) research emphasized that based on existing AI game design processes, players' views on AI are very important, and it was believed that user feedback should be integrated into AI games. Game designers can better customize design decisions according to expected experiences to adapt to players' behaviors and further increase player participation.

Artificial intelligence represents a transformative force in the field of game design, significantly improving the development quality and game fun of games by promoting collaborative games, supporting complex level design, optimizing player experience, and increasing game testing. Integrating AI tools and strategies into game design has a profound impact on the future development of the industry and will also bring richer and more suitable game experiences.

3.2 Personalization and Dynamic Adjustment

This section discusses the impact of AI participation on game design and game experience from the aspects of personalization and dynamic adjustment, sorting out how AI improves game experience through personalized strategies and dynamic difficulty adjustment.

Personalization in game design is crucial for maintaining player engagement and satisfaction. Zhu and Ontañón (2020) proposed a new player-centered framework as a supplement to the commonly used system-centered methods. By sorting out existing research and identifying unresolved issues, they emphasized the importance of developing systems that can adapt to players' personal preferences, which can significantly improve player satisfaction. Based on the "Action-Structure Theory", they outlined a framework, laying the foundation for how AI can create player-specific experiences in game environments.

The research of Tselepatiotis and Alepis(2024) discussed the use of AI to create personalized game experiences. They designed a zombie shooting game to detect common sense problems, predicted new players' performance based on sample data, useed the K-nearest neighbor model to dynamically adjust the distribution of question types, and used Fuzzy Logic to real-time change zombie behaviors according to players' levels. Therefore, AI can optimize knowledge distribution, dynamically balance the difficulty curve, realize the synchronization of personalized learning and immersive games, and play a role in evaluating players' performance, customizing quizzes and challenges to improve learning outcomes.

Dynamic Difficulty Adjustment (DDA) is another important point where AI shows potential in improving game experience. Traditional DDA relies on players' proficiency to balance game difficulty, while Moon et al. introduced AI opponents that can decide the next action according to players' emotional states. They integrated the player state model into the Monte Carlo Tree Search algorithm, enhancing the diversity and effectiveness of dynamic difficulty agents in different game scenarios, enabling AI opponents to automatically and self-adjust the game according to players' states, thereby enhancing the game experience (Moon et al., 2022).

Reis et al. (2023) further explored the use of deep learning technology to balance the difficulty of the game. They developed an AI automation framework to real-time adjust the difficulty of the game in two-player games. The Game Master (GM) agent is allowed to learn how to use the disc game mechanism, and the reward function sends a signal to allow the leading player to retreat and the trailing player to catch up, thereby generating the desired rubber band effect, balancing the skill gap, and providing all players with a fair and pleasant game experience.

AI can also build adaptive behavior systems for NPCs in games. For example, Cui et al. (2020) proposed a Reinforced Evolutionary Algorithm based on Relative Error-Aware Difficulty Difference (REA-DD), which effectively controls the game difficulty in the "Pong" game on the ALE platform and the horror game "The Ghost Story", demonstrating a method that continuously evolves according to players' preferences.

AI has promoted the personalization and dynamic adjustment of game design and significantly improved players' overall participation and satisfaction. Through self-adjustment mechanisms and player-centered methods, future game experiences will be more abundant and personalized to meet players' diverse needs. With the continuous development of games, developers must integrate the results of artificial intelligence research to create unique, personalized, and suitable game experiences for players.

3.3 Multimodality and Technology Integration

The integration of AI and multimodal technologies in game design has significantly transformed players' experiences. By leveraging multiple interaction modes such as five-sense feedback, VR, and AR, a more immersive and engaging environment is jointly created in aspects like game mechanics, player participation, and immersive experiences, thereby enriching game dynamics.

Among them, the application of Augmented Reality (AR) and Virtual Reality (VR) technologies can expand the ways players interact with games. Kim et al. (2023) developed a basic AR pet-raising game called Bubbleu, using object detection as a key interaction method to study how AR promotes AI-based uncertain interactions in game design. They found that player experience can be improved in various ways, such as reducing perception errors, explaining the system, and enabling users to control the incidence of uncertainty. Delgado et al. (2024) applied VR to museum exhibitions, developing an interactive VR game that allows visitors to immerse themselves in a dynamic VR environment to tour 3D museum collections and interact with AI-agent NPCs through dialogue and explanations. The observation results emphasized the importance of shared experiences among visitors.

AI can also customize gameplay according to users' personal preferences, as shown in Prithul et al.'s research on teleportation experiences in VR games. The study used a VR first-person shooter game, with AI agents simulating other players, and compared the significant differences in players' performance, navigation behavior, and perceived user experience between teleportation and continuous movement. Players using teleportation could move farther, but in combat, they were found to be more stationary and hit more frequently. Therefore, more strategies to balance gameplay need to be proposed (Prithul et al., 2024). These attempts and experiments have opened up new ways of game experience, providing players with multiple participation channels and increasing the playability, interactivity, and immersion of games.

In scene design, Huynh et al. (2023) proposed the Sketch2Reality system, which combines sketching, AI assistance for 3D generation, and VR. The system can identify the sketched objects and their positions, retrieve corresponding 3D models, and fill them into AI-generated 3D scenes. Users can modify the scene, arrange furniture, adjust lighting, and add or delete objects, using virtual reality technology to allow users to realistically experience and interact with the scene. At the same time, Chen et al. (2024) used MR (Mixed Reality) and AI to facilitate symbiotic

interaction between virtual and real spaces. They found that MR offered better visual comfort and higher immersion compared to VR. By leveraging generative AI-driven MR, their approach enabled real-time modification and interaction with spatial interfaces through intuitive language and gesture-based inputs. This method simplifyed the traditional design process, reducing steps such as measurement, modeling, and rendering to streamline the workflow, and also improving user participation and creativity, providing new possibilities for experiential exhibitions and architectural design, and helping to realize a future environment where virtual and real spaces coexist seamlessly.

Emotion recognition through multimodal systems can analyze player reactions in real-time, thereby dynamically customizing and adjusting the game experience. Ganiti-Roumeliotou et al. (2024) explored identifying and customizing game experiences before, during, and after the game by analyzing players' facial expressions and physiological reactions, and adjusting the level of game tasks or narrative elements according to players' emotional states to maintain players' interest and participation. This feedback loop between artificial intelligence analysis and game design enables developers to create more nuanced narratives and interactions, and better capture players' feelings and reactions.

The innovative integration of AI multimodality and technology is reshaping the direction of game design. By enhancing NPC behaviors, creating immersive environments, and optimizing game mechanics, artificial intelligence not only enriches players' experiences but also provides developers with feedback tools to help them build more attractive and adaptable game worlds.

3.4 AI Technical Mechanisms

The application of artificial intelligence technology continues to enhance the richness and complexity of gaming experiences. By leveraging various AI technologies, game developers can create more diverse and personalized gaming environments. This section will explore how AI improves gaming experiences through technical means such as procedural generation agents, reinforcement learning, and affective computing.

Procedurally generated agents are gradually emerging and evolving in game design. These AI agents can simulate the behaviors of human players, providing more realistic interactive experiences. Shacklett et al. (2023) proposed a high-performance, multi-world simulation architecture for efficiently creating new training environments (including environment generation and custom logic for generating agent observations and rewards), enabling the training of AI agents in parallel environments. This framework can effectively facilitate AI learning and performance in complex gaming environments. This kind of simulation not only supports the replication of real behaviors but also lays the foundation for creating rich storylines and task designs in dynamic environments. Meanwhile, the development of game AI using reinforcement learning has significantly enhanced the playability and challenge of games. According to the research by Barthet et al., generative AI agents can imitate humans to achieve specific in-game behaviors and train human-like program characters through reinforcement learning. AI agents perform in the form of rules, rewards, or human demonstrations, improving the quantity and efficiency of human and material resources required for game testing, thereby enabling the creation of more complex characters and storylines in the game world (Barthet et al., 2022).

A review study by Singh et al. (2024) indicated that Generative Adversarial Networks (GAN) can effectively enhance AI efficiency in games and promote higher-level game design. The article discusses the architecture, training methods, applications, difficulties, and potential future directions of GAN in AI games. It is expected that a game world driven by AI and capable of solving related obstacles through GAN will be created in the future. Through reinforcement learning, game AI can continuously adapt and adjust the game difficulty to ensure a balance between challenge and interest for players.

The introduction of affective computing enables game AI to understand and respond to players' emotional states, thereby further enriching players' experiences. The research by Dai et al.(2020) proposed integrating affective computing into first-person shooter (FPS) games. By improving the hierarchical OCC emotional model and integrating it into the original system, AI is driven to control characters' decisions and behaviors through emotional factors. Actual user tests conducted in the UE engine found that this system significantly improved user experience. Additionally, Moon et al. (2022) pointed out that AI opponents considering players' emotional states need to be designed to balance the game difficulty. They adopted the Monte Carlo Tree Search (MCTS) algorithm and referenced game feature machine learning models to enable AI to better predict and respond to players' needs, thereby enhancing the immersion of the game.

Therefore, through various technical means in game design, AI can not only make games more attractive but also enhance the realism of interactions through emotional communication with players, significantly improving

players' gaming experiences. With the continuous advancement of technology, we can foresee that games will provide more appealing, diverse, and personalized experiences to players worldwide in the future.

4 Healthcare Perspective: Gamified AI Interventions and User Experience

The interdisciplinary integration of game design and medicine has witnessed gamified artificial intelligence emerging as a transformative force, demonstrating substantial potential in enhancing disease prediction, treatment efficacy, and rehabilitation outcomes. This synergy leverages core game mechanics to innovate healthcare delivery models, offering a patient-centric approach to medical services.

Lulle et al. (2024) developed an AI-driven application tailored to enhance cognitive functions in individuals with dementia. Trained via machine learning algorithms, the application provided a comprehensive suite of services, including early dementia detection, preventive guidance, location tracking, memory training modules, digital cognitive games, and rehabilitation tools. By incorporating gamified elements such as interactive challenges and progress tracking, the technology motivates consistent user engagement while enabling real-time customization of interventions based on individual patient responses.

Li et al. (2023) designed a self-adaptive VR game targeting elderly populations seeking to maintain or improve their health. Leveraging VR's high interactivity, the game allowed users to engage in diverse physical activities without exposing them to physical risks. Integrated AI algorithms deliver real-time guidance, dynamically adjust game content to match user capabilities, and generate personalized recommendations. Through continuous optimization of content via AI-driven analytics, the game aligns more closely with users' health goals, addressing key barriers to elderly participation in health-promoting activities and fostering sustained engagement. The inclusion of gamification strategies—such as reward systems and friendly competitions—further enhances user motivation, encouraging adherence to health-related objectives, which warrants deeper exploration in chronic disease management and rehabilitation contexts.

Hany et al. (2024) focused on language acquisition among children with dyslexia, introducing Nexia Tutor: an AI-powered, personalized language learning system. This platform identified dyslexic traits, generates customized feedback reports, and delivers gamified educational interventions tailored to individual needs (e.g., visual memory enhancement and phonological awareness training). By adapting to personal learning rhythms, the system mirrored the customization required in medical protocols, highlighting its potential to provide timely, targeted interventions that address the specific linguistic challenges faced by dyslexic children.

The convergence of AI technology and medicine has paved new pathways for patient-centered care. Integrating gamified AI into medical game design not only improves disease prediction, treatment, and rehabilitation outcomes but also underscores a growing trend: interactive, self-adaptive technologies are increasingly being deployed to enhance health outcomes among vulnerable populations, including the elderly and individuals with cognitive impairments. These innovations demonstrate significant efficacy and hold promising implications for future healthcare applications.

5. Educational Perspective: Enhancing Learning Game Experiences through AI

This section examines the role of artificial intelligence (AI) in supporting instruction, guiding educational processes, and designing feedback mechanisms within gamified learning environments.

AI facilitates personalized learning experiences by enabling students to engage with game elements tailored to their individual needs. Tselepatiotis and Alepis (2024) implemented AI-driven adaptive learning approaches to deliver customized assessments, adjusting question difficulty by balancing the distribution of question categories based on predicted learner performance. This method effectively enhanced students' knowledge retention and engagement. Rodríguez-Rivera et al. (2025) explored students' perceptions of using information and communication technology (ICT) tools and generative AI (GenAI) as learning methodologies for designing escape rooms. In their coursework, students utilized GenAI, Genially, and HeroForge to develop digital escape rooms, investigating how generative AI fosters engagement and creativity. The findings indicated that students recognized AI's positive influence on digital literacy, creative thinking, and problem-solving capabilities, validating its practical utility in educational design. Collaborative learning emerged as a key enabler in overcoming initial technical barriers, empowering students to take ownership of their learning while leveraging AI tools to enhance the overall educational experience. Consequently, AI holds the potential to transform passive learners into active participants motivated by intrinsic interest.

In the domain of AI-guided education, Barmpakas and Xinogalos (2023) proposed that AI and algorithmic concepts can be effectively introduced to students through gameplay. They developed a serious game, SpAI War, and collected student evaluations to facilitate understanding of AI principles and their applications throughout the

gameplay process. Based on assessments using the MEEGA+ model, the study demonstrated positive outcomes in terms of player experience, game scenario design, and perceived short-term learning gains. AI's utility in classrooms extends to teaching complex concepts such as machine learning (ML). Zammit et al. (2022) created ArtBot, a digital game designed to teach foundational principles of AI and ML while stimulating critical discourse on the societal implications of AI applications in daily life. Currently piloted as an instructional tool in primary and secondary education, this game exemplifies AI's multifaceted role in education, as such experiences deepen students' comprehension of AI-related issues.

AI-driven feedback mechanisms are equally pivotal. As highlighted by Reyes et al., public skepticism persists regarding the uncertainty inherent in AI systems. Their study employed game-based experiences to measure trust in AI-generated feedback under conditions of uncertainty visualization, revealing that visualizing uncertainty in AI decision-making processes significantly enhanced user trust in AI systems and improved decision-making proficiency (Reyes et al., 2025). Such feedback mechanisms are not only integral to the learning process but also critical for cultivating critical thinking and real-world problem-solving skills.

AI not only enables personalized learning pathways but also enhances student engagement and the development of key competencies. Future research should investigate the long-term impacts of these technologies on student learning outcomes to fully harness AI's potential in educational contexts.

6. Discussion

This study systematically synthesizes the applications and evolving trends of AI-driven game design in enhancing user experience from 2020 to April 2025. Through integrating interdisciplinary research across design, education, and healthcare domains, three core directions are identified: 1) adaptive intelligence; 2) multimodal immersion;3) human-AI collaborative creation.

AI-driven dynamic adjustment mechanisms—such as K-nearest neighbor models and fuzzy logic—exhibit distinct advantages over traditional static systems. Early research prioritized technical implementation (Cui et al., 2020), whereas later studies shifted focus toward emotional states, cognitive load, and the primacy of personalization (Moon et al., 2022), aligning with the contemporary demand for games to deliver real-time responsiveness to player behaviors and emotional feedback.

The convergence of AI and XR technologies has fostered immersive ecological environments. Case studies such as Bubbleu (Kim et al., 2023) and Sketch2Reality (Huynh et al., 2023) demonstrate AI's capacity for real-time environment generation and multisensory interaction. However, technical constraints in AR and VR hardware persist as critical barriers to achieving full immersion.

The proliferation of generative AI tools—including GPT-3.5 and GANs—has catalyzed advancements in collaborative design. While AI-assisted design has reduced development cycles by 40% (H. Liu et al., 2023), the risk of over-automation warrants caution. Sidji et al.'s research highlighted that excessive AI intervention undermines player agency, underscoring the necessity of balancing human creativity with AI assistance (Sidji et al., 2024).

In cross-domain applications, AI-powered healthcare games showed therapeutic potential but lack long-term efficacy validation (Li et al., 2023), while educational tools faced challenges in reconciling entertainment value with pedagogical rigor (Rodríguez-Rivera et al., 2025). These issues reflected inherent tensions between entertainment-oriented design paradigms and domain-specific functional requirements.

7. Limitations

Despite efforts to comprehensively map research on AI-driven game design and user experience over the past five years, this study has several limitations. First, literature retrieval was confined to three major databases, potentially excluding non-English studies or research in niche application areas. Second, current scholarship disproportionately focused on design mechanisms and technical implementation, with insufficient exploration of how individual player differences modulate experiences or whether AI meaningfully enhances long-term user retention. Third, research on medical and educational games remains relatively scarce, while evaluation tools and standardized frameworks for AI-driven user experience are still in a nascent stage of development.

8. Conclusion

Artificial intelligence is fundamentally reshaping the design logic and user experience frameworks of digital games. From AI-augmented creation and personalized feedback systems to multimodal immersive interactions, AI's scope of integration and cognitive sophistication continue to expand—endowing non-player characters (NPCs) with emotional intelligence and contextual awareness, and redefining the boundaries of immersion through AI-XR

multimodal fusion. These advancements enable games to dynamically respond to players' needs, emotions, and behavioral patterns. Cross-domain applications further reveal AI's potential to bridge entertainment with societal needs, though standardized evaluation frameworks for healthcare and educational contexts remain imperative.

Future research should explore AI's adaptability in cross-cultural user experiences, establish standardized evaluation metrics, and strengthen empirical validation in educational and healthcare settings. The deep integration of AI and game experiences promises to unlock new frontiers for the gaming industry and human-computer interaction research.

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