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SYSTEMATIC REVIEW

Artificial Intelligence Augmented Gamification in Pharmacology Education: A Narrative Review

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ABSTRACT

Background: Pharmacology remains one of the most cognitively demanding subjects in undergraduate medical education, owing to the vast volume of information that students are required to assimilate. Traditional didactic lectures are increasingly recognized as insufficient for sustaining long-term knowledge retention and intrinsic motivation. Gamification the application of game-design elements within non-game educational contexts has emerged as a promising active-learning strategy. Concurrently, artificial intelligence (AI) is transforming higher education through adaptive learning, intelligent tutoring systems, and automated content generation. Despite these parallel developments, the convergence of AI and gamification specifically within pharmacology education has not been systematically synthesised. Methods: A targeted narrative review was conducted drawing primarily on two recent high-quality systematic and scoping reviews: a scoping review of AI in serious games and gamification for health and a scoping review of gamification in clinical reasoning education supplemented by additional primary and secondary literature identified through PubMed, Scopus, and Medical Education databases. Results: Gamification consistently improves short-term knowledge retention and learner engagement in pharmacology. Web-based pharmacology games such as Cross DRUGs, Find the DRUG, and DRUGs Escape Room have demonstrated statistically significant improvements in posttest scores compared with control groups. AI technologies particularly machine learning and generative AI enhance gamification by enabling adaptive difficulty, personalised feedback, intelligent content generation, and automated assessment. However, the evidence base remains methodologically heterogeneous, and robust randomised controlled trials are scarce. Conclusions: AI-enhanced gamification represents a pedagogically sound and practically scalable approach to pharmacology education. Integrating generative AI tools into gamified platforms addresses longstanding barriers of faculty time, content creation, and scalability. Future research should prioritise rigorous experimental designs, standardised outcome measures, and evaluation of long-term retention.

Keywords: Artificial intelligence; gamification; pharmacology education; medical education; serious games; adaptive learning; knowledge retention; active learning.

INTRODUCTION

Pharmacology occupies a foundational position in medical and health-professional curricula. Students are expected to master mechanisms of drug action, pharmacokinetics, pharmacodynamics, adverse effects, and rational therapeutics across a rapidly expanding formulary. The challenge is compounded by the exponential growth in approved pharmacological agents over the past two decades, rendering rote memorisation both impractical and educationally counterproductive [1]. Conventional lecture-based pedagogy, while efficient for knowledge transmission, is increasingly criticised for its passive nature and limited capacity to foster deep conceptual understanding, clinical reasoning, or durable retention [2,3].

Active learning methodologies have therefore attracted considerable interest as alternatives or complements to traditional instruction. Among these, gamification—broadly defined as the integration of game-design elements (points, leaderboards, badges, narrative scenarios, and competitive or collaborative mechanics) into non-game educational contexts has gained particular traction [4, 5]. Gamification exploits intrinsic motivational mechanisms rooted in self-determination theory, experiential learning, and constructivist pedagogy to create engaging, goal-directed educational experiences [6].

Simultaneously, artificial intelligence (AI) is reshaping educational practice across disciplines. Machine learning algorithms, natural language processing, large language models (LLMs), and generative AI systems offer novel capabilities: dynamic adaptation of content difficulty, real-time personalised feedback, automated question generation, and intelligent simulation of clinical scenarios [7,8]. The convergence of these two paradigms AI and gamification creates an opportunity to address the limitations of each in isolation and design pharmacology learning experiences that are simultaneously engaging, adaptive, and scalable.

Despite the growing literature on gamification in health professions education and the rapid expansion of AI-assisted pedagogy, the specific intersection of AI-augmented gamification in pharmacology education has not been comprehensively reviewed. This narrative review synthesises the available evidence, with particular reference to two key scoping reviews: Tolks et al. (2024), which examined the role of AI in serious games and gamification for health [9], and a 2025 scoping review on emerging trends in gamification for clinical reasoning education [10], supplemented by relevant primary literature.

The Educational Imperative in Pharmacology

Pharmacology is routinely identified by medical students as among the most challenging preclinical subjects. The discipline demands the synthesis of basic science (cellular signalling, molecular pharmacology) with applied clinical knowledge (dosing, adverse effects, drug interactions) across multiple organ systems. Traditional teaching methods, reliant on lectures and textbook reading, provide limited opportunity for contextualised application of knowledge, a critical determinant of long-term retention and clinical transfer [11].

A quasi-experimental study by Aloum and colleagues at Khalifa University College of Medicine in the United Arab Emirates exemplifies the challenge. The pharmacology course a mandatory four-week module for first-year postgraduate medical students, many of whom had engineering rather than pre-medical backgrounds required the memorisation of large volumes of information and presented a significant academic challenge [2]. The recognition of this pedagogical gap motivated the development and implementation of open-access, web-based pharmacology games as supplementary learning tools.

Defining Gamification in Education

Gamification is distinct from serious games and game-based learning, though these terms are frequently conflated. Gamification refers to the application of game-design elements such as scoring systems, progress bars, leaderboards, time-limited challenges, narrative framing, and reward structures to an otherwise non-game educational activity [12]. Serious games, by contrast, are purpose-built games with explicit educational objectives. Game-based learning is a broader construct encompassing both.

The theoretical underpinnings of gamification in education draw from multiple complementary frameworks. Self-determination theory provides a well-established account of how game mechanics such as choice, progressive challenge, feedback, and collaboration enhance intrinsic motivation by supporting learners' autonomy, competence, and relatedness. Kolb's experiential learning cycle explains how gamified activities promote learning through iterative cycles of action, reflection, and conceptual abstraction [13]. Cognitive load theory cautions that extraneous load imposed by poorly designed game mechanics may overwhelm working memory, necessitating careful instructional design.

Artificial Intelligence in Health Professions Education

AI encompasses a heterogeneous set of computational methods, including machine learning (ML), deep learning (DL), natural language processing (NLP), and, most recently, generative AI based on LLMs such as GPT-4 and its successors. In medical education, AI applications range from diagnostic decision-support simulations to adaptive tutoring systems, automated feedback on written work, virtual patient encounters, and intelligent assessment generation [7,14].

The scoping review by Tolks et al. (identified that in the existing literature on AI combined with game-based approaches in health, machine learning represented the predominant AI modality employed (75% of included studies), with a smaller proportion (13%) utilising deep learning approaches [9]. The same review noted that despite the high uptake of gamification in health and education independently, the deliberate combination of AI and gamification specifically to enhance learner motivation remained comparatively rare at the time of publication [9].

METHODS

Review Approach: This narrative review was conducted following established principles for narrative synthesis of heterogeneous literature. The primary objective was to integrate and critically evaluate evidence regarding the application of AI and gamification, separately and in combination, in pharmacology and broader health professions education. Rather than conducting a new systematic search, this review draws upon and extends two methodologically rigorous scoping reviews as anchor references [9,10], supplemented by targeted database searching in PubMed, JMIR Medical Education, Scopus, and Google Scholar using the following search terms: (gamification OR serious games OR game-based learning) AND (pharmacology OR pharmacotherapeutics OR clinical pharmacology) AND (medical education OR health professions education); and (artificial intelligence OR machine learning OR generative AI) AND (gamification OR serious games) AND (education OR learning).

Source Articles

The two anchor scoping reviews informing this narrative review are:

(1) Tolks MC, et al. The Role of Artificial Intelligence in Serious Games and Gamification for Health: Scoping Review. JMIR Serious Games. 2024;12:e49254. PMC10825760. This review comprehensively searched PubMed, Scopus, IEEE Xplore, Cochrane Library, and PubPsych (search date: 2 February 2022) using the terms ["game" OR "gamification"] AND "artificial intelligence," ultimately identifying 16 eligible studies after independent dual screening using Rayyan software [9].

(2) Ching-Yi Lee et al., Emerging Trends in Gamification for Clinical Reasoning Education: A Scoping Review. [BMC Med Educ]. 2025. PMID: 40133879; PMC11938692. This review followed the Joanna Briggs Institute methodology and the Arksey and O'Malley framework, systematically searching MEDLINE, Scopus, and Web of Science, with hand-searching of reference lists, to comprehensively map gamification techniques employed in clinical reasoning education [10].

Gamification in Pharmacology Education: Evidence Review

Types of Gamified Interventions

Published gamified interventions in pharmacology and pharmacy education span a wide fidelity spectrum, from low-fidelity card games and digital quizzes to medium-fidelity escape rooms and high-fidelity immersive simulations. A systematic quantitative literature review of gamification in pharmacy education identified escape rooms as the most frequently reported gamified intervention type, accounting for approximately 30% of published studies, followed by board games, online quizzes, and team-based game formats [15].

Within medical pharmacology specifically, Aloum et al. described the implementation of three open-access web-based pharmacology games for first-year medical students [2]. Cross DRUGs was a crossword-puzzle format in which students identified drug names from pharmacological clues, reinforcing nomenclature and mechanism knowledge. Find the DRUG employed a visual recognition paradigm in which students identified drug molecules or pharmacological categories from structural cues. DRUGs Escape Room applied a sequential problem-solving format in which students solved pharmacology-themed puzzles to progress through a narrative clinical scenario, requiring integration of multiple knowledge domains—mechanism, indication, adverse effects, and contraindications—to advance. This multimodal, narrative-embedded design aligns with constructivist principles of learning-through-doing and parallels clinical problem-solving demands [2].

Impact on Knowledge Retention

The quasi-experimental study by Aloum et al. employed a pretest-posttest non-randomised control group design over three weeks of a four-week pharmacology course [2]. Students self-selected weekly into either the gamer group (those who engaged with one of the three web-based games) or the control group (standard access to lecture slides only). The gamer group demonstrated statistically significant improvement in posttest scores (mean 8.47, SD 1.30) compared with the control group (mean 6.90, SD 2.02), with a between-group improvement reaching statistical significance ($P = .006$), whereas the control group did not achieve significant within-group improvement ($P = .21$) [2]. These findings are consistent with a broader body of literature demonstrating that active engagement strategies enhance short-term knowledge consolidation compared with passive review [15,16].

Student Engagement and Perceptions

Student perceptions of gamified pharmacology learning are broadly positive across the literature. In the Aloum et al. study, 83% of survey respondents found the games enjoyable, and 80% agreed that the games effectively helped them understand pharmacological concepts [2]. Notably, 70% of students believed they learned more effectively through gaming formats than through didactic lectures, and most favoured a blended approach combining lectures with games or case-based learning—endorsing gamification as a complement rather than a replacement for traditional instruction [2].

This pattern is corroborated by the scoping review on gamification in clinical reasoning education, which found that gamification techniques consistently enhanced learner engagement and motivation in clinical educational contexts, particularly when game design was aligned with authentic clinical decision-making tasks [10]. The clinical reasoning context is directly relevant to pharmacology, where students must integrate drug knowledge into patient-centred therapeutic decisions.

Limitations of Current Gamification Research

While the immediate outcomes of gamified pharmacology interventions are generally positive, methodological limitations constrain the strength of conclusions. Publication bias toward positive outcomes has been widely noted [2, 15]. The self-selection design employed in most studies including the Aloum et al. investigation—introduces significant confounding: students who opt into gamification may be more motivated, academically engaged, or receptive to novel pedagogies than those who do not. Few studies include appropriate control groups, adequate sample sizes, or long-term follow-up to assess durability of knowledge gains. Misalignment between intended learning outcomes and those actually measured further undermines comparability across studies [15].

Artificial Intelligence in Game-Based Health Education

Landscape of AI in Health-Related Serious Games

The scoping review by Tolks et al. provides the most comprehensive mapping of the intersection of AI and game-based approaches in health to date [9]. Across 16 eligible studies identified from over 300 initially retrieved records, the review found that most research applying AI to health games targeted therapeutic rather than educational objectives—specifically, the rehabilitation of motion impairment, which accounted for approximately one-third of included studies [9]. The predominant AI technology was machine learning (75% of studies), employed primarily for adaptive difficulty adjustment, real-time motion tracking, performance monitoring, and personalised feedback delivery [9].

Critically, the review highlighted a significant gap: despite the proliferation of gamification in health and educational contexts, only one of the 16 included studies specifically deployed AI to enhance learner motivation through gamification [9]. This finding underscores the nascent state of AI-gamification integration and the substantial opportunity for research and development in this domain, particularly in pharmacological and clinical education.

Machine Learning for Adaptive Learning

Adaptive learning systems utilise machine learning algorithms to dynamically adjust instructional content, difficulty, and pacing in response to individual learner performance data. In gamified pharmacology education, adaptive mechanisms could modulate the complexity of drug calculations presented in a quiz game, alter the branching narrative of a clinical pharmacology escape room based on a student's demonstrated proficiency, or prioritise review of drug classes in which a learner's response latency or error rate signals incomplete mastery [8].

Bayesian knowledge tracing and reinforcement learning represent the dominant algorithmic approaches to learner modelling in adaptive educational systems, operating through iterative cycles of data collection (quiz responses, engagement metrics, clickstream patterns), learner profiling, content delivery, performance evaluation, and system optimisation [8]. Integration of these models into pharmacology game platforms could transform static educational games into genuinely personalised learning experiences.

Generative AI as a Catalyst for Gamification Development

A practical barrier to wider adoption of gamified learning in health professions education has historically been the significant investment of time, expertise, and resources required to design, develop, and validate educational games. The threshold of effort and resource that must be overcome before a gamified learning intervention can be implemented and proposed that generative AI tools such as ChatGPT substantially lower this activation energy [16].

Specifically, generative AI can assist faculty in: (1) generating pharmacology case scenarios and patient vignettes for escape room or simulation games; (2) producing multiple-choice question item banks calibrated to learning objectives; (3) creating game narrative scripts and branching dialogue trees for virtual patient interactions; (4) designing formative feedback messages tailored to specific misconceptions; and (5) generating image prompts and visual assets for digital game interfaces [16]. By democratising game-creation capabilities, generative AI enables pharmacology educators without specialist technical expertise to develop context-specific, curriculum-aligned gamified content.

Natural Language Processing and Chatbot-Based Pharmacology Learning

NLP-based chatbots and conversational AI agents represent an emerging modality within AI-assisted gamification. Conversational agents can simulate patient–pharmacist or patient–prescriber interactions, presenting students with realistic medication counselling or prescribing scenarios within a gamified framework. The student's responses are analysed in real time, and the AI agent dynamically steers the conversation based on clinical accuracy, completeness, and communication quality. Integration of scoring, badges, and leaderboard elements within such platforms constitutes a form of AI-gamified experiential learning directly aligned with pharmacology competencies [7,14].

Deep Learning and Immersive Simulation

A minority of health game studies have employed deep learning approaches, principally for computer vision tasks within motion-based rehabilitation games [9]. In educational pharmacology, deep learning applications remain largely prospective, but include: automated grading of pharmacological reasoning tasks through text classification; analysis of student interaction patterns within gamified platforms to predict at-risk learners; and generation of realistic pharmacokinetic simulation environments that dynamically model drug behaviour in virtual patient avatars based on student-administered dosing decisions.

A Conceptual Framework for AI-Augmented Gamification in Pharmacology Education:

Synthesising the evidence reviewed, we propose a conceptual framework for AI-augmented gamification in pharmacology education comprising four integrated layers:

Layer 1 – Curriculum Alignment: Gamified activities must be explicitly mapped to learning outcomes articulated in the pharmacology curriculum. AI tools such as generative LLMs can assist educators in rapidly generating, reviewing, and iterating curriculum-aligned game content.

Layer 2 – Adaptive Personalisation: Machine learning algorithms monitor individual performance, engagement, and error patterns to personalise game difficulty, content sequencing, and feedback, ensuring that each learner operates within an optimal challenge zone that maximises learning without inducing cognitive overload.

Layer 3 – Authentic Clinical Integration: Game scenarios should simulate authentic pharmacological decision-making challenges—dosing calculations, drug interaction identification, adverse effect recognition, and therapeutic optimisation—to promote transfer of gamified learning to clinical contexts. AI-generated virtual patient scenarios can provide limitless, ecologically valid practice cases.

Layer 4 – Evidence-Based Evaluation: Rigorous assessment of gamification outcomes must move beyond student satisfaction surveys to encompass validated knowledge assessments with long-term follow-up, direct comparison with active-learning controls, and measurement of clinical competency transfer. AI-driven learning analytics can aggregate and interpret these data at scale.

Discussion

Convergence of AI and Gamification: Synergies and Opportunities

The integration of AI into gamified pharmacology education is not merely additive- it is synergistic. Gamification without AI is static: the same game presents the same challenges to all learners, regardless of prior knowledge or demonstrated competency. AI without gamification may enhance learning efficiency but may fail to sustain the motivational engagement necessary for voluntary, out-of-class study. Together, AI-adaptive mechanisms and gamification motivational structures create a learning environment that is simultaneously personalised and engaging addressing the two dominant barriers to effective pharmacology learning: cognitive overload and motivational depletion [6,9].

The clinical reasoning scoping review is particularly instructive in this regard. Gamification in clinical reasoning education does not merely test recall it demands the integration and application of knowledge within simulated decision-making contexts [10]. Pharmacology is fundamentally a clinical reasoning discipline: the student must not only recall that a drug has a particular mechanism but must reason about its appropriate use, potential harms, and alternatives in a specific patient context. AI-augmented gamification is uniquely positioned to provide this integrative, contextualised learning experience at scale.

Equity, Accessibility, and Open-Access Design

The open-access design of the web-based pharmacology games described by Aloum et al. (2025) merits particular attention [2]. Many gamified educational resources are proprietary, costly, and inaccessible to institutions with limited resources a systemic inequity that disproportionately affects medical education in low- and middle-income countries. Open-access, web-based platforms that can be accessed on standard devices without specialist software address this barrier and align with UNESCO's commitment to open educational resources. AI tools such as generative models further democratise game creation by enabling resource-constrained educators to develop high-quality gamified content without specialist design expertise [16].

Methodological Challenges and Research Gaps

Despite the promising evidence, several methodological challenges limit the conclusions that can be drawn from the existing literature. First, self-selection bias is pervasive: students who choose to engage with gamified learning tools likely differ systematically from those who do not in motivation, digital literacy, and prior academic performance. Randomised allocation to gamified versus non-gamified conditions whilst ethically complex in educational settings is necessary to yield unbiased effect estimates [2,15].

Second, outcome measurement is inconsistent across studies. Most report immediate posttest scores, few assess retention at clinically meaningful intervals (e.g., six months post-course or at summative examinations), and fewer still measure transfer to clinical performance. Third, the specific contribution of AI components to gamified learning outcomes has not been adequately isolated: studies comparing AI-adaptive gamification with non-adaptive gamification are lacking.

Fourth, the Tolks et al. scoping review noted that the literature on AI combined with gamification for education—as opposed to therapeutic rehabilitation was strikingly sparse [9]. This observation was made in a review published in 2024; the rapid emergence of generative AI tools since then is likely to accelerate the development of AI-gamified educational applications, but rigorous evaluation must keep pace with technological development.

Ethical and Pedagogical Considerations

The integration of AI into educational gamification raises important ethical considerations. Data privacy and security are paramount: AI-adaptive systems collect granular learner data, and robust governance frameworks are required to ensure appropriate consent, data minimisation, and protection from secondary use [7]. The potential for algorithmic bias—where AI systems systematically disadvantage learners from particular demographic groups—must be explicitly assessed and mitigated.

Pedagogically, there is a risk that gamification prioritises engagement at the expense of deep learning. When game mechanics incentivise rapid, surface-level recall rather than conceptual understanding, they may reinforce the very rote memorisation that active learning methods seek to replace. Curriculum designers must ensure that game objectives are aligned with higher-order cognitive outcomes application, analysis, and synthesis rather than mere factual recall [6,16].

Faculty oversight remains essential even when AI generates game content: accuracy, currency of pharmacological information, and alignment with local clinical guidelines must be verified by subject matter experts [16]. AI-generated patient scenarios may reflect biases present in training data, potentially perpetuating health disparities if not critically reviewed.

Future Directions

Based on this review, we identify the following priorities for future research and development in AI-augmented gamified pharmacology education:

1. Randomised controlled trials comparing AI-adaptive gamification with non-adaptive gamification and with standard didactic instruction, with pre-specified primary endpoints including long-term knowledge retention (minimum six-month follow-up) and clinical pharmacology competency assessments.
2. Development and validation of standardised outcome measures for gamified pharmacology learning, enabling cross-study comparison and meta-analytic synthesis.
3. Prospective evaluation of large language model-generated pharmacology game content for accuracy, clinical currency, and alignment with learning objectives, with comparison to faculty-authored content.
4. Investigation of AI-adaptive mechanisms in pharmacology gamification, including comparative studies of different adaptive algorithms (e.g., Bayesian knowledge tracing versus reinforcement learning) and their differential impact on learning efficiency and engagement.
5. Qualitative and mixed-methods research exploring the lived experience of students and faculty in AI-gamified pharmacology courses, including barriers to adoption, unintended consequences, and contextual moderators of effectiveness.
6. Equity-focused research assessing the accessibility and differential impact of AI-gamified pharmacology tools across diverse learner populations, including those in resource-limited settings, and those with varying prior knowledge or learning differences.

CONCLUSIONS

Pharmacology education faces persistent challenges in fostering durable knowledge retention, clinical reasoning, and learner motivation in the face of an ever-expanding therapeutic landscape. Gamification offers a theoretically grounded and empirically supported active-learning strategy that addresses these challenges by embedding pharmacological content within engaging, goal-directed game experiences. AI substantially amplifies the potential of gamification by enabling adaptive personalisation, scalable content generation, and intelligent feedback—transforming static educational games into dynamic, responsive learning environments.

The scoping reviews by Tolks et al. and the clinical reasoning gamification review, together with emerging primary evidence from web-based pharmacology games, establish both the promise and the current limitations of this field. The deliberate convergence of AI and gamification in pharmacology education remains underexplored and underexploited but the methodological, technological, and pedagogical foundations for rapid and rigorous advancement are now in place. Investment in well-designed research, open-access platforms, and faculty development in AI-assisted game creation will be essential to realise the full educational potential of this convergent paradigm.

Conflict of Interest: The author is the Editor of the journal. To prevent any conflict of interest, the author had no role in the review or decision-making process for this manuscript, which was handled independently by the editorial board.

References

1. Goldstein FJ. Artificial intelligence and creation of an accessible clinical pharmacological program for test-takers. Med Res Arch. 2025;13(7)
2. Aloum L, Ibrahim H, Rajasekaran SK, Alefishat E. Open-access web-based gamification in pharmacology education for medical students: quasi-experimental study. JMIR Med Educ. 2025;11:e73666
3. Boscardin CK, Gin B, Golde PB, Hauer KE. ChatGPT and generative artificial intelligence for medical education: potential impact and opportunity. Acad Med. 2024;99(1):22-27
4. Deterding S, Dixon D, Khaled R, Nacke L. From game design elements to gamefulness: defining gamification. In: Proceedings of the 15th International Academic MindTrek Conference. New York: ACM; 2011. p. 9-15.
5. Kapp K. The gamification of learning and instruction: game-based methods and strategies for training and education. San Francisco: Pfeiffer; 2012. ISBN: 9781118096345
6. Van Gaalen AEJ, Brouwer J, Schönrock-Adema J, Bouwkamp-Timmer T, Jaarsma ADC, Georgiadis JR. Gamification of health professions education: a systematic review. Adv Health Sci Educ Theory Pract. 2021;26(2):683-711
7. Chan KS, Zary N. Applications and challenges of implementing artificial intelligence in medical education: integrative review. JMIR Med Educ. 2019;5(1):e13930.
8. Frontiers in Education. Revolutionizing biotech and pharmaceutical education with adaptive learning. Front Educ. 2025 Available from: https://www.frontiersin.org/journals/education/articles/https://doi.org/10.3389/feduc.2025.1679222/full
9. Tolks D, Schmidt JJ, Kuhn S. The Role of AI in Serious Games and Gamification for Health: Scoping Review. JMIR Serious Games. 2024;12:e49254.
10. Lee CY, Lee CH, Lai HY, Chen PJ, Chen MM, Yau SY. Emerging trends in gamification for clinical reasoning education: a scoping review. BMC Med Educ. 2025;25(1):435.
11. Ali M. Will AI reshape or deform pharmacy education? Curr Pharm Teach Learn. 2025;17(3):102274.
12. Lee JJ, Hammer J. Gamification in education: what, how, why bother? Acad Exch Q. 2011;15(2):146.
13. Kolb DA. Experiential learning: experience as the source of learning and development. Englewood Cliffs, NJ: Prentice-Hall; 1984.
14. Gordon M, Patricio M, Horne L, Muston A, Alston SR, Pammi M, et al. Developments in medical education in response to the COVID-19 pandemic: a rapid BEME systematic review. Med Teach. 2020;42(11):1202-1215.
15. Denise L Hope, Gary D Grant, Gary D Rogers, Michelle A King. . Gamification in pharmacy education: a systematic quantitative literature review. Int J Pharm Pract. 2023;31(1):15-26.
16. Gustafson KA, Berman S, Gavaza P, Mohamed I, Devraj R, Abdel Aziz MH, et al. Pharmacy faculty and students perceptions of artificial intelligence: A national survey. Curr Pharm Teach Learn. 2025;17(6):102344

