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Use of artificial intelligence in spaced repetition strategies for medical education and meaningful learning: a systematic review.

Uso de la inteligencia artificial en estrategias de repetición espaciada para la educación médica y el aprendizaje significativo: revisión sistemática.

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Summary:

Medical education faces the challenge of managing large volumes of information and preventing superficial learning. Spaced repetition, based on the forgetting curve, strengthens long-term retention and promotes meaningful learning. Its integration with artificial intelligence (AI) allows for personalized review intervals, automated material generation, and immediate feedback, expanding the pedagogical potential of this strategy. **Objective:** To evaluate the effectiveness and applicability of AI-assisted spaced repetition in health sciences education. **Methods**: A descriptive systematic review was conducted according to PRISMA 2020 guidelines. The search was performed in Google Scholar and Web of Science (2020–2025) using the terms "spaced repetition," "medical education," "learning," and "artificial intelligence." Original studies, reviews, and applied reports addressing spaced repetition with or without AI were included. Of the initial 1,870 records, 18 studies met the inclusion criteria and were analyzed qualitatively. **Results**: Direct evidence showed that AI improves the personalization of review intervals, the quality of feedback, and knowledge consolidation. Indirect evidence confirmed the effectiveness of traditional spaced repetition, with sustained benefits in academic performance and recall on standardized tests. Complementary evidence highlighted that AI enhances other learning processes, such as automated tutoring, clinical simulation, and microlearning. **Conclusions**: AI-assisted spaced repetition represents an innovative pedagogical strategy consistent with competency-based medical education. It facilitates personalized learning, strengthens retention, and promotes student autonomy. However, the methodological limitations of the available studies underscore the need for longitudinal, multicenter research to evaluate its educational and clinical impact and incorporate ethical strategies that ensure equity and human oversight in the use of these technologies.

Keywords: spaced repetition; medical education; artificial intelligence; meaningful learning.

Resumen:

La educación médica enfrenta el reto de gestionar grandes volúmenes de información y prevenir el aprendizaje superficial. La repetición espaciada, basada en la curva del olvido, fortalece la retención a largo plazo y favorece el aprendizaje significativo. Su integración con la inteligencia artificial (IA) permite personalizar los intervalos de repaso, automatizar la generación de materiales y ofrecer retroalimentación inmediata, ampliando el potencial pedagógico de esta estrategia. **Objetivo:** Evaluar la efectividad y aplicabilidad de la repetición espaciada asistida por IA en la docencia de Ciencias de la Salud. **Métodos**: Se realizó una revisión sistemática descriptiva conforme a PRISMA 2020. La búsqueda se llevó a cabo en Google Scholar y Web of Science (2020–2025) utilizando los términos "spaced repetition", "medical education", "learning" y "artificial intelligence". Se incluyeron estudios originales, revisiones y reportes aplicados que abordaran la repetición espaciada con o sin IA. De 1870 registros iniciales, 18 estudios cumplieron los criterios de inclusión y fueron analizados cualitativamente. **Resultados**: La evidencia directa mostró que la IA mejora la personalización de los intervalos de repaso, la calidad de la retroalimentación y la consolidación del conocimiento. La evidencia indirecta confirmó la eficacia de la repetición espaciada tradicional, con beneficios sostenidos en rendimiento académico y memoria en exámenes estandarizados. La evidencia complementaria destacó que la IA potencia otros procesos formativos, como la tutoría automatizada, la simulación clínica y el microaprendizaje. **Conclusiones**: la repetición espaciada asistida por IA representa una estrategia pedagógica innovadora y coherente con la educación médica basada en competencias. Facilita la personalización del aprendizaje, fortalece la retención y promueve la autonomía estudiantil. Sin embargo, las limitaciones metodológicas de los estudios disponibles subrayan la necesidad de investigaciones longitudinales y multicéntricas que evalúen su impacto educativo y clínico, e incorporen estrategias éticas que garanticen la equidad y la verificación humana en el uso de estas tecnologías.

Palabras clave: repetición espaciada; educación médica; inteligencia artificial; aprendizaje significativo.

1. Introduction

Health sciences education faces the ongoing challenge of adapting to the rapid pace of scientific and technological advancements. This continuous flow of information compels teachers and students to constantly update their knowledge, often leading to cognitive overload and superficial learning. Evidence shows that intensive assimilation of content in short periods results in rapid forgetting when structured review strategies are not employed (1). In this context, spaced repetition emerges as an evidence-based pedagogical tool that organizes reviews at progressively longer intervals to reinforce memory traces and consolidate long-term retention. In medical education, this strategy has been shown to improve conceptual understanding, knowledge transfer to clinical practice, and the development of independent learning (2-3).

The incorporation of artificial intelligence (AI) amplifies and optimizes the potential of spaced repetition. Adaptive algorithms and large-scale language models can dynamically adjust the frequency and difficulty of activities according to student performance, generate individualized materials, and provide immediate feedback. Technologies such as Retrieval-Augmented Generation (RAG) allow linking content to validated sources, organizing relevant information, and creating clinical simulation scenarios, promoting more contextualized and meaningful learning (4–6).

However, this integration also raises ethical, methodological, and pedagogical challenges. These include the validity of AI-generated content, algorithmic biases that can influence information selection, and inequality in access to digital platforms (7). Although the literature has extensively documented the effectiveness of spaced repetition and AI educational applications separately, evidence on their convergence remains limited and scattered (8–10).

Given this scenario, the objective of this systematic review is to analyze the available evidence on the effectiveness of AI-assisted spaced repetition in Health Sciences teaching, contrasting its benefits, limitations and possible applications to strengthen meaningful learning.

2. Methods

A descriptive systematic review was conducted, following the PRISMA 2020 guidelines, with the aim of synthesizing the scientific evidence on the application of AI-assisted spaced repetition in health sciences education. Studies that, while not directly integrating AI, addressed pedagogical strategies that could be combined with this technology were also considered.

The search was conducted using the Google Scholar academic search engine and the Web of Science database, selecting articles published within the last five years (2020–2025) to ensure the currency and relevance of the information. The search strategy employed the following English descriptors: "spaced repetition," "medical education," "learning," and "artificial intelligence," combined with Boolean operators ("AND," "OR") to broaden and refine the results. Inclusion criteria included original articles, systematic reviews, meta-analyses, and perspective or opinion studies with an educational foundation, published in English or Spanish, that provided relevant data on the use of spaced repetition—with or without AI—in health sciences learning. Duplicate studies, those lacking pedagogical application or empirical evidence, and those without full-text access were excluded. The study selection process was documented using a PRISMA flowchart (Figure 1), which reflects the identification, screening, eligibility, and inclusion phases. Bibliographic organization and management were performed using Zotero software, which allowed for structured information extraction and categorization of studies by type of evidence.

The articles finally selected were classified into three groups:
1. Direct evidence: studies that integrated AI with spaced repetition.
2. Indirect evidence: research on spaced repetition without AI, but with integration potential.
3. Complementary evidence: studies on AI in medical education without a specific focus on spaced repetition.

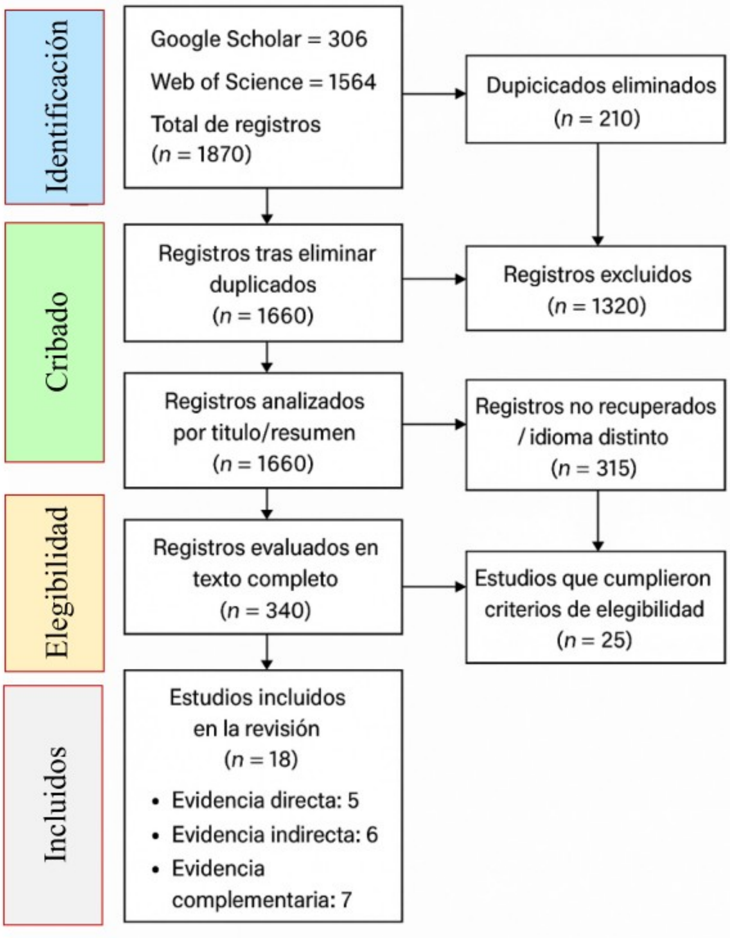

Figure 1. Identification and slection of the included studies.

3. Results

The systematic search identified 1870 records in Google Scholar (n = 306) and Web of Science (n = 1564). After removing 210 duplicates, 1660 titles and abstracts were evaluated, of which 1320 studies were excluded for not meeting the inclusion criteria. Then, 340 full texts were reviewed, excluding 315 for not providing empirical evidence or for lack of access to the full text. Finally, 18 articles met the criteria and were included in the qualitative synthesis, grouped into three categories: direct evidence, indirect evidence, and complementary evidence. The studies were grouped into three categories:

1. Direct evidence (AI + spaced repetition)

Five studies directly evaluated the integration of artificial intelligence and spaced repetition, showing improvements in interval personalization, immediate feedback, and automated generation of educational content. Consistent benefits were reported in knowledge consolidation and academic performance, with retention increases of up to 75–80% in digital environments with generative AI (Table 1).

2. Indirect evidence (spaced repetition without AI)

Six studies confirmed the effectiveness of traditional spaced repetition in medical education, with sustained improvements in academic performance and retention, especially on standardized tests such as the USMLE Step 1. This evidence highlights that the strategy is robust even without AI, and has broad potential for automated personalization (Table 2).

3. Complementary evidence (Educational AI without a focus on spaced repetition)

Seven studies evaluated other AI applications in medical education, including clinical image generation, automated tutoring, microlearning, and clinical simulation. All reported improvements in self-directed learning, adherence, and personalization, reinforcing the overall potential of AI to optimize cognitive and educational processes (Table 3).

4. Discussion

The results of this systematic review show that spaced repetition—both in its traditional application and when integrated with artificial intelligence (AI)—is a highly effective strategy for improving knowledge retention, conceptual understanding, and learner autonomy in the health sciences. Based on the eighteen included studies, the findings are grouped into three dimensions that allow us to understand the breadth and depth of the phenomenon : (1) the direct pedagogical effectiveness of AI applied to spaced repetition, (2) the proven robustness of spaced repetition without AI, and (3) the complementary contributions of AI in other educational processes.

1. Direct pedagogical effectiveness of AI applied to spaced repetition

Studies integrating AI with spaced repetition (1–5) show that the technology enhances personalized learning, automates material generation, and improves immediate feedback. Arango-Ibáñez et al. (2) demonstrated that *active recall* combined with AI facilitates knowledge consolidation in medical students. Similarly, Çiçek et al. (6) showed that ChatGPT-3.5 can provide feedback equivalent to that of expert tutors, improving clinical reasoning. Bachiri et al. (3) reported significant increases in retention (75–80%) using generative AI for the automatic creation of questions, while Bjurström et al. (4) documented the increasing use of AI-powered smart flashcards among medical students. However, these advances are accompanied by methodological limitations: cross-sectional designs, small sample sizes, and limited measurement of clinical impact. Furthermore, from an ethical and human perspective, the evidence agrees that AI does not replace faculty supervision. The generation of clinical scenarios or medical images requires expert human validation, given the risk of errors, biases or inappropriate content (1, 3, 5).

2. Pedagogical soundness of spaced repetition without AI

Indirect studies (6–11) confirm that traditional spaced repetition works even in the absence of AI, offering a horizon of equity for resource-limited institutions. Wothe et al. (21), Gilbert et al. (8), and Cooper et al. (7) found sustained improvements on standardized tests such as the USMLE Step 1, reinforcing Anki's intrinsic effectiveness as a structured learning tool. The meta-analysis by Martinengo et al. (12) provided robust evidence of improvements in knowledge, clinical skills, and professional conduct through digital interventions based on spaced repetition. Mehta et al. (13) and Yao et al. (22) showed that this strategy improves retention from the early years of training and is especially useful in visual learning. This demonstrates that spaced repetition already provided personalized, self-regulated, and competency-oriented education; AI does not redefine the method but rather optimizes it, adding predictive, adaptive, and analytical capabilities.

3. Complementary contributions of AI in medical education

Studies applying AI in medical education without focusing directly on spaced repetition (12–18) show additional benefits. Stirrat et al. (16) demonstrated that AI can generate realistic clinical images useful for teaching, while Kim (11) and Valladares and Rojas (18) showed that chatbots can complement human tutoring and promote student autonomy. Sriram et al. (14) reported that AI in clinical simulation personalizes learning progression, while Ahmed et al. (1) and Slinger et al. (15) showed adherence rates exceeding 70% on AI-assisted microlearning platforms.

Table 1. Direct evidence (AI + spaced repetition)

Reference	Title	Type of study	Sample / Context	Applied strategy	Tool used	Results	Limitations / Level of evidence
Arango-Ibáñez JP et al., 2024 (2)	Evidence-Based Learning Strategies in Medicine Using AI	Experimental	80 medical students	*Active recall* and spaced repetition with test generation, mnemonics, and visual aids	ChatGPT-4, DALL·E 3	AI improved feedback and knowledge consolidation	Short duration; no longitudinal follow-up
Xu Y et al., 2024 (22)	Medical education and physician training in the era of artificial intelligence	Narrative review	International Studies	Integration of AI in medical training	ChatGPT-4 applied to curricula and simulations	Democratize access to knowledge; improve personalization	Lack of quantitative measurement
Çiçek FE et al., 2025 (6)	ChatGPT versus expert feedback on clinical reasoning questions	Randomized controlled trial	60 clinical medicine students	Spaced repetition with immediate feedback	ChatGPT-3.5	Performance similar to expert tutors; improved critical thinking	1 institution; small sample
Bjurström MF et al., 2025 (4)	Digital learning resource use among Swedish medical students	National survey	1250 students	Use of digital flashcards and AI	Anki, Quizlet, ChatGPT	66.4% use flashcards weekly; positive perception	Subjective self-assessment
Bachiri YA et al., 2025 (3)	Harnessing generative AI to boost active retrieval and retention in MOOCs	Multi-method experimental	50 students and 10 teachers	Generative AI for automatic item creation	T5 System + RoberTa	75–80% improvement in retention	Limited customization

Table 2. Indirect evidence (spaced repetition without AI, with potential integration).

Author	Title	Type of study	Sample / Context	Applied strategy	Results	Potential for integration with AI
Wothe JK et al., 2023 (21)	Academic and Wellness Outcomes Associated with use of Anki Spaced Repetition Software	Observational	120 students	Daily use of Anki	Better scores on USMLE Step 1 and greater well-being	Adaptive algorithms
Gilbert MM et al., 2023 (8)	A Cohort Study Assessing the Impact of Anki as a Spaced Repetition Tool	Longitudinal cohort	95 students	Anki training for 1 year	Improved sustained performance	Automated usage analytics
Cooper S et al., 2023 (7)	The Effect of Spaced Repetition Learning Through Anki	Cross	150 students	Curricular use of Anki	Improvements in USMLE Step 1 and less failure	Automated curriculum synchronization
Martinengo L et al., 2024 (12)	Spaced Digital Education for Health Professionals	Systematic review and meta-analysis	Healthcare professionals	Digital interventions with spaced repetition	Improvement in clinical knowledge and skills	Smart reminders
Mehta A et al., 2023 (10)	Implementation of Spaced Repetition by First-Year Medical Students	Comparative retrospective	29 students	Early implementation of Anki	Better grades and retention	Predictive AI for reinforcements
Yao K et al., 2025 (23)	Spaced Repetition Learning in Radiology Education	Review applied	Radiology Education	Anki for visual learning	High effectiveness in visual learning	AI for pattern recognition

USMLE Step 1: Standardized basic science exam for medical certification in the United States.

Table 3. Complementary evidence (AI applied to medical education without a focus on spaced repetition).

Author	Title	Type of study	Sample / Context	AI-powered strategy	Relevance	Limitations / Level of evidence
Stirrat T et al., 2024 (17)	Advancing radiology education for medical students	Applied descriptive	Teachers and residents	AI-powered clinical image generation	Improves teaching in radiology	Without quantitative measurement
Kim TW, 2023 (11)	Application of artificial intelligence chatbots in education	Quasi-experimental	Medical Students	Automated tutoring with ChatGPT	Increases autonomous learning	Without longitudinal follow-up
Sriram A et al., 2025 (16)	Artificial Intelligence in Medical Education	Experimental with control	80 surgical residents	AI in clinical simulation	Personalize progression and practice	External validation is lacking
Valladares AG, Rojas JA, 2023 (18)	Artificial intelligence tutoring versus tutoring with experts	Cross-sectional comparison	60 students	AI vs. Human Tutoring	AI complements the teacher	It does not evaluate long-term results
Kaur G et al., 2025 (10)	Navigating Digital Medical Education in the Current Era	Theoretical review	University medical education	Educational analytics with AI	It proposes pedagogical integration	There is no empirical evidence
Ahmed T et al., 2023 (1)	QuizTime: Innovative Learning Platform	Platform description	Vanderbilt University	Customized asynchronous questionnaires	Just-in-time learning	Without experimental control
Slinger P et al., 2025 (15)	Innovative Mobile App (CPD By the Minute)	Prospective multi-method	105 anesthesiologists	Mobile microlearning	75% adherence and self-assessment improvement	Limited sample

Even so, these advances must be implemented with caution. The automated generation of educational content can create extremely realistic materials that, without supervision, may lead to confusion or learning errors (12, 14). Furthermore, technological equity challenges remain a legitimate concern, as unequal access to devices, connectivity, and AI platforms can widen educational gaps.

Ethical, pedagogical and human implications

From an ethical and pedagogical perspective, the integration of AI in medical education requires clear guidelines. In addition to recognizing algorithmic bias, data privacy, and equitable access as core risks, concrete mitigation strategies are needed. These include: (a) incorporating mandatory modules on AI ethics and digital literacy into curricula; (b) establishing institutional protocols for systematic human review of AI-generated content before its use in teaching; (c) using only platforms with transparent data handling and anonymization policies; and (d) designing access policies that include offline or low-cost alternatives to reduce the technological gap among students. These measures ensure that AI is used as a support tool and not as a substitute for professional judgment.

The reviewed evidence agrees that the integration of AI in medical education has enormous potential, but it introduces ethical, epistemological, and social questions that cannot be ignored and reflect that AI should be understood as a resource to enhance, not replace, the teaching profession:

- Technological equity: unequal access can widen educational gaps (4, 12, 15).
- Cognitive dependence: intensive use of AI without supervision can impair critical thinking (13, 15).
- Human verification: teachers remain responsible for validating all AI-generated content (1, 3, 12).
- Teaching load: intensive personalization of learning implies greater dedication to monitoring and feedback (6–8, 14).

The scientific evidence reviewed shows that AI-assisted spaced repetition is not only a promising strategy but also an opportunity to connect the neuroscience of learning, pedagogy, and emerging technology. When implemented with human supervision, ethical awareness, and institutional equity, it can strengthen student retention, decision-making, and autonomy—three essential elements for contemporary medical education.

Summary of the main findings

Taken together, the reviewed findings allow us to identify three central ideas. First, spaced repetition—with or without AI—maintains a strong and consistent effectiveness in improving retention, deep understanding, and independent learning in the health sciences. Its effectiveness is supported by both experimental studies and longitudinal research, reaffirming its value as a structural pedagogical strategy.

Second, artificial intelligence doesn't transform the essence of the method, but rather acts as a catalyst that optimizes its processes: it adjusts intervals, personalizes learning paths, generates materials more quickly, and allows for immediate feedback. However, these benefits always require expert human verification, since excessive realism and automation can introduce errors, biases, or unvalidated content.

Third, the integration of AI in medical education opens up opportunities, but also ethical and operational challenges. Technological gaps persist, as do the risks of cognitive dependence and the additional burden on teachers to supervise, validate, and guide the training process. This demands clear guidelines, digital literacy, equity policies, and institutional mechanisms that guarantee the safe, responsible, and pedagogically sound use of these tools.

5. Conclusions

- AI-assisted spaced repetition is emerging as an innovative and effective pedagogical strategy in health sciences education. Its integration with adaptive learning systems enhances knowledge retention, self-regulation, and cognitive efficiency in students. AI amplifies the potential of spaced repetition by providing immediate feedback, adjusting review intervals, and generating personalized resources, aligning with current trends in competency-based medical education.
- Despite its effectiveness, methodological limitations persist in the reviewed literature, particularly regarding sample size, heterogeneity of study designs, and the lack of longitudinal studies evaluating long-term outcomes and their actual clinical impact. It is recommended that multicenter, controlled research be conducted to delve deeper into these aspects and allow for a more rigorous assessment of the effectiveness of AI-assisted spaced repetition in different educational contexts.
- The combination of AI and spaced repetition does not replace the pedagogical foundation of the strategy, but rather transforms and amplifies the teacher's role as a critical mediator of knowledge and the student's role as an active participant in their own learning. This synergy between human and artificial intelligence can contribute to a more effective, equitable, and sustainable medical education, geared toward training critical, reflective, and ethically responsible professionals.

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6. References.

1. Ahmed T, Stinson K, Johnson J, Latif Z. QuizTime: innovative learning platform to support just-in-time asynchronous quizzes to improve health outcomes. *AMIA Annu Symp Proc*, **2023**, 2023, 253–260. https://pmc.ncbi.nlm.nih.gov/articles/PMC10785841/
2. Arango-Ibanez JP, Posso-Nuñez JA, Díaz-Solórzano JP, Cruz-Suárez G. Evidence-based learning strategies in medicine using AI. *JMIR Med Educ*, **2024**, 10, e54507. http://doi.org/10.2196/54507
3. Bachiri YA, Mouncif H, Bouikhalene B. Harnessing generative AI to boost active retrieval and retention in MOOCs with spaced repetition. *Knowl Manag E-Learn*, **2025**, 17(3), 391–408. https://doi.org/10.34105/j.kmel.2025.17.018
4. Bjurström MF, Lundkvist E, Sturesson LW, Borgquist O, Lundén R, Fagerlund MJ, Lipcsey M, Kander T. Digital learning resource use among Swedish medical students: insights from a nationwide survey. BMC Med Educ, 2025, 25(1), 849. http://doi.org/10.1186/s12909-025-07446-7
5. Burel J, Trost O, Demeyere M, Rives N, Estour F, Ladner J, et al. Spaced repetition and other key factors influencing medical school entrance exam success: insights from a French survey. *BMC Med Educ*, **2025**, 25(1), 1036. http://doi.org/10.1186/s12909-025-07605-w
6. Çiçek FE, Ülker M, Özer M, Kıyak YS. ChatGPT versus expert feedback on clinical reasoning questions and their effect on learning: a randomized controlled trial. *Postgrad Med J*, **2025**, 101(1195), 458–463. http://doi.org/10.1093/postmj/qgae170
7. Cooper S, Twardowski N, Vogel M, Perling D, Ryznar R. The effect of spaced repetition learning through Anki on medical board exam performance. *Int J Med Students*, **2023**, 11, e1549. http://doi.org/10.5195/ijms.2023.1549
8. Gilbert MM, Frommeyer TC, Brittain GV, Stewart NA, Turner TM, Stolfi A, Parmelee D. A cohort study assessing the impact of Anki as a spaced repetition tool on academic performance in medical school. *Med Sci Educ*, **2023**, 33(4), 955–962. http://doi.org/10.1007/s40670-023-01826-8
9. Kaczmarek JI, Pokrywka J, Biedalak K, Kurzyp G, Grzybowski Ł. Optimizing retrieval-augmented generation of medical content for spaced repetition learning. *arXiv*, **2025**, preprint 2503.01859. http://doi.org/10.48550/arXiv.2503.01859

10. Kaur G, Nematollahi S, Das T. Navigating digital medical education in the current era: process over platform. *US Cardiol Rev*, **2025**, 19, e05. http://doi.org/10.15420/usc.2024.29
11. Kim TW. Application of artificial intelligence chatbots, including ChatGPT, in education, scholarly work, programming, and content generation and its prospects: a narrative review. *J Educ Eval Health Prof*, **2023**, 20, 38. http://doi.org/10.3352/jeehp.2023.20.38
12. Martinengo L, Ng MSP, Ng TDR, Ang YI, Jabir AI, Kyaw BM, Car LT. Spaced digital education for health professionals: systematic review and meta-analysis. *J Med Internet Res*, **2024**, 26(1), e57760. http://doi.org/10.2196/57760
13. Mehta A, Brooke N, Puskar A, Woodson MCC, Masi B, Wallon RC, Greeley DA. Implementation of spaced repetition by first-year medical students: a retrospective comparison based on summative exam performance. *Med Sci Educ*, **2023**, 33(5), 1089–1094. http://doi.org/10.1007/s40670-023-01839-3
14. Preiksaitis C, Rose C. Opportunities, challenges, and future directions of generative artificial intelligence in medical education: scoping review. *JMIR Med Educ*, **2023**, 9, e48785. http://doi.org/10.2196/48785
15. Slinger P, Omar M, Younus S, Charow R, Baxter M, Campbell C, et al. Innovative mobile app (CPD By the Minute) for continuing professional development in medicine: multimethods study. *JMIR Med Educ*, **2025**, 11(1), e69443. http://doi.org/10.2196/69443
16. Sriram A, Ramachandran K, Krishnamoorthy S. Artificial intelligence in medical education: transforming learning and practice. *Cureus*, **2025**, 17, e80852. http://doi.org/10.7759/cureus.80852
17. Stirrat T, Martin R, Umair M, Waller J. Advancing radiology education for medical students: leveraging digital tools and resources. *Pol J Radiol*, **2024**, 89, e508–e516. http://doi.org/10.5114/pjr/193518
18. Valladares Patiño AG, Rojas Peñafiel JA. Artificial intelligence tutoring versus tutoring with experts in learning the preclinical and clinical areas of medicine. *LACCEI*, **2023**, 1, 1504. http://doi.org/10.18687/LACCEI2023.1.1.1504
19. Weidener L, Fischer M. Artificial intelligence in medicine: cross-sectional study among medical students on application, education, and ethical aspects. *JMIR Med Educ*, **2024**, 10, e51247. http://doi.org/10.2196/51247
20. Weidener L, Fischer M. Proposing a principle-based approach for teaching AI ethics in medical education. *JMIR Med Educ*, **2024**, 10, e55368. http://doi.org/10.2196/55368
21. Wothe JK, Wanberg LJ, Hohle RD, Sakher AA, Bosacker LE, Khan F, Olson AP, Satin DJ. Academic and wellness outcomes associated with use of Anki spaced repetition software in medical school. *J Med Educ Curric Dev*, **2023**, 10, 23821205231173289. http://doi.org/10.1177/23821205231173289
22. Xu Y, Jiang Z, Ting DSW, Kow AWC, Bello F, Car J, Tham YC, Wong TY. Medical education and physician training in the era of artificial intelligence. *Singapore Med J*, **2024**, 65(3), 159–166. http://doi.org/10.4103/singaporemedj.SMJ-2023-203
23. Yao K, Nguyen J, Mathur M. Spaced repetition learning in radiology education: exploring its potential and practical application. *J Am Coll Radiol*, **2025**, 22(1), 15–21. http://doi.org/10.1016/j.jacr.2024.11.020