Journal of Health Development
e2663-1776

Review article

Prospects of Artificial Intelligence Application in Medical Education in the Republic of Kazakhstan: A Literature Review

Elvira Kokayeva [1], Aigerim Baimagambetova [2], Assem Dossanova [3], Aigul Zhunussova [4], Aigerim Mukhamedyarova [5], Oxana Tsigengagel [6*]

[1] Senior Lecturer of the Department of Internal Diseases, Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2] Dean of the School of Public Health, Astana Medical University, Astana, Kazakhstan
[3] Vice -rector for Academic Affairs, Astana Medical University, Astana, Kazakhstan
[4] Director of the Department of Accreditation and Quality Management, Astana Medical University, Astana, Kazakhstan
[5] Head of the Center for Educational Technology Transfer, Astana Medical University, Astana, Kazakhstan
[6] Head of the Department of Biostatistics, Bioinformatics, and Information Technologies, Astana Medical University, Astana, Kazakhstan
* Correspondence: tsigengagel.o@gmail.com

Received: 09 May 2025
Revised: 24 June 2025
Accepted: 09 July 2025
Published: 31 August 2025

Citation: Elvira Kokayeva, Aigerim Baimagambetova, Assem Dossanova, Aigul Zhunussova, Aigerim Mukhamedyarova, Oxana Tsigengagel. Prospects of Artificial Intelligence Application in Medical Education in the Republic of Kazakhstan: A Literature Review. J Health Dev. 2025, 60 (4), jhd012. https://doi.org/10.32921/2663-1776-2025-60-4-jhd012

Abstract

The integration of artificial intelligence (AI) in education presents a transformative opportunity to keep pace with technological advancements. In medical education, AI can personalize training, improve diagnostic skills through simulations, and enhance access to databases. However, its implementation faces significant challenges, including high costs, ethical concerns, and risks to academic integrity. In Kazakhstan, despite strategic goals for digitalization, these global challenges are compounded by local barriers.

This review aims to analyze the benefits and challenges of AI integration in medical education based on international and national literature and to develop recommendations for stakeholders in Kazakhstan.

A scoping review of 34 relevant sources (up to May 2025) was conducted using PubMed, Web of Science, Scopus, and Google Scholar databases, with a specific focus on studies related to Kazakhstan.

The analysis confirmed AI's significant potential to enhance education. However, several critical barriers were identified in Kazakhstan: a low level of AI literacy among students (up to 95.3% lack specialized knowledge) and faculty, pronounced infrastructural inequality between regions, and a deficit in local scientific capacity. For the successful integration of AI, Kazakhstan must shift its focus from merely implementing technology to cultivating human capital. Bridging the gap between AI's potential and the system's actual readiness requires systemic actions: large-scale training of personnel, fostering interdisciplinary research, and creating an equitable, ethically grounded educational ecosystem.

Keywords: medical education, artificial intelligence, digital health, Kazakhstan.

1. Introduction

AI has developed sporadically over the years and has only recently gained momentum with the advent of deep learning and artificial neural networks. The term AI, coined by John McCarthy in 1955, is defined as a machine with intelligent behaviors such as perception, reasoning, learning, or communication, and the ability to perform human-like tasks [1,2]. AI has become a transformative force in medical education, offering innovative solutions to enhance the learning experience and prepare future healthcare professionals for an

increasingly digital healthcare landscape. The integration of AI technologies into medical education represents a paradigm shift from traditional teaching methods to more adaptive, personalized, and efficient approaches that better address the complexities of modern healthcare [3,4].

The application of AI in medical education encompasses a variety of functions. For instance, AI systems can personalize the educational process by analyzing student performance data and tailoring educational content to address individual knowledge gaps [5]. This personalized approach not only fosters a deeper understanding of complex medical concepts but also enhances the critical thinking and problem-solving skills essential for effective patient care [6]. Moreover, AI-powered tools can facilitate realistic simulations and intelligent tutoring systems, allowing students to practice clinical skills in a controlled environment without the risks associated with real-life patient interactions [7].

Despite its numerous benefits, the integration of AI into medical education presents significant challenges that must be addressed to ensure its effective implementation. Ethical considerations, including data privacy, algorithmic bias, and transparency in AI applications, are critical issues that require thorough examination [1]. For example, concerns about how AI systems make decisions can lead to mistrust among students and educators if not properly addressed. Furthermore, the potential for biased algorithms can exacerbate existing disparities in healthcare education and patient outcomes [2,3]. Additionally, both educators and students must receive adequate training to effectively utilize these technologies and understand their implications in clinical practice [4]. This underscores the imperative to develop a robust framework for the ethical use of data [1]. As the healthcare landscape transforms, becoming more complex and data-driven, there is a pressing need for educational methodologies that can effectively adapt to these dynamic changes.

At the same time, studies focused specifically on Kazakhstan paint a more concrete and alarming picture. An analysis by Orynbassar et al. (2024) showed that, despite the successes of individual innovation hubs like Astana Hub, the overall level of AI adoption in the country's education system still significantly lags behind that of global leaders [5].

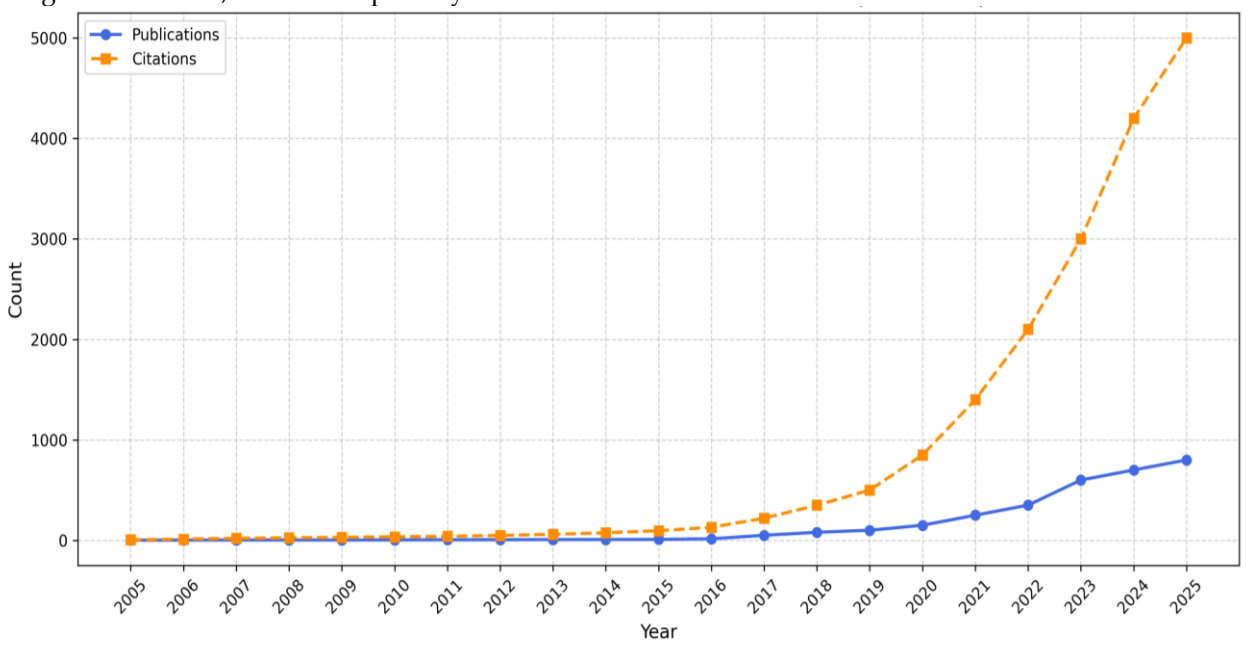

Figure 1 – The total number of publications and the sum of citations by year over the last two decades. Retrieved from Web of Science on "artificial intelligence in medical education" on May 2025

The greatest concern is the low level of readiness among both students and faculty. A study covering medical and biomedical sciences students revealed that the vast majority (up to 95.3%) have no specialized knowledge in AI, which fosters a neutral or even negative attitude towards its application in medicine [6]. This critical "digital knowledge gap" is exacerbated by infrastructural and financial constraints, especially in regional universities, as well as the absence of adapted educational programs capable of preparing specialists to work in this new technological reality [7].

Thus, there is a significant gap between the declared potential of AI and the actual readiness of Kazakhstan's medical education system to adopt it. Interestingly, a preliminary search in Web of Science on the use of AI in medical education (dated May 2025) demonstrated a growing enthusiasm in this field, with an increase in the total number of publications and citations over the past two decades (Figure 1). This reflects the growth in research and development of AI in medical education in recent years. Thus, this review aims to systematize the evidence on the advantages and obstacles of integrating AI into medical education in Kazakhstan and to formulate strategic recommendations to bridge the identified gap between its potential and current readiness. The purpose of this study is to review international and national data regarding the integration of AI into medical education, to analyze its benefits and challenges, and to formulate practical recommendations for key stakeholders.

2. Methodology

A comprehensive literature search was conducted across Scopus, Web of Science, ERIC, PubMed, EMBASE, and Google Scholar, focusing on full-text articles in English up to May 2025. Key search terms included "artificial intelligence", "machine learning", "deep learning", "medical education", "medical student", "medical curriculum", "medical school", "medical training" and "Kazakhstan". The objective was to identify studies that discuss the benefits and challenges of integrating AI in medical education. Selected studies focused on specific AI applications and their pros and cons, while case reports, commentaries, letters to the editor, and previously published reviews were excluded. Data were extracted to highlight benefits, challenges, and ethical considerations related to AI in medical education.

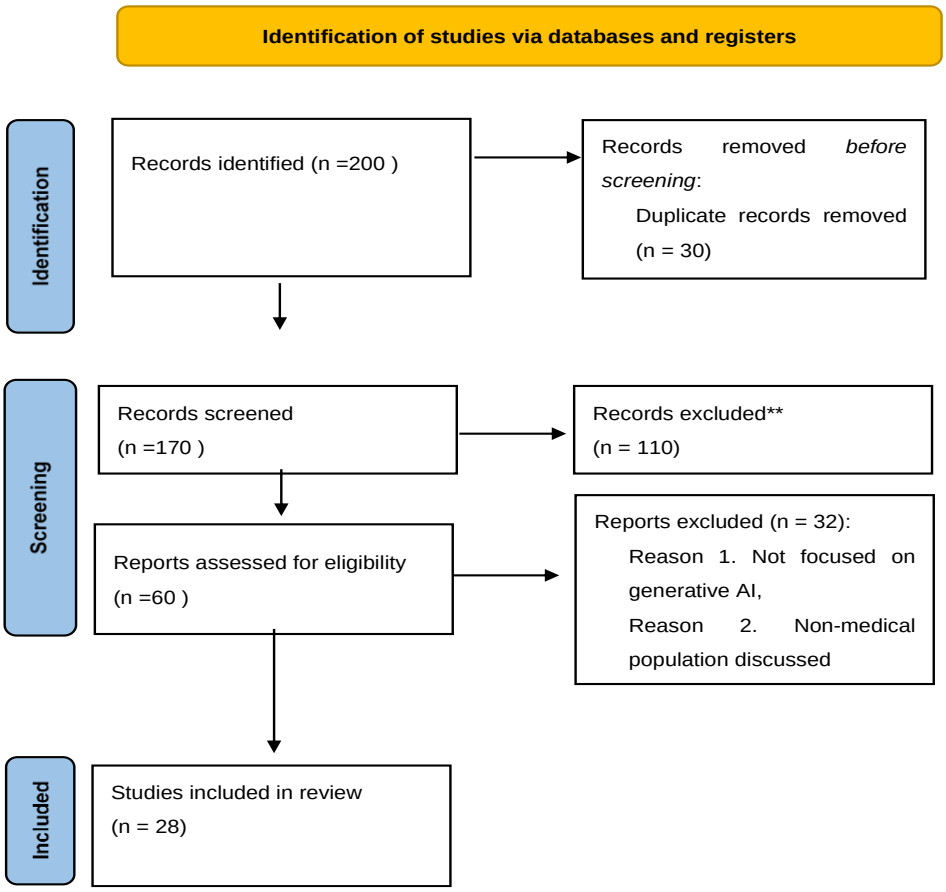

Figure 2 – PRISMA flow diagram of search and screening for generative AI in medical education articles

A narrative synthesis summarized common themes, emphasizing potential benefits like personalized learning and improved curriculum development, as well as critical challenges for successful AI integration. This review follows the PRISMA statement guidelines for systematic literature

searching (Figure 2). Our initial search yielded 200 unique records After the removal of 30 duplicates, 170 studies were screened. Of these, 110 were deemed irrelevant to our research focus, and an additional 32 were excluded because they did not specifically address generative AI in medical education or involved a non-physician population. Ultimately, a total of 28 articles were included in the final analysis.

3. Benefits and Challenges of AI Integration

Our comprehensive review of the selected literature allowed for a thematic synthesis of the key findings regarding the integration of AI into education in Kazakhstan, with a specific focus on its implications for medical training. The analysis revealed five overarching themes: (1) Readiness and Attitudes towards AI, (2) Educational Strategies and Content, (3) Infrastructure and Policy, (4) Application in Medicine, and (5) Ethics, Law, and Academic Integrity. These themes and their corresponding aspects, supported by evidence from the analyzed sources, are detailed in Table 2.

The findings indicate a significant paradox: while there is a strong governmental push for digitalization and a generally positive perception of AI's potential among students, this is contrasted by critical gaps in readiness and core competencies. A key barrier identified across multiple sources is the low level of AI literacy among both students and faculty, coupled with infrastructural and financial constraints, particularly in regional institutions.

Furthermore, while the potential for AI to enhance learning through personalization and innovative pedagogical methods is widely acknowledged, its practical implementation is hindered by a lack of adapted curricula and a deficit in local scientific expertise. Ethical concerns, including algorithmic bias, data privacy, and academic integrity, are prominent, with Kazakhstan's regulatory framework still in the developmental stage. Finally, the analysis highlights a concerning trend of retracted publications in the field, indicating issues with the quality and rigor of research, which further complicates evidence-based policymaking.

Table 2 – Thematic Analysis of AI Integration in Education in Kazakhstan (with a Focus on Medicine)

Theme	Aspect / Finding	Rationale in the Context of Kazakhstan and/or Education	Source(s)
Theme 1: Readiness and Attitudes towards AI			
Students: Positive Perception but Low Readiness		Studies in Kazakhstan show that while students widely use AI tools (especially ChatGPT) and perceive them as useful, up to 95% lack specialized AI knowledge, leading to a fundamental readiness gap. Some resistance and challenges in usage are also noted.	Yilmaz et al., 2023, Zhunusbekova &, Askarkyzy 2024, [8,9]
Faculty: Resistance and Competency Deficit		A significant portion of teachers in Kazakhstan (up to 16%) are skeptical of innovation. There is a critical shortage of faculty equipped with the necessary ethical, pedagogical, and technical competencies to work with AI.	Abisheva et al., 2024, Nurbekova et al., 2024 [10, 11]
Patients: Cautious Optimism		Patients in Kazakhstan generally have a positive view of AI in healthcare but prefer it to be a supplementary tool under human supervision due to risks of medical errors and privacy violations.	Tursynbek et al., 2024 [12]
Theme 2: Educational Strategies and Content			
Personalization and Adaptive Learning		AI is seen as a key tool for individualizing learning, analyzing student performance, and automating administrative tasks, thereby freeing up time for educators. This is confirmed by general reviews on Kazakhstan and international experience.	Orynbassar et al., 2024], Kabassova, 2024 [5,13]

Theme	Aspect / Finding	Rationale in the Context of Kazakhstan and/or Education	Source(s)
	Development of Cognitive and Practical Skills	AI-based instruction has been proven effective in developing logical thinking in future teachers. In medicine, AI tools can enhance diagnostic skills (e.g., in radiology), though their superiority over traditional methods is not always definitive.	Bokan et al., 2025], Schropp et al., 2024 [14,15]
	Innovative Pedagogical Methods	Combining AI with game-based methods (gamification) and modern technologies (STEM) significantly increases student engagement and educational outcomes.	Bekzhassarova, 2025, Serik et al., 2025 [16,17]
	Language and Writing Support	AI tools (e.g., "Write & Improve") demonstrate effectiveness comparable to traditional teacher feedback and can be leveraged to support trilingual education (Kazakh, Russian, English).	Bodaubekov et al., 2025, Zholdigaly et al., 2024 [18,19]
Theme 3: Infrastructure and Policy			
	State Strategy and Digitalization	AI integration is part of Kazakhstan's national digitalization policy, creating a favorable political background. Successful projects exist (e.g., Astana Hub, "Torelik" judicial system), but their impact on education is still limited.	Vykhodets, 2022, Nurkey et al. [20,21]
	Digital Divide and Access	This is a key barrier for Kazakhstan. The gap in access to technology and high-speed internet between urban and rural areas hinders the equitable implementation of AI and exacerbates educational inequality.	Orynbassar et al., 2024 Nurgazina et al., [5, 22]
	Infrastructural and Financial Constraints	Despite state support, universities face a lack of funding, modern equipment, and qualified IT specialists for the full-scale integration of AI.	Talkibaev & Sadykov, 2024, Smagulov et al., 2025 [23,24]
Theme 4: Application in Medicine			
	Enhancing Clinical Care Quality	The successful application of AI in Kazakhstan's healthcare (e.g., in stroke care and remote patient monitoring) proves its effectiveness and directly creates a demand for training medical personnel who can work with these systems.	Mukhammedzhanova & Suleimenova, 2024, Makhanbetkhan et al., 2025, [25,26]
	Development of Local Software	The importance of training students to develop their AI-based software, rather than merely using off-the-shelf solutions, is emphasized as a foundation for technological sovereignty.	Serik et al., 2025 [17]
	Diagnostics and Prognostication (Int'l Experience)	Advanced platforms like MOSAIC demonstrate the superiority of AI over traditional statistical methods in classifying and prognosticating rare cancers, showcasing the technology's potential.	D'amico et al., 2024 [27]
Theme 5: Ethics, Law, and Academic Integrity			
	Algorithmic Bias	AI tools trained on human-labeled data reproduce human biases, creating a risk of systematic errors, for instance, in radiology. This highlights the need for models trained on diverse, local data.	Lenskjold et al., 2024 [28]
	Regulatory Policy in Kazakhstan	The country is actively discussing approaches to the legal regulation of AI, drawing on the experience of the EU and the UK, but this process is still ongoing, and a comprehensive framework is yet to be established.	Konusova, 2023, Bissaliyev et al., 2025 [29,30]

Theme	Aspect / Finding	Rationale in the Context of Kazakhstan and/or Education	Source(s)
Academic Integrity and Deepfakes		Widespread use of AI by students in Kazakhstan for assignments poses serious challenges to academic integrity. The emergence of deepfakes presents a new, under-explored threat to learning and assessment.	Zhunusbekova &Askarkyzy, 2024 [9]
The Problem of Retracted Papers		An important meta-finding: The large number of retracted papers in the field of AI in education indicates significant issues with research quality and scientific ethics, which undermines the trustworthiness of the evidence base.	Plata, 2023 [31]

The Human Capital Deficit: A Core Barrier to Progress

The most significant finding of this review is not the lack of technology but the profound deficit in human readiness. The data showing that up to 95.3% of medical students lack specialized AI knowledge is a stark indicator that the system is failing to prepare its key stakeholders for the future [6]. This "AI literacy gap" is not merely a technical issue; it fosters a culture of either mistrust or, conversely, uncritical acceptance of AI tools [9]. This situation is further compounded by faculty resistance, with a notable portion of educators (up to 16%) remaining skeptical of innovation, and a documented lack of specific ethical and pedagogical competencies for teaching with AI [10,30]. Without a concerted effort to upskill both students and educators, any investment in AI infrastructure will yield minimal returns, creating "digital decorations" rather than functional educational tools.

This human capital deficit is deeply intertwined with the low scientific output in the region. As the scientometric analysis shows, the low publication activity in medical AI in Central Asia signifies a shortage of local experts who can drive research, develop culturally and contextually relevant AI models, and train the next generation of educators [31]. This creates a vicious cycle of dependency on foreign technologies, which may carry inherent biases and fail to address local healthcare needs [26].

The Paradox of Policy and Infrastructure: A Top-Down Approach with Bottom-Up Challenges

The government of Kazakhstan has demonstrated a clear commitment to digitalization through national strategies and high-profile projects like Astana Hub. This top-down political will creates a favorable environment for innovation. However, our findings reveal a disconnect with the on-the-ground reality. The "digital divide" remains a major obstacle, with significant disparities in internet access and technological resources between urban centers and rural regions [22]. This means that while a student in Almaty or Astana might have access to cutting-edge AI tools, a student in a regional medical college is left behind, thus exacerbating existing social and educational inequalities.

Moreover, successful pilot projects in clinical settings, such as AI-assisted stroke care and remote patient monitoring, highlight another paradox [25,32]. The healthcare sector is beginning to adopt AI, creating an immediate demand for AI-literate medical professionals. Yet, the educational system that is supposed to supply these professionals is lagging, creating a mismatch between the needs of the future labor market and the competencies of its graduates.

The Emerging Crisis of Academic and Scientific Integrity

The widespread use of generative AI for academic tasks has introduced a new dimension to academic integrity [19,17]. While tools like ChatGPT can be powerful learning aids, their misuse for plagiarism and cheating poses a threat to the validity of assessment methods. This requires a fundamental rethinking of how we evaluate student knowledge, moving away from simple recall towards assessing critical thinking, problem-solving, and ethical reasoning.

Perhaps more alarmingly, this review uncovered a significant number of retracted publications in the field of AI in education. This "retraction crisis" is a red flag, signaling systemic issues with research quality, peer-review processes, and scientific ethics on a global scale. For a developing field, this undermines the trustworthiness of the very evidence base upon which policymakers and educators are expected to build their strategies. It calls for a more critical and discerning approach to scientific literature and emphasizes the need for Kazakhstan to foster its own rigorous and ethical research culture.

4. Conclusions

The integration of AI into medical education is a global trend, yet in Kazakhstan, it faces unique challenges. Despite national strategic goals, our review reveals a critical aim between the potential of AI and the system's actual readiness. This aim is driven by three key barriers: low AI literacy among students and faculty, infrastructural inequality, and a deficit in local scientific capacity. For a successful transformation, the paradigm must shift from merely implementing technology to deliberately cultivating human capital. Kazakhstan's priorities must be a large-scale upskilling of its workforce, fostering local interdisciplinary research, and building an equitable, ethically grounded educational ecosystem. Only this approach will prepare a new generation of physicians capable of effectively leveraging AI for the benefit of society.

Limitations of the Review. This scoping review has several limitations. Firstly, the analysis is based on a limited number of studies specifically focused on medical education in Kazakhstan, which required extrapolation from broader educational or regional contexts. Secondly, the rapidly evolving nature of AI means that some findings may quickly become outdated. Finally, the large number of retracted articles in this field suggests that the quality of available evidence can be variable. Future research should include longitudinal studies to track the long-term impact of AI integration and more granular case studies within specific Kazakhstani medical universities.

Author Contributions: Conceptualization – O.T. and A.Zh.; methodology – E.K. and A.M.; validation – V.R.; formal analysis – A.B. and A.D.; investigation – E.K. and A.M.; resources – E.K. and A.M.; data curation – E.K. and A.M; writing (original draft preparation) – A.B. and A.D.; writing (review and editing) – E.K., A.M., O.T. and A.Zh.; supervision – A.B. and A.D.; project administration – E.K. and A.M. All authors have read and agreed to the published version of the manuscript.

Data availability statement: The data used to support the findings of this study are available from the corresponding author upon request.

Funding: This research received no external funding.

Declaration of competing interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Қазақстан Республикасындағы медициналық білім беру саласында жасанды интеллектті қолдану перспективалары: Әдеби шолу

Кокаева Э.А. [1], Баймагамбетова А.А. [2], Досанова А.К. [3], Жунусова А.Б. [4], Мухамедьярова А.Б. [5], Цигенгагель О.П. [6]

[1] Ішкі аурулар кафедрасы, Аль-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан
[2] Қоғамдық денсаулық сақтау мектебінің деканы, Астана медицина университеті, Астана, Қазақстан
[3] Академиялық жұмыстар жөніндегі проректор, Астана медицина университеті, Астана, Қазақстан
[4] Аккредитация және сапаны басқару департаментінің директоры, Астана медицина университеті, Астана, Қазақстан
[5] Білім беру технологияларын трансферттеу орталығының басшысы, Астана медицина университеті, Астана, Қазақстан
[6] Биостатистика, биоинформатика және ақпараттық технологиялар кафедрасының меңгерушісі, Астана медицина университеті, Астана, Қазақстан

Түйіндеме

Жасанды интеллектті (ЖИ) білім беру жүйесіне енгізу технологиялық дамумен қатар қадам басудың жаңашыл мүмкіндігі болып табылады. Медициналық білім беруде ЖИ оқытуды жекешелендіріп, симуляциялар арқылы диагностикалық дағдыларды жетілдіріп, деректер базасына қолжетімділікті арттыра алады. Алайда оны енгізу келесідей бірқатар елеулі қиындықтарға тап болады: жоғары шығындар, этикалық мәселелер және академиялық адалдыққа төнетін қауіптер. Қазақстанда цифрландыруға бағытталған стратегиялық мақсаттарға қарамастан, бұл жаһандық мәселелер жергілікті кедергілермен күрделене түсуде.

Бұл шолудың мақсаты – халықаралық және ұлттық әдебиеттер негізінде медициналық білімге ЖИ интеграциясының артықшылықтары мен проблемаларын талдап, Қазақстандағы мүдделі тараптар үшін ұсынымдар әзірлеу.

PubMed, Web of Science, Scopus және Google Scholar дерекқорларын пайдалана отырып (2025 жылдың мамыр айындағы жағдай бойынша) Қазақстанға қатысты зерттеулерге баса назар аудара отырып, 34 сәйкес дереккөзге шолу жүргізілді.

Талдау ЖИ-тің білім беру сапасын арттыруда айтарлықтай әлеуеті бар екенін растады. Алайда Қазақстан үшін бірқатар маңызды кедергілер анықталды: студенттердің ЖИ саласындағы білім деңгейінің төмендігі (95,3%-ға дейін арнайы білімі жоқ), оқытушылардың дайын еместігі, өңірлер арасындағы инфрақұрылымдық теңсіздік және жергілікті ғылыми әлеуеттің жетіспеушілігі. ЖИ-ті сәтті енгізу үшін Қазақстан технологияларды жай енгізуден адам капиталының дамуына басымдық беруі қажет. ЖИ мүмкіндігі мен жүйенің нақты дайындығы арасындағы алшақтықты жою үшін жүйелі шаралар қажет: кадрларды жаппай даярлау, пәнаралық зерттеулерге қолдау көрсету және әділетті, этикалық тұрғыдан негізделген білім беру экожүйесін қалыптастыру.

Түйін сөздер: медициналық білім беру, жасанды интеллект, цифрлық денсаулық сақтау, Қазақстан.

Перспективы применения искусственного интеллекта в медицинском образовании в Республике Казахстан: Обзор литературы

Кокаева Э.А. [1], Баймагамбетова А.А. [2], Досанова А.К. [3], Жунусова А.Б. [4], Мухамедьярова А.Б. [5], Цигенгагель О.П. [6]

[1] Кафедра внутренних болезней, Казахский национальный университет имени Аль-Фараби, Алматы, Казахстан
[2] Декан Школы общественного здравоохранения, Медицинский университет Астана, Астана, Казахстан
[3] Проректор по академической работе, Медицинский университет Астана, Астана, Казахстан
[4] Директор департамента аккредитации и управления качеством, Медицинский университет Астана, Астана, Казахстан
[5] Руководитель центра трансферта образовательных технологий, Медицинский университет Астана, Астана, Казахстан
[6] Заведующая кафедрой биостатистики, биоинформатики и информационных технологий, Медицинский университет Астана, Астана, Казахстан

Резюме

Интеграция искусственного интеллекта (ИИ) в образование представляет собой преобразующую возможность идти в ногу с технологическими достижениями. В медицинском образовании ИИ может персонализировать обучение, улучшать диагностические навыки с помощью симуляций и улучшать доступ к базам данных. Однако его внедрение сталкивается со значительными проблемами, включая высокие затраты, этические проблемы и риски для академической честности. В Казахстане, несмотря на стратегические цели цифровизации, эти глобальные проблемы усугубляются локальными барьерами.

Целью данного обзора является анализ преимуществ и проблем интеграции ИИ в медицинское образование на основе международной и национальной литературы и разработка рекомендаций для заинтересованных сторон в Казахстане.

Был проведен обзор 34 соответствующих источников (по состоянию на май 2025 года) с использованием баз данных PubMed, Web of Science, Scopus и Google Scholar с особым акцентом на исследования, связанные с Казахстаном.

Анализ подтвердил значительный потенциал ИИ для улучшения образования. Однако для Казахстана были выявлены критические барьеры: низкий уровень грамотности в области ИИ среди студентов (до 95,3% не имеют специальных знаний) и преподавателей, выраженное инфраструктурное неравенство между регионами и дефицит местного научного потенциала. Для успешной интеграции ИИ Казахстан должен переключить свое внимание с простого внедрения технологий на развитие человеческого капитала. Преодоление разрыва между потенциалом ИИ и фактической готовностью системы требует системных действий: масштабной подготовки кадров, содействия междисциплинарным исследованиям и создания справедливой, этически обоснованной образовательной экосистемы.

Ключевые слова: медицинское образование, искусственный интеллект, цифровое здравоохранение, Казахстан.