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Research paper

The Effectiveness of The Application of Artificial Intelligence in Teaching Students of Medical Institutions

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Abstract

The purpose of this article is to study the effectiveness of integrating artificial intelligence into medical education and to identify the key advantages, challenges, and prospects. A comparative analysis of the implementation of artificial intelligence technologies in Kyrgyzstan, Kazakhstan, Tajikistan, Canada, Germany, Austria, and Switzerland was carried out. Randomised controlled trials, meta-analyses, systematic reviews, and surveys were used to assess the effectiveness of introducing artificial intelligence into medical university curricula. It was found that the use of artificial intelligence technologies helps to reduce task completion time by an average of 35 minutes, improve clinical skills (effect 0.68; 95% CI: 0.30-1.06, $p<0.001$) and increase satisfaction with the learning process (effect 0.46; 95% CI: 0.26-0.66, $p<0.001$). The level of knowledge about artificial intelligence was studied, which was 0.4 (95% CI: 0.3-0.5, $p<0.01$), and the positive attitude of students towards its use was 0.7 (95% CI: 0.6-0.8, $p<0.01$). It has been shown that adaptive learning systems based on artificial intelligence improve diagnostic skills, accuracy of clinical decisions, and situation modelling. Virtual and augmented reality contribute to the safe development of skills. The challenges of implementing technologies are identified, including the need for ethical standards, minimising algorithmic biases, and preparing teachers.

Keywords: *Chatbots; Curricula; Innovative Technologies; Neural Networks; Personalised Learning; Virtual Reality.*

1. Introduction

The integration of artificial intelligence (AI) into higher education institutions (HEIs) is a strategic direction for modernising educational processes. The use of AI helps to improve curricula, adapt them to the needs of modern students, create innovative learning environments, and develop important professional competencies. Moreover, AI has become an integral part of medical education reform, providing personalised learning and modelling real-life clinical scenarios. AI is used to create adaptive learning materials that identify gaps in the knowledge of medical students and provide accurate feedback in real time. This helps to reduce the cognitive load of students and helps to strengthen their diagnostic and analytical skills.

AI is increasingly being implemented at all levels of medical education: undergraduate, graduate, clinical, and continuing (Dudar et al. 2025). The main areas of its application are radiology, diagnostics, dentistry, ophthalmology, and cardiology. Universities are actively developing courses in programming, computer science, and algorithms to prepare students to work in the field of smart medicine (Karymsakova et al. 2020; Prontenko et al. 2019). The analysis of scientific sources shows that there are wide possibilities for using AI in higher education and the scientific space, including automation of assessment processes, support for the development of independent learning, and improved communication between students and teachers. Researchers Khan et al. (2023) noted that AI-based tools such as ChatGPT have gained wide popularity due to advances in natural language processing, which have opened new horizons for academic activities in the field of medical education. The use of these technologies has significantly accelerated the preparation of scientific papers, increased the productivity of the educational process in medical universities, and simplified the transition to innovative educational methods. Crompton & Burke (2023) found that AI played an important role in supporting teachers in the automatic creation of test tasks and comprehensive assessment materials. The study confirmed the ability of AI to generate plausible short-answer questions, but emphasised the need for teachers to carefully review such tasks to ensure that they meet learning objectives, especially in the context of final assessments. Mir et al. (2023) confirmed that AI contributed to the development of educational content that met the current challenges of modern medicine, allowing future doctors and teachers to work with up-to-date data and tools. The researchers concluded that this approach increased the relevance of the learning process, contributed to the development of clinical thinking and practical skills that are critical for the adaptation of future medical professionals to the rapidly changing medical environment.

Other studies conducted by Sun et al. (2023) have shown that traditional curricula do not always keep pace with the rapid development of technology, leading to a gap between the knowledge of medical students and clinicians. Most medical students feel insufficiently prepared

to work with AI, which highlights the need to update educational programmes at all levels. Another study conducted by Turner et al. (2024) found that assessment in medical education faces several complex challenges, among which the key ones are a large amount of diverse data, limited material and human resources, and the presence of systemic bias. However, in these circumstances, AI, along with its subfields – machine learning (ML) and deep learning (DL) – has been able to significantly improve the effectiveness of this approach, overcoming the limitations of traditional assessment methods. This approach not only reduced the workload of teachers but also opened new opportunities for personalised learning interventions, such as individual coaching, academic performance forecasting, and timely identification of students who needed additional support. In addition, the researchers found that the integration of AI into medical education was accompanied by several ethical and technical challenges. One of the main ones was to ensure the transparency of the algorithms and prevent the spread of biases that may arise due to the uneven distribution of data or incorrect programming of models.

The growing interest of medical students in AI reflects their awareness of the importance of digital tools for the future of medical practice. In this context, the results of a multicentre study based on a survey conducted by Pinto dos Santos et al. (2019), which covered 260 students (166 women and 94 men), demonstrated a high interest in the study of artificial intelligence. Most respondents agreed that the use of artificial intelligence will revolutionise and improve radiology (77% and 86%), while denying the possibility of completely replacing radiologists (83%). More than two-thirds of respondents supported the need to integrate artificial intelligence into medical curricula (71%).

In the light of global changes and the introduction of the latest technologies in the healthcare sector, the reform of medical education has become particularly relevant. Orozalieva et al. (2021) found that in Kyrgyzstan, the healthcare system faced difficulties related to the shortage of healthcare professionals and the lack of their training to meet the current needs of the industry. To address these challenges, a medical education reform was launched in partnership between Kyrgyzstan and Switzerland with the support of the Swiss Agency for Development and Cooperation. The initiative was aimed at adapting curricula to international standards, integrating modern educational technologies, and enhancing the professional competence of medical professionals, which was an important step towards strengthening the national healthcare system.

The inclusion of AI in formal medical education is a necessary step to prepare future professionals to work in high-tech environments (Znamenshchykov et al. 2020). The development of structured curricula will help bridge the gap between traditional education and modern technological challenges, as well as ensure high-quality training of medical professionals to work in digital healthcare.

The purpose of this study was to assess the effectiveness of introducing artificial intelligence into medical education, as well as to identify its main advantages, challenges, and prospects for use. The main objective of this project was to improve the quality of medical training by updating curricula and introducing modern educational approaches, with a special focus on the use of AI.

2. Materials and methods

This study analyses the implementation of AI in medical education in different countries, including Kyrgyzstan, Kazakhstan, Tajikistan, Germany, Austria, Switzerland, and Canada. The selection of countries for this study was deliberate and aimed at providing a diverse perspective on the integration of artificial intelligence in medical education. The countries were chosen based on their geographical and socio-economic diversity. Specifically, Kyrgyzstan, Kazakhstan, and Tajikistan represent Central Asia, offering insights into the challenges and opportunities of AI integration in developing regions. In contrast, Germany, Austria, Switzerland, and Canada represent Europe and North America, providing a viewpoint from more developed regions with advanced healthcare and educational systems. This comparative approach allows for a comprehensive analysis of how different regions adapt and implement AI technologies in medical education, highlighting both universal trends and region-specific issues. The goal was to assess the effectiveness of AI integration into medical curricula, determine its impact on the quality of education, and identify key benefits and potential challenges. To achieve this goal, several methodological approaches were used to obtain a comprehensive picture of the process of AI implementation in the educational process.

At the first stage, the scientific literature on the use of AI in medical education was analysed. The sources were selected from the scientometric databases Web of Science, Scopus, PubMed, and Google Scholar. After applying the inclusion/exclusion criteria, 35 scientific publications that met the requirements of methodological reliability, high-quality research, and relevance (2019-2025) were selected for analysis. Particular attention was paid to the papers that investigated the interaction of AI technologies with personalised learning methods and assessed their effectiveness compared to traditional teaching approaches.

The second stage involved a comparative analysis of traditional teaching methods and innovative AI-based technological approaches. The concepts of data-driven learning and adaptive learning aimed at personalising the educational process and improving its efficiency were studied. The analysis included an assessment of the following indicators: students' cognitive skills and their ability to make diagnostic decisions; the level of learning and students' adaptation to new teaching methods; the time required to master complex topics, comparing the learning speed of different approaches; and students' motivation to learn, which was assessed through surveys, analysis of learning outcomes, and feedback from participants.

The third stage assessed the integration of intelligent tutoring systems (ITS) and a chatbot (ChatGPT) into the learning process. The potential applications of these technologies across various medical fields were explored. Particular attention was paid to how the use of AI affects the automation of knowledge assessment, correction of learning paths, and improvement of students' clinical competencies. At the fourth stage, the researchers studied the strategies for implementing AI in medical education. Initiatives, university policies, and private educational programmes aimed at digitalising the educational process were analysed. Special attention was paid to the reform in Kyrgyzstan, in partnership with the Swiss Agency for Development and Cooperation. At the final stage, the research results were systematised and analysed to identify the main trends and challenges in the use of AI in medical education. A special focus was made on the ethical aspects of AI implementation, including the issues of algorithm bias, transparency of decision-making, and the impact on student autonomy.

To ensure the reliability of the results, randomised controlled trials, meta-analyses, and systematic reviews were used, and survey-based research was analysed, which allowed us to form an objective picture of the effectiveness of AI implementation in medical university curricula.

3. Results and discussion

3.1 Personalisation and automation of learning with AI

In conformity with the latest educational initiatives in Kyrgyzstan (Orozalieva et al. 2021), the field of digital transformation of medicine is only gaining momentum, and regional educational institutions have the potential to implement AI, in particular through the modernisation of curricula, the use of adaptive digital platforms and the integration of innovative technologies (Heller et al. 2023), which contribute to

the personalisation of learning, automation of assessment and the creation of interactive environments for the training of future medical professionals.

AI is changing modern medical education, laying the foundations for innovative approaches to training future doctors (Masters 2019). To ensure the high quality of the educational process, teachers must have fundamental knowledge of AI, understand its impact on medicine and educational methodologies, and be prepared to adapt curricula to the challenges of digital transformation. Given these conditions, over the past ten years, Kyrgyzstan has seen a significant improvement in the standards of medical education through the introduction of innovative technologies, including AI-based solutions, which have led to a noticeable increase in the qualifications of medical personnel. A similar transformation is observed in Tajikistan, where undergraduate, postgraduate, and continuing education programmes have been reorganised by the recommendations of the World Federation of Medical Education, using AI tools to optimise the learning process (Fedorchenko et al. 2024). At the same time, Kazakhstan is gradually improving the quality of the educational process in the field of medicine and scientific research, which is reflected in the growing number of scientific publications and the integration of AI technologies to improve teaching efficiency (Fedorchenko et al. 2024).

The use of AI in the educational process was explained by its ability to perform complex cognitive tasks, such as data analysis, learning, knowledge accumulation, and practical application. Machine learning algorithms, neural networks, and deep learning allowed for efficient work with large amounts of information, making these technologies a key tool in personalising the learning process (Boychenko & Bublii, 2024). AI has adapted educational materials to the individual needs of students, which is especially important for students from remote regions or those with limited access to resources (Sabatayeva et al. 2018). Thus, AI technologies not only increased the accessibility of knowledge but also removed barriers to learning, promoting equal access to quality medical education.

The use of AI in the form of chatbots created new prospects for improving the educational process, as they not only answered students' questions but also automated routine tasks, such as creating flashcards or short summaries, providing instant feedback (Ali et al 2024; Ghorashi et al. 2023). Ali et al. (2024) reported that natural language processing (NLP) was an important AI feature that automated feedback, simplified complex concepts, and facilitated individualised learning. For example, NLP technologies could be used to analyse gaps in students' knowledge and form personalised educational strategies, which increase the efficiency of the learning process. Moreover, AI-based chatbots, such as ChatGPT, provided curriculum organisation, self-assessment, and personalisation of learning materials by analysing data based on the personal needs of each student (Srinivasan et al. 2024). In addition, they also acted as interactive clinical assistants at the preclinical stage and in the inpatient setting, helping students understand complex clinical scenarios and improve decision-making skills. The main advantages of chatbots were the integration of educational content, quick access to information, simultaneous support for multiple users, and real-time assistance.

ITS, which used advanced AI algorithms, revolutionised the approach to medical education, creating conditions for not only personalised but also dynamic and interactive learning (Diachuk 2024). They mimicked the benefits of individual work with a teacher by analysing data on students' learning preferences, knowledge level, and learning style. ITS allowed automatically detecting knowledge gaps and offered personalised educational trajectories that adapted to the progress of each student (Narayanan et al. 2023). This provided not only automated feedback but also facilitated the integration of modern technologies into teaching and student collaboration. Teachers coordinate the educational process, provide support, and create a harmonious environment in which AI acts as a tool that complements rather than replaces traditional approaches to learning. Therefore, educators play a central role in the implementation of AI in the educational process, guiding the adaptation of curricula.

According to research by Ghorashi et al. (2023), AI-based technologies have been a powerful tool for creating certification tests, analysing students' academic progress, and improving teaching materials. Automation of routine processes significantly reduced the administrative burden on teachers, allowing them to focus on strategic aspects of teaching, such as integrating innovative approaches and supporting individual student needs. In addition, AI was able to analyse large amounts of data, creating individualised learning paths, identifying gaps in students' knowledge, and providing recommendations for additional materials and tasks to improve their understanding (Protsak et al. 2023). This approach contributed to a more effective adaptation of learning to the needs of each student and improved the quality of the educational process in general.

It is worth noting that virtual reality (VR) is one of the most promising tools in modern medical education, providing interactive learning environments. In the studies conducted, augmented reality and gamification created conditions that contributed to the development of students' technical and cognitive skills. VR systems allowed for the simulation of realistic clinical scenarios, which was especially valuable in cases where it was not possible to simulate real patients (Sapci & Sapci, 2020). Moreover, due to their interactivity, such environments facilitated the development of critical skills needed in clinical practice while ensuring patient safety.

Lin et al. (2024) conducted a detailed study of the impact of VR learning on cognitive, emotional, and psychomotor aspects in nursing education. The systematic review and meta-analysis analysed eight randomised controlled trials that demonstrated significant improvements in key learning components among medical students. Statistically significant effect sizes were found for improving knowledge (0.24; 95% CI: 0.05-0.42; $p=0.011$), developing practical skills (0.68; 95% CI: 0.30-1.06; $p<0.001$), confidence in their abilities (0.287; 95% CI: 0.008-0.567; $p=0.044$) and satisfaction with the learning process (0.46; 95% CI: 0.26-0.66; $p<0.001$). These results emphasise the high efficiency of VR as an innovative tool in the training of future medical professionals. The use of VR contributes to the creation of an interactive and realistic learning environment that allows students to safely practice clinical scenarios, develop critical thinking, and improve technical skills. Particularly important is the impact of VR on increasing students' confidence in their practical abilities, which has a positive impact on their readiness for clinical practice. However, the authors emphasise the need for further research to assess the long-term effects of VR in medical education and to study its effectiveness in other contexts and among different categories of students (Lin et al. 2024). The integration of such technologies into curricula should be accompanied by methodological support for teachers and the development of standards for the optimal use of VR in the educational process.

3.2 The role of AI in shaping clinical competencies and critical thinking

AI plays a key role in the development of clinical competencies of future specialists. The use of AI allows for the creation of interactive learning environments that simulate realistic clinical scenarios, where medical students can practice critical skills and make decisions in conditions as close as possible to real clinical practice. Such technologies ensure patient safety while providing students with the opportunity to improve their practical skills.

Studies have demonstrated that Support Vector Machines (SVMs) have been shown to be highly effective in medical education. These models have been successfully used for diagnostics, assessment of surgical skills, and personalisation of the learning process. Their accuracy, which reached 92%, is an indicator of a significant contribution to improving the technical and practical skills of medical students (Lin et al. 2024). SVMs have proven to be versatile tools (Tozsin et al. 2024) that can be used for: objective assessment of students' level

of training, diagnosis of acute abdominal pain, classification of the level of knowledge of beginners and experienced professionals, and determination of the level of surgical skill.

A study conducted by Reading Turchioe et al. (2024) demonstrated the significant role of AI in improving task performance, especially among novice students. The median time saved on tasks was 35 minutes, which indicates a significant facilitation of the learning process using AI. In addition to reducing time, students achieved more complex levels of data analysis, surpassing the results of previous years when such tools were not used. The qualitative analysis showed that the main advantage of AI was to help overcome programming difficulties that could significantly slow down students' progress. This was especially useful for beginners, for whom AI examples and support were crucial. In summary, AI has demonstrated its ability to support the development of students' conceptual thinking necessary for working with data. It has proven to be an effective tool in teaching data analysis and visualisation, contributing to the development of new opportunities for medical research and training of future professionals.

Another study conducted by Brügge et al. (2024) demonstrated the significant potential of AI in improving clinical decision-making (CDM) skills among medical students. Participants of the group that received structured feedback after four training sessions showed statistically higher results ($p=0.049$), which indicates the effectiveness of the approach. The improvements were particularly significant in contextualisation ($p=0.046$) and information retrieval ($p=0.02$), which highlights the importance of feedback in clinical skills training.

AI provided unique opportunities for adaptive and personalised learning, providing students with scalable and cost-effective tools for professional development (Kuznietsov & Kuznietsova, 2024). The use of simulations that modelled real-life clinical scenarios significantly improved diagnostic thinking, contributing to the development of practical skills. Such approaches allowed students to safely work through difficult situations, forming a stable clinical mindset. At the same time, the authors emphasised the need for further research to determine the long-term impact of such technologies on the quality of training of future medical professionals. Scaling up approaches and developing standardised methods for integrating AI into curricula are promising areas for further improving medical education.

It is worth noting that AI's ability to process large volumes of scientific literature allows students to quickly find relevant information, reducing the time spent searching for sources and directing efforts to a deeper study of research methodologies. With the ability to generate automated summaries, AI facilitates the efficient analysis of medical histories by highlighting key aspects such as symptoms, diagnoses, and test results.

Dave et al. (2023) argued that ChatGPT-based virtual assistants have become interactive tools for improving practical skills, such as medical record keeping and laboratory data analysis. In addition, its functionality has contributed to the understanding of modern approaches to clinical trials, helping students to master the process of selecting patients for clinical trials. The ability of AI to provide personalised medication recommendations and warn of possible side effects made it a useful tool in teaching rational pharmacotherapy (Sholoiko & Kravchenko, 2024; Shevchenko & Kopantseva, 2024). Its interactive capabilities were used to assess students' clinical skills in a simulated environment, contributing to their confidence and readiness for practice. In addition, chatbots could significantly increase the level of medical literacy among students, developing critical thinking and improving approaches to diagnosis and treatment. Thus, AI has integrated modern technologies into the process of training medical specialists, making education more innovative, efficient, and adapted to the real needs of clinical practice.

The application of AI in science also covered a wide range of areas, including research, writing, and idea generation (Babenko et al. 2020). Studies have confirmed AI's ability to create formal scientific articles with an elegant style and readability, simplifying information retrieval and reducing the time required to prepare materials. Instead of searching for sources, it provided direct answers to queries, allowing researchers to focus more on methodology (Dave et al. 2023). Despite its many advantages, the use of AI posed new ethical challenges, including transparency, reliability, and possible abuse. The use of generative models required the development of ethical standards and tools for detecting AI content to maintain trust in the academic community. Therefore, the successful integration of AI into medical education is only possible with a responsible approach that considers both the benefits of technology and its limitations.

Similar results were confirmed by Berberoglu et al. (2024), which found that ChatGPT and QuillBot platforms significantly improved the process of knowledge acquisition and research skills. Accordingly, ChatGPT provided students with a unique opportunity for interactive simulation to practice patient communication skills, which were a key component of clinical training. Tools such as DALL-E contributed to the development of visual and diagnostic competencies, allowing students to integrate modern approaches to image analysis and interpretation. However, these technologies also posed challenges related to ethics, risks of misinformation, and potential impact on students' critical thinking. This required a responsible approach to the introduction of AI into the educational process and the development of independent and ethical thinking among students. Over-reliance on AI tools could hurt clinical thinking and decision-making, which emphasised the need for caution and a critical approach to their use (Zhetenbayev et al. 2022). Therefore, to effectively integrate AI into medical education curricula, faculty members must adapt quickly by acquiring AI competencies, mastering various AI tools, and integrating them into teaching and assessment methods. This approach ensures the responsible use of AI, promoting innovation in medical education and preserving the basic principles of independent learning and clinical excellence (Berberoglu et al. 2024).

Table 1 below shows the impact of AI on the development of clinical competencies of future medical professionals.

Table 1: The role of AI in shaping the clinical competencies of future medical professionals

Basic AI technologies	Application in education	Impact and results
SVM	Diagnostics, assessment of surgical skills, personalisation of training	Up to 92% accuracy, improved technical skills
ChatGPT	Medical record management, laboratory data analysis, clinical scenario simulation	Time savings (35 minutes), increased level of data analysis
Simulations and intellectual systems	Clinical skills training, structured feedback, testing	Statistical improvement in clinical outcomes ($p=0.049$)
AI for analysis of scientific data	Writing scientific articles, generating ideas, and analysing literature	Quick access to relevant sources, reduced time for paper preparation

Source: compiled by the authors based on Lin et al. (2024), Tozsin et al. (2024), Reading Turchioe et al. (2024), Brügge et al. 2024, Dave et al. (2023), Berberoglu et al. 2024.

Table 1 shows that AI technologies significantly improve the quality of medical education. SVM technologies provide high accuracy in diagnostics and assessment of surgical skills, improving students' technical competencies. ChatGPT chatbots help to optimise medical records, analyse laboratory data, and simulate clinical situations, which saves time and increases the level of information analysis. Simulation systems and intelligent learning platforms improve students' clinical skills and provide effective feedback.

In general, comparing traditional approaches with AI-based approaches, there are significant differences in the methodology and effectiveness of the educational process. Traditional approaches to medical education were based on the integration of theoretical knowledge with

practical experience, which was implemented through classroom lectures, clinical rotations, and independent work with scientific literature. At the same time, the traditional system of education had certain limitations, including insufficient access to educational resources in remote regions, lack of adaptability of curricula and a significant workload for teachers due to the need for continuous knowledge assessment and lectures. In turn, adaptive AI-based learning systems allowed for personalisation of the educational process according to the level of training of the student, automated AI-based assessment algorithms provided prompt feedback, and virtual and augmented simulation platforms using AI created a safe environment for practicing practical skills (Lin et al. 2024). In addition, AI-based digital educational resources helped to overcome geographical limitations by providing equal access to learning materials regardless of location. Knowledge assessment in the traditional system was implemented through testing, exams, and quizzes, while AI-oriented approaches included automated response analysis and AI-based adaptive testing. Access to learning materials in traditional systems was limited to printed sources, while digital platforms and AI assistants provided an interactive and updated information environment. Personalisation of learning was a key advantage of adaptive AI-based systems compared to standardised curricula, and automation of assessment and support through intelligent AI chatbots significantly reduced the workload of teachers (Alam et al. 2023).

3.3 The potential of AI to transform medical education

Generative models demonstrate significant potential in transforming the educational process, providing effective analysis of medical information and creation of clinical content. According to the literature, the high accuracy and scalability of such systems allowed them to exceed the standards set for certification exams (Stadler et al. 2024), such as the United States Medical Licensing Examination (USMLE). Moreover, generative AI has proven to be able to create multiple-choice questions (MCQs), ensuring their relevance and compliance with the requirements of medical terminology. A key element of the successful use of these systems was the skill of query generation, which guaranteed the accuracy and relevance of the created materials. The combination of basic AI models with highly specialised systems increased the efficiency of test task development, simplifying the training and assessment processes (Borisova et al. 2020).

The integration of generative AI into medical education not only met the growing requirements for assessment quality but also created new standards that combined technological advances with the needs of modern healthcare. As a result, students gained access to advanced learning tools, and teachers – effective mechanisms to support the educational process (Stadler et al. 2024). AI has gradually become an important component of modern medical education, but the level of students' awareness and attitude towards these technologies remains uneven.

A survey of 487 medical students from Germany, Austria, and Switzerland revealed an insufficient level of integration of formal education on AI and AI ethics into the curriculum (Weidener & Fischer, 2024). Nevertheless, 39% of respondents had experience of using AI-based chat applications such as ChatGPT, and 72% believe that AI will have a positive impact on medicine. Most respondents (75%) stressed the need to include AI and ethics courses in the curriculum, recognising their importance for modern medical education. The issues of AI ethics were especially relevant, as students considered them to be extremely important for their professional development. The results of this study highlighted a significant gap between the active use of AI in everyday learning and the lack of attention to relevant topics in curricula (Stadler et al. 2024). This mismatch can be a significant obstacle to the development of competencies necessary for the effective application of AI in clinical practice. Integrating AI and ethics education into medical curricula is critical, as it equips students not only with technical knowledge, but also with the ethical principles and critical thinking necessary to use technology safely and responsibly in a digitised healthcare environment (Kusmoldayeva et al. 2024; Krokhmalnyi et al. 2021). Ensuring this balance will help prepare future healthcare professionals who are able to work with the latest AI technologies, integrating them into clinical practice while maintaining high standards of safety and ethics.

A cross-sectional study conducted by Jha et al. (2022) assessed the knowledge, perception of the role of AI in medicine, and learning preferences of 216 medical students and interns (37% response rate). The average AI knowledge score was 11 (IQR=4) out of 25, with those who had received additional training performing better ($p=0.04$). More than 49% of respondents believed that AI reduces the number of jobs for doctors, and 67% believed that AI will affect their choice of speciality. 80% of the participants claimed that the healthcare system is not ready for the challenges associated with the introduction of AI, while 90% pointed out the need to include AI in the curricula of medical faculties. The findings highlighted the need to integrate AI education programmes into students' curricula.

The ethical use of AI, particularly in its interaction with humans and its influence on decision-making, remains a key challenge (Cascella et al. 2025). As AI technologies become increasingly integrated into healthcare training, it is crucial to consider their potential to support culturally sensitive education and help reduce health inequities. By leveraging AI, educational programs can be tailored to address diverse cultural contexts, thereby promoting equity and inclusivity in healthcare training (Kozubenko & Homonai 2025). Scientific evidence underscores the necessity of incorporating ethical aspects into the curriculum to foster students' critical thinking and responsible attitudes towards the use of new technologies. Future research should focus on developing effective methods to integrate AI into curricula, considering the dynamic evolution of technology. This will ensure that medical professionals are not only adept at using AI but are also committed to employing it ethically, ultimately contributing to more equitable and culturally competent healthcare systems.

A systematic analysis made by Dashti et al. (2024) found that the basic level of knowledge about AI was 59% among dental students and 72% among practicing dentists. Despite this gap in knowledge, the majority of students (72%) compared to practitioners (63%) believed in the significant potential of AI for the development of the dental industry. The findings highlighted the need for in-depth AI training in dental curricula, as well as in continuing education programmes for practicing dentists. The inclusion of such courses will increase the level of awareness of AI technologies, expand the competencies of specialists, and facilitate their effective application in professional activities. The integration of AI into curricula should be systematic and focus not only on technical aspects but also on the ethical principles of technology use. The conscious introduction of AI through high-quality training and education will ensure the safe and effective use of these technologies while maintaining high standards of professional ethics (Pavlova et al. 2024; Sopivnyk et al. 2024).

AI, particularly ChatGPT, has shown to be highly effective in decision-making, writing scientific papers, and conducting research, highlighting its importance in these areas (Kullolli 2024; Uludag 2023). However, their integration has been accompanied by several significant challenges, including ethical issues, copyright concerns, lack of transparency, and difficulty distinguishing AI-generated content from human work. Additional risks included algorithmic bias, plagiarism, lack of originality, dissemination of inaccurate information, and incorrect citations that could undermine the credibility of academic and scientific results. Adherence to the principles of transparency, integrity, and accuracy was key to overcoming these challenges. Addressing these challenges requires the introduction of clear guidelines, regulatory frameworks, and technologies to identify AI-generated content. Investing in quality control mechanisms, including the introduction of strict human oversight, standardised review procedures, and adherence to rigorous academic standards, has been important to ensure the accuracy and ethical use of AI outputs.

Academic institutions, publishers, and research foundations play an important role in creating policies that promote transparency and responsible use of AI (Jeyaraman et al. 2023). These policies should include guidelines for the proper use of AI technologies, prevention of their misuse, and adherence to ethical standards. Thus, the responsible integration of AI can allow the academic community to harness the transformative potential of these technologies while maintaining high standards of integrity in education and research. Effective solutions to these challenges will help build trust in AI as a tool that significantly improves the quality and efficiency of academic activities.

It is worth noting that medical institutions should provide the necessary infrastructure, resources, and expertise to effectively implement AI in medical education. This includes clearly defining educational goals so that AI complements rather than replaces traditional teaching methods, as well as engaging developers, teachers, students, and bioethicists to develop strategies that consider ethical and legal aspects. Respect for the principle of user autonomy requires transparency of AI, including disclosure of its limitations, to avoid the spread of misinformation and misconceptions.

To ensure equal access to technology, it is necessary to introduce scholarships, financial support, and adaptive AI design. Regular audits of algorithms should become a mandatory element to eliminate bias and ensure fairness in the learning process. Moreover, algorithms should be thoroughly tested, and students should be trained to critically evaluate the results of AI. Furthermore, to ensure the responsible use of AI, it is necessary to focus on three key aspects: establishing an ethical framework, promoting interdisciplinary collaboration, and investing in education. The ethical framework should guarantee the safety, privacy, and autonomy of patients while ensuring equality and inclusiveness (Gordon et al. 2024). Interdisciplinary collaboration allows for considering complex healthcare challenges, and investment in education helps to train professionals who can critically evaluate and effectively use AI. Integrating AI into medicine and education requires joint efforts to create a sustainable future that ensures technological progress while respecting the principles of safety and ethics (Bogoyavlenskiy et al. 2023; Kosherbayeva et al. 2018).

Several papers highlighted the significance of incorporating AI ethics into medical education; however, four of them failed to delineate the exact content of these courses, concentrating instead on a broad approach to ethical concerns. At the same time, some papers focused on the responsibility of users for using AI in a clinical context. These publications highlighted the need to include complex ethical issues such as bias, patient autonomy, over-reliance on AI, and challenges that could affect the fundamental principles of medical ethics (Astărăstoae et al. 2024). Teaching AI ethics should become a key component of the training of future medical professionals, ensuring that they understand the possible consequences and responsible use of these technologies (Yermukhanova et al. 2022).

Thus, the integration of AI into medical education opens significant opportunities for transforming the learning process (Weidener & Fischer, 2023). Due to its wide range of capabilities, AI helps to improve students' technical, cognitive, and ethical competencies, creating conditions for the training of highly qualified medical professionals. However, the effective implementation of AI requires a responsible and carefully planned approach that considers the aspects of transparency, inclusiveness, and security (Busch et al. 2023). Firstly, it is necessary to ensure that AI tools comply with ethical standards and the principle of user autonomy by informing users about the limitations of the technology and preventing misinformation. It is also crucial to develop inclusive practices that guarantee equal access to educational resources and technologies for all students, regardless of their place of residence or socioeconomic conditions. Implementation of this approach will allow achieving high-quality education and create a modern educational environment (Kolomiets & Kushnir, 2023) that not only takes into account the challenges of the digital age but also prepares students to work in the complex conditions of the modern healthcare system.

Table 2 below summarizes the key aspects of using AI systems in medical education.

Table 2: Overview of key aspects of using artificial intelligence systems in medical education

Aspect	Advantages	Challenges
Virtual assistants	Automation of routine tasks, real-time feedback	Ethical issues, dependence on technology
Generative models	Creation of clinical content, test tasks, and data visualisation	Issues of content authenticity, copyright
Automated analytical systems	Quick information search, summary generation, research support	Risk of misinformation, need for ethical standards
Interactive learning environments	Ability to simulate clinical scenarios, safe learning environment	Ensuring realistic simulations, the need for resources
Virtual reality in education	Simulation of complex scientific experiments, an interactive environment for hands-on learning	High costs of equipment and need for specialised technical expertise

Source: compiled by the authors based on Stadler et al. (2024), Weidener & Fischer (2024), Jha et al. (2022), Cascella et al. (2025), Dashti et al. (2024), Jeyaraman et al. (2023), Gordon et al. (2024).

Table 2 provides an overview of the key aspects of using artificial intelligence systems in medical education, highlighting both the advantages and challenges associated with various AI applications. Virtual assistants offer the automation of routine tasks and real-time feedback, although they present ethical issues and the risk of over-reliance on technology. Generative models excel in creating clinical content and visualizations but face challenges related to content authenticity and copyright concerns. Automated analytical systems facilitate quick information searches and research support, yet they carry the risk of misinformation and necessitate strict ethical standards (Petrova et al. 2018; Aviv et al. 2024). Interactive learning environments enable the simulation of clinical scenarios in a safe learning setting but require significant resources to ensure realism (Harmash et al. 2023). Lastly, virtual reality in education allows for the simulation of complex scientific experiments and provides an interactive environment for hands-on learning, despite the high costs of equipment and the need for specialized technical expertise. This table underscores the transformative potential of AI in enhancing medical education while also pointing out the critical challenges that need to be addressed to fully harness these technologies.

The integration of artificial intelligence into medical education represents a transformative shift that enhances the personalization, efficiency, and accessibility of learning (Shevchuk & Hunaza, 2025). AI technologies, including virtual assistants, generative models, automated analytical systems, interactive learning environments, and virtual reality, offer substantial advantages such as automating routine tasks, creating tailored educational content, and simulating realistic clinical scenarios (Huretska 2023). These innovations not only improve the technical and cognitive skills of medical students but also facilitate a more inclusive and adaptable educational experience.

However, the adoption of AI in medical education is not without challenges. Ethical concerns, issues of content authenticity, the risk of misinformation, and the high costs associated with advanced technologies like VR highlight the need for careful and responsible implementation. Addressing these challenges requires a multifaceted approach that includes establishing ethical guidelines, ensuring transparency, and fostering interdisciplinary collaboration. Additionally, it is crucial to invest in education and infrastructure to support the effective use of AI tools and to train educators and students alike in leveraging these technologies responsibly. In conclusion, while AI holds significant potential to revolutionize medical education by making it more innovative and responsive to the needs of modern healthcare, its successful integration depends on a balanced approach that considers both the technological possibilities and the ethical implications. By

doing so, medical education can evolve to meet the demands of the digital age, ultimately preparing students to excel in a rapidly changing healthcare landscape.

4. Conclusion

The digital transformation of medical education in Kyrgyzstan is gaining momentum due to the integration of innovative technologies, among which artificial intelligence occupies a special place. Modernising curricula with adaptive digital platforms allows personalising the learning process, automating assessments, and creating interactive environments for training future medical professionals. This approach removes barriers to access to knowledge, which is especially important for students from remote regions, and contributes to improving the overall quality of education. Modern machine learning algorithms, big data analysis methods, and deep learning technologies ensure efficient information processing and the creation of personalised educational trajectories. The use of chatbots and virtual assistants not only provides prompt feedback and answers to students' questions but also automates routine tasks, which helps to speed up the learning process. Intelligent learning systems that can simulate realistic clinical scenarios help students improve both technical and cognitive skills necessary to make informed clinical decisions in complex environments.

The study results showed that teachers play a key role in the process of integrating AI-based technologies into curricula. They should not only have basic knowledge of digital tools, but also actively adapt the educational process to the requirements of the digital age. The development of specialised training modules with a focus on AI-based technologies and the ethical aspects of their use is critical for the quality training of future professionals. The use of generative digital systems to create multiple-choice tasks or automated processing of scientific materials optimises the learning process and allows for a deeper analysis of medical data. AI-based technologies have been shown to significantly improve the development of clinical competencies. Big data analysis methods are successfully used for diagnostics, assessment of surgical skills, and personalisation of the educational process, contributing to the development of practical skills of students. The integration of simulation systems and intelligent learning platforms provides structured feedback that improves the quality of clinical thinking and facilitates informed diagnostic decision-making.

However, along with the significant potential of AI-based technologies, several ethical challenges have been identified. Problems with the transparency of algorithms, the possibility of bias, the risks of misinformation, and overdependence on digital systems can negatively affect the critical thinking of students. Therefore, it is important to develop clear ethical standards, regulatory frameworks, and guidelines to ensure the responsible use of these technologies in medical education. Thus, the integration of innovative digital solutions into the system of training future doctors opens great opportunities for personalising learning and improving clinical competencies. Effective use of AI-based technologies requires a systematic approach that combines evidence-based teaching methods, interdisciplinary collaboration and high ethical standards. Ensuring equal access to digital resources, investing in the development of educational infrastructure, and professional training of teachers will create a modern learning environment that meets the requirements of digital medicine and promotes efficient and safe practice.

Further research should focus on the development of comprehensive models for the use of digital technologies in medical education that combine adaptive learning platforms, interactive simulations of clinical scenarios, and standardised ethical approaches to optimise the educational process.

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