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**Review Paper**

# Artificial Intelligence in Pharmacy Education: Opportunities, Challenges and Future Directions

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## ABSTRACT

Background: Artificial intelligence (AI) is rapidly transforming healthcare and pharmacy practice, creating a need to prepare future pharmacists for AI-assisted professional environments. Pharmacy education has an important role in developing students' AI knowledge, practical competencies, and ethical understanding.Objective: This narrative review aimed to summarize the applications of AI in pharmacy education, assess students' awareness, knowledge, attitudes, and perceptions, and discuss the benefits, challenges, and future directions of AI integration into pharmacy curricula.Methods: A narrative literature review was conducted using PubMed, Scopus, Google Scholar, Web of Science, and ScienceDirect. English-language articles published between September 2023 and February 2026 were eligible for inclusion, and the literature search was conducted between April 2026 and June 2026. Studies addressing AI applications in pharmacy education, AI-assisted learning, curriculum integration, students' knowledge and perceptions, educational technologies, ethical considerations, and future directions were included. Relevant data were extracted and synthesized thematically. Six studies meeting the eligibility criteria were included.Results: The reviewed studies showed that pharmacy students generally had moderate awareness but limited knowledge and practical competency regarding AI. Despite these limitations, participants demonstrated positive attitudes toward AI integration. AI was reported to support personalized learning, clinical decision-making, virtual simulations, research, drug discovery, pharmacovigilance, medication management, and patient safety. Generative AI tools, particularly ChatGPT, were increasingly used for academic and research activities. However, concerns regarding data privacy, ethical and legal issues, misinformation, academic misconduct,

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overdependence, and employment displacement were identified.Conclusion: AI has considerable potential to enhance pharmacy education and prepare future pharmacists for technology-driven healthcare. Structured AI education, practical training, faculty development, ethical instruction, and critical appraisal skills should be incorporated into pharmacy curricula. Further multicenter and longitudinal studies are needed to evaluate the effectiveness of AI-focused educational interventions.

## INTRODUCTION

Artificial Intelligence (AI) has become one of the defining technological innovations of the 21st century. Its rapid evolution has transformed numerous industries by improving operational efficiency, increasing productivity, and reshaping the interaction between humans and intelligent digital systems.(1-4)AI enables computer systems to imitate human cognitive abilities, including learning, reasoning, problem-solving, and decision-making. These capabilities allow machines to process large amounts of information, recognize patterns, and support complex tasks with greater accuracy and speed.(5-8)

Today, AI is widely integrated into everyday life and has found applications across diverse sectors such as finance, education, manufacturing, and business. Its ability to automate processes and generate data-driven insights has made it an essential technology in modern society.(9-13) Among its many applications, AI has had a profound impact on healthcare and pharmaceutical sciences. It supports disease diagnosis, clinical decision-making, drug discovery, and personalized patient care, ultimately improving healthcare outcomes and contributing to significant medical advancements.(14-17)

Artificial intelligence (AI) has become an important tool in modern healthcare by supporting early disease detection and enabling the development of personalized treatment strategies. In pharmacy, AI facilitates the analysis of clinical documents and extracts relevant patient information, allowing healthcare professionals to access critical data more efficiently. In addition, AI-based pharmacovigilance systems integrate information from multiple sources to identify adverse drug reactions at an early stage, thereby improving medication safety and reducing drug-related risks.(18,19)

AI also plays a significant role in accelerating drug discovery and development by applying machine learning algorithms to analyze large molecular datasets and identify potential therapeutic targets. Furthermore, AI-powered clinical decision support systems assist healthcare professionals in selecting appropriate medications and optimizing drug dosages based on evidence, ultimately improving treatment outcomes and enhancing patient safety.(20,21,22)

To facilitate the effective integration of artificial intelligence (AI) into pharmacy practice, education on emerging technologies should be made more accessible to pharmacy students and practicing pharmacists. Strengthening AI-related knowledge and digital competencies will enable future pharmacists to confidently adopt AI-supported tools in clinical and professional settings.(24)

Following the COVID-19 pandemic, there has been growing recognition of the importance of incorporating advanced technologies such as artificial intelligence, machine learning, robotics, and simulation-based learning into pharmacy education. These innovations can improve students' learning experiences and better prepare them for technology-driven healthcare practice.(23,24)

The integration of artificial intelligence (AI) into education has enhanced teaching and learning by promoting creativity, critical thinking, and problem-solving skills. In medical and pharmacy education, AI-based learning tools support interactive learning experiences and help students

develop competencies required for modern healthcare practice.(25)

In Saudi Arabia, the adoption of AI in pharmacy education reflects the global movement toward digital transformation and competency-based healthcare training. Integrating AI into pharmacy curricula can better prepare students to use emerging technologies effectively in future clinical practice.(26)

Ethical issues like data privacy and security are essential, especially since AI systems often depend on sensitive patient data.(28,29). A 2023 study in the Indian Dermatology Online Journal highlighted concerns about AI-driven diagnostics and the risk of breaking confidentiality if datasets are not properly secured.(28)

Another key challenge is the lack of technical skills among pharmacy educators. This gap can limit the effective teaching of AI-related topics. Faculty development and training are needed to address this issue.(27,29)In addition, relying too much on AI may weaken the growth of critical thinking and clinical judgment.(27,29,30)

Therefore, AI should be integrated as a supportive tool while continuing to emphasize interpersonal communication, empathy, and professional reasoning—skills that are fundamental to effective pharmacy practice and cannot be replaced by machines.(29,30)

## METHODS:-

### Search Strategy

A narrative literature review was conducted to summarize the current evidence on the application of artificial intelligence (AI) in pharmacy education. A comprehensive literature search was performed using the electronic databases PubMed, Scopus, Google Scholar, Web of Science, and ScienceDirect. Articles published in English between **September 2023 and February 2026** were eligible for inclusion. The literature search was conducted between **April 2026 and June 2026**. The search strategy employed combinations of keywords and Medical Subject Headings (MeSH) terms, including *Artificial Intelligence*, *AI*, *Machine Learning*, *Pharmacy Education*, *Pharmacy Students*, *Pharmaceutical Education*, *Digital Health*, and *Health Professions Education*. Boolean operators ("AND" and "OR") were used to refine the search strategy.

### Eligibility Criteria

Original research articles, systematic reviews, narrative reviews, scoping reviews, and relevant guideline or policy papers published in English were included if they addressed the application of AI in pharmacy education, AI-assisted learning, curriculum integration, pharmacy students' knowledge and perceptions of AI, educational technologies, ethical considerations, or future directions in AI-based pharmacy education. Editorials, letters to the editor, conference abstracts without full-text availability, duplicate publications, articles published in languages other than English, and studies unrelated to pharmacy education were excluded.

### Study Selection

The titles and abstracts of all retrieved articles were screened for relevance according to the predefined eligibility criteria. Full-text articles meeting the inclusion criteria were subsequently reviewed in detail. Duplicate records were identified and removed before the final selection. Eligible studies were included for narrative synthesis and organized into thematic categories related to AI applications, educational benefits, pharmacy students' knowledge and perceptions, challenges, ethical considerations, and future directions in pharmacy education.

### Data Extraction and Synthesis

Relevant information was extracted from the selected studies using a standardized data extraction approach. The extracted data included the first author, year of publication, country, study design, study population, AI applications, educational outcomes, key findings, reported benefits, challenges, and recommendations. The evidence was synthesized narratively and organized into thematic sections to provide a comprehensive overview of the current literature on artificial intelligence in pharmacy education.

### Quality Assurance

To enhance the reliability and credibility of this review, priority was given to peer-reviewed articles published in reputable academic journals. The selected studies were critically evaluated for their relevance, methodological quality, and contribution to the objectives of this review. As this was a narrative review, a formal risk-of-bias assessment was not

### Results:-

A total of six published studies investigating the application of artificial intelligence (AI) in pharmacy education were included in this narrative review. The selected literature comprised one cross-sectional survey and five review articles, providing comprehensive evidence on pharmacy students' awareness, knowledge, attitudes, perceived benefits, challenges, and recommendations regarding AI integration into pharmacy education and practice.

### Study Characteristics

The included studies were conducted across different countries and educational settings involving undergraduate pharmacy students, pharmacy graduates, and practicing pharmacists.

**Table 1. Comparative analysis of six included studies on artificial intelligence in pharmacy education.**

| Aspect | Study 1 | Study 2 | Study 3 | Study 4 | Study 5 | Study 6 |
|---|---|---|---|---|---|---|
| **Study Design** | Cross- Sectional Survey | Review | Review | Review | Review | Review |
| **AI awareness** | Moderate | Moderate | Moderate | Moderate - high | Low | Moderate -high |
| **Attitude towards AI** | Positive | Positive | Positive | Positive | Positive | Positive |
| **AI knowledge** | Limited | Knowledge gap | Limited exposure | Practical gap | Limited | Limited formal training |
| **Major benefits identified** | Clinical decision support | Healthcare efficiency | Personalized learning | Drug discovery and CDSS | Patient care | Research and learning |
| **Major Challenges identified** | Ethical concerns | Curriculum gap | Ethical concerns | Data privacy | Employment concerns | Dependence and academic misconduct |
| **Major recommendation** | Integrate AI into curriculum | Structured AI curriculum | Dedicated AI courses | Formal AI training | Curriculum revision | AI literacy programmes |
| **Overall conclusion** | Positive attitude but inadequate preparedness | Need for AI education | AI complements | Promote responsible AI use | Bridge the educational gap | Encourage responsible AI use |

Sample sizes ranged from 117 to 387 participants, with most respondents being undergraduate pharmacy students aged between 18 and 25 years. Female participants constituted the majority of the study populations in most of the included studies.

As summarized in Table 1, although the study designs varied, all studies focused on evaluating AI awareness, educational preparedness, perceptions, and the potential impact of AI on pharmacy education and future pharmacy practice.

## Awareness, Knowledge, and Attitudes Toward AI

The reviewed studies consistently demonstrated that pharmacy students possessed moderate awareness of artificial intelligence and its increasing role in healthcare. However, their overall knowledge remained limited, mainly because of inadequate exposure to AI concepts within pharmacy curricula. Most participants were familiar with the term "artificial intelligence" but reported insufficient understanding of machine learning, deep learning, natural language processing, and AI applications in pharmaceutical care.

Despite these knowledge gaps, students demonstrated positive attitudes toward AI integration into pharmacy education and professional practice. They recognized AI as an important technology that could support pharmacists in clinical decision-making, improve healthcare delivery, and enhance future career opportunities. This contrast between limited knowledge and positive attitudes was consistently observed across the reviewed studies.

## Benefits of AI in Pharmacy Education

The included studies highlighted numerous educational and professional benefits of AI. AI was reported to support personalized learning, adaptive educational platforms, intelligent tutoring systems, virtual patient simulations, clinical decision support systems, drug discovery, pharmacovigilance, medication management, research assistance, and evidence-based pharmaceutical care.

As illustrated in Figure 1, AI contributes to pharmacy education by enhancing learning experiences while simultaneously improving clinical reasoning, problem-solving abilities, and research productivity. Several studies also emphasized AI's ability to reduce medication errors, improve patient safety, optimize treatment decisions, and increase healthcare efficiency.

## Challenges and Barriers

Although AI was viewed positively, several challenges were consistently identified. According to Table 1, the most frequently reported barriers included limited AI literacy, insufficient curriculum integration, ethical concerns, data privacy and confidentiality issues, misinformation generated by AI systems, overdependence on AI technologies, academic misconduct, and concerns regarding future employment opportunities.

These findings indicate that the successful implementation of AI in pharmacy education requires careful consideration of ethical principles, responsible AI use, and structured educational policies.

## Recommendations for Curriculum Integration

Across all included studies, respondents strongly supported the incorporation of AI into pharmacy education. Common recommendations included curriculum revision, dedicated AI courses, structured AI literacy programmes, faculty development initiatives, practical workshops, interdisciplinary collaboration, and ethical AI training.

As summarized in Table 1, all studies emphasized that formal AI education is essential for preparing

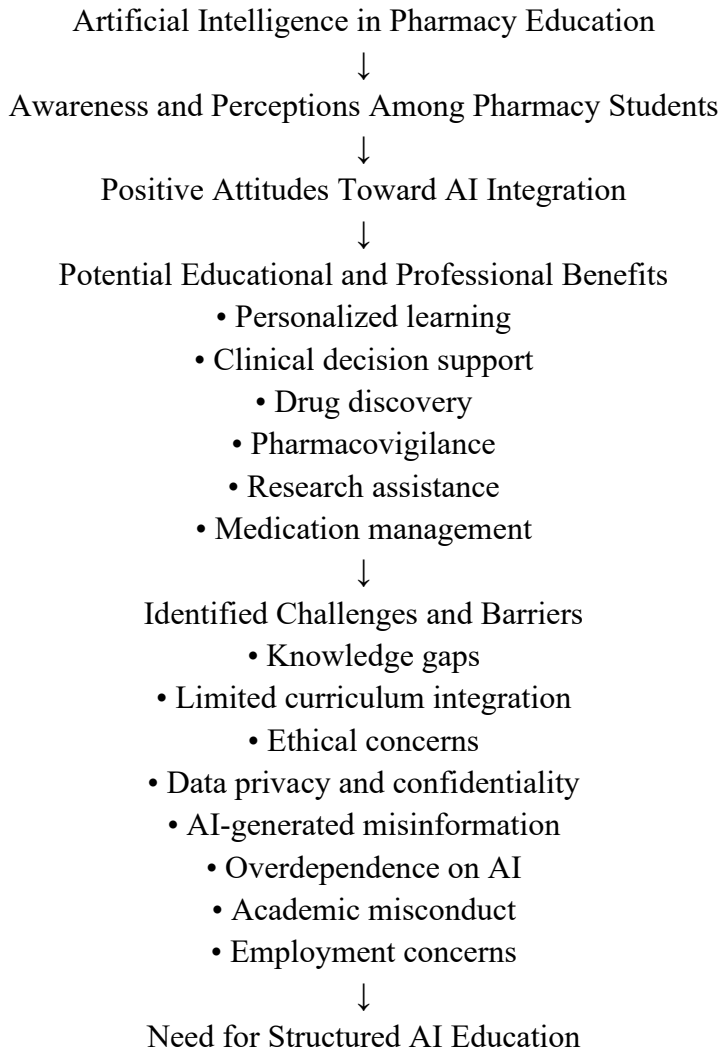
future pharmacists to effectively utilize AI technologies while maintaining professional judgment and patient-centered care.

**Overall Findings**

The overall findings are summarized in Figure 1, which illustrates the progression from increasing awareness of AI among pharmacy students to positive perceptions regarding its educational and clinical applications. AI offers several advantages, including personalized learning, clinical decision support, drug discovery, pharmacovigilance, medication management, and research assistance. However, these benefits are accompanied by challenges such as knowledge gaps, curriculum limitations, ethical concerns, data privacy issues, misinformation, overdependence, and academic misconduct.

Collectively, the reviewed evidence suggests that integrating structured AI education, practical workshops, AI ethics, and faculty training into pharmacy curricula can substantially improve AI literacy, professional competence, and the responsible implementation of AI in pharmacy practice.

**Figure 1. Conceptual framework illustrating the major findings of the narrative review, including AI awareness and perceptions, potential benefits, identified challenges, and strategies for responsible AI integration in pharmacy education and practice.**



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Curriculum Integration + Practical Workshops + AI Ethics + Faculty Training

↓

Improved AI Literacy and Professional Competence

↓

Responsible, Ethical and Effective Use of AI in Pharmacy Practice

## DISCUSSION

The present narrative review demonstrates that artificial intelligence is becoming an integral component of pharmacy education and healthcare practice. Although pharmacy students generally possess limited knowledge regarding AI concepts and practical applications, they consistently exhibit positive attitudes toward AI integration. This discrepancy suggests that students appreciate the potential value of AI but lack sufficient educational opportunities to develop the necessary competencies.

As presented in Table 1, all reviewed studies identified moderate awareness of AI but consistently reported knowledge gaps due to limited formal instruction and practical exposure. Similar findings across different countries indicate that inadequate AI education remains a global challenge in pharmacy programmes. These results emphasize the urgent need for structured curriculum reforms that equip pharmacy students with AI-related knowledge and practical skills before entering professional practice.

The widespread use of AI tools, particularly generative AI platforms such as ChatGPT, demonstrates the growing acceptance of AI among pharmacy students. Students increasingly use AI to prepare study materials, retrieve drug information, conduct literature searches, summarize scientific articles, complete assignments, and support research activities. While these technologies improve learning efficiency and accessibility, they also highlight the importance of developing critical appraisal skills. Students must be trained to verify AI-generated information using reliable scientific evidence before applying it in academic or clinical settings.

The reviewed literature consistently identified several educational and clinical benefits of AI. AI has the potential to personalize learning, improve clinical reasoning, strengthen evidence-based decision-making, facilitate drug discovery, enhance pharmacovigilance, optimize medication therapy management, and improve patient safety. These findings support the concept illustrated in Figure 1, where increased awareness of AI is associated with recognition of its educational and professional benefits.

Despite these advantages, the included studies also identified several important challenges that should not be overlooked. Ethical concerns, data privacy, algorithmic bias, misinformation, overdependence on AI systems, academic misconduct, and fears regarding employment displacement were repeatedly reported. These concerns reinforce the idea that AI should function as a clinical support tool rather than replacing pharmacists' professional expertise, clinical judgment, and patient communication.

One of the most consistent findings across all reviewed studies was the recommendation to integrate AI into pharmacy education through structured curriculum development. Participants advocated for dedicated AI courses, practical workshops, simulation-based learning, interdisciplinary collaborations, faculty development programmes, and formal instruction on AI ethics and governance. Such educational strategies would help bridge the existing knowledge gap while ensuring that future

pharmacists develop both technical competence and ethical responsibility.

The conceptual framework presented in Figure 1 further emphasizes that effective AI integration requires more than technological adoption alone. Curriculum integration, faculty training, practical workshops, and ethical education are fundamental components for improving AI literacy and professional competence. These interventions are expected to promote the responsible, ethical, and effective use of AI in pharmacy practice while maintaining patient-centered care and professional accountability.

This review has several limitations. Most included studies employed cross-sectional survey designs and relied on self-reported data, which may introduce response bias. Additionally, the studies were conducted in different countries using varying methodologies and assessment tools, limiting direct comparisons. Because this review is narrative in nature, a formal risk-of-bias assessment was not performed. Future multicenter and longitudinal studies are warranted to evaluate the long-term effectiveness of AI-focused educational interventions and their impact on clinical competence and patient outcomes.

Overall, the reviewed evidence indicates that AI has significant potential to transform pharmacy education by enhancing learning, strengthening clinical decision-making, improving research productivity, and preparing pharmacy students for technology-driven healthcare systems. However, successful implementation depends on structured curriculum development, continuous faculty training, ethical governance, and the promotion of critical thinking to ensure that AI complements, rather than replaces, professional judgment in pharmacy practice.

## CONCLUSION

Artificial intelligence (AI) is rapidly transforming pharmacy education by introducing innovative approaches to teaching, learning, clinical decision-making, and research. The findings of this narrative review indicate that although pharmacy students generally demonstrate positive attitudes toward AI and recognize its potential to improve pharmaceutical education and healthcare delivery, their knowledge and practical competency remain limited because of insufficient formal education and training. AI offers numerous benefits, including personalized learning, clinical decision support, drug discovery, pharmacovigilance, medication management, and research assistance. However, challenges such as inadequate AI literacy, limited curriculum integration, ethical concerns, data privacy issues, misinformation, and overdependence on AI must be addressed to ensure its safe and responsible implementation.

The reviewed evidence consistently highlights the need to integrate AI into pharmacy curricula through structured educational programmes , practical workshops, faculty development initiatives, and training in ethical and responsible AI use. Such educational reforms will equip future pharmacists with the knowledge, technical skills, and critical thinking abilities required to effectively utilize AI while maintaining professional judgment and patient-centered care. As AI continues to evolve, collaboration among academic institutions, healthcare professionals, policymakers, and technology developers will be essential to ensure that pharmacy graduates are well prepared for AI-assisted healthcare environments. Further multicenter and longitudinal studies are recommended to evaluate the long-term impact of AI education on students' competencies and professional practice.

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