Artificial Intelligence in Pharmacy Education: Balancing Technological Advances and Ethical Concerns Among Aspiring Pharmacists

Abbreviated Title: Artificial Intelligence in Pharmacy Education

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KEYWORDS

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ABSTRACT

Background: Pharmacists give health information and pharmaceutical guidance to patients. This study examined pharmacy student's views on how artificial intelligence (AI) may affect pharmacy practice and identified curricular reform needs.

Materials and Methods: Bachelor of Pharmacy (BPharm) students of JamiaHamdrad, India, participated in a cross-sectional questionnaire survey. Perception scores between genders were compared using Mann-Whitney U test, whereas comparisons involving more than two groups were conducted using the Kruskal-Wallis H test (SPSS Inc., version 22). Exploratory Factor Analysis (EFA) employed principal component analysis and varimax rotation.

Results: In all, 245 students completed the survey. This included 148 (60.4%) males and 97 (39.6%) females. About 47% (114) students were in their second study year. The students expressed positive perception towards AI in healthcare due to its potential to enhance healthcare professional's (HCP's) access to information (89.8%), improve patients' access to services (78%), decrease errors (69.8%), and assist HCPs in making more informed decisions (70.18%). Moreover, majority of students (80%, n = 196) agreed that the academic curriculum should incorporate knowledge and skills related to AI, while 77.1% believed that training regarding ethical issues associated with AI applications should also be included.

Conclusions: Majority of the students had positive perceptions about the concepts and benefits of AI. Moreover, most students expressed a need for an update on the pharmacy curriculum. The update should revolve around equipping Bpharm students with the knowledge and skills to effectively use AI applications and ensure the professional values and rights are protected.

1. Introduction

Artificial intelligence (AI) is a complex discipline within computer science that seeks to develop machines with the ability to imitate human intellect.According to Russell and Norvig (2020), AI is defined as the study of agents that receive percepts from the environment and perform actions. They define AI as the capability of a machine to imitate intelligent human behavior, encompassing a wide range of activities (Wang, 2019). AI comprises a variety of intelligent technologies that can acquire information, engage in logical reasoning, and do activities that were traditionally carried out by human expertise (Sarker, 2022). It utilises a range of methodologies and instruments to address complex issues in diverse fields, such as healthcare and structural engineering. The healthcare sector is now undergoing a substantial revolution as a result of the integration of AI. AI plays a crucial role in supporting clinical decision-making and providing valuable information for healthcare professionals. While AI is not a standalone tool for diagnosing and curing ailments, it significantly aids in disease detection, treatment planning, and improving patient outcomes (Secinaro et al., 2021). AI has the capacity to profoundly transform patient care delivery, drug research, and medication management within the pharmaceutical sector. (Bhatt et al., 2023; Katwaroo et al., 2024; Sourajyoti Goswami & Mohit Kumar Singh, 2023). The global pharmaceutical industry, supported by advanced healthcare systems worldwide, stands to gain significant benefits from the integration of AI in the pharmacy sector. Pharmacy professionals have a crucial responsibility in guaranteeing the safety of medications, promoting adherence, and delivering essential patient information(Albanese et al., 2010). As AI technologies infiltrate the pharmacy landscape, understanding the awareness, perceptions, and opinions of pharmacy students - becomes paramount.

1.1 The Evolving Role of AI in Pharmacy:

The applications of AI in pharmacy are varied and show potential for improving efficiency and precision in numerous operations. AI-powered robots can automate medication dispensing, reducing the potential of human errors and optimizing workflow efficiency (Stasevych & Zvarych, 2023). Large volumes of patient data can be analysed by AI algorithms to improve medication regimens, identify potential drug interactions, and create individualised treatment plans. (Schork, 2019). Additionally, chatbots powered by AI can provide patients with round-the-clock access to pharmaceutical information and address fundamental inquiries, hence reducing the workload on pharmacists(Khan et al., 2023). AI-powered medication management systems have the potential to enhance drug adherence and minimise medication errors, resulting in improved patient outcomes(Chalasani et al., 2023; Das et al., 2023). AI-driven drug discovery has the potential to expedite the creation of new treatments and customise medical care according to an individual's genetic makeup(Boniolo et al., 2021).Furthermore, AI can also automate administrative work, freeing up pharmacists' time for patient consultation and engagement(Jarab et al., 2023a). Moreover, AI researchers and Indian pharmaceutical businesses are working together to create AI-driven medication adherence solutions and drug discovery platforms(Wei et al., 2024).But in addition to AI's obvious potential, questions about how to incorporate it into pharmacy practice also emerge. Automation-related job displacement is a serious worry, with some fearing AI may take the role of human interaction in pharmaceutical care(Hasan, Jaber, Khabour, et al., 2024). Moreover, the ethical aspects related to

the protection of data privacy, the presence of algorithmic bias, and the possibility of AI being misused in healthcare necessitate meticulous deliberation. (Li et al., 2023).

Many Bachelor of Pharmacy (BPharm)programmes around the world do not include extensive experiential education in their training, the incorporation of AI education is particularly beneficial. AI can provide virtual simulations and training modules that mimic real-world scenarios, thus offering experiential learning opportunities that would otherwise be unavailable (Asad et al., 2021). This can enhance students' understanding of complex pharmacological concepts and improve their decision-making skills in a controlled environment (Hanson et al., 2020). Moreover, AI-driven platforms can offer personalized learning experiences, adapting to the individual needs and learning pace of each student, thereby improving educational outcomes (Maghsudi et al., 2021). Furthermore, with the growing dependence on AI-powered tools in patient care, such as medication management and drug interaction analysis, pharmacists are now using technologies that may not have been part of their training during studies. Therefore, this technological leap is not only accelerating the pace of pharmaceutical innovation but also redefining the skillsets required for professionals in the field.Their role will likely shift towards interpreting AI-generated insights, ensuring the ethical use of these technologies, and providing the human touch that remains crucial in patient care (Bajwa et al., 2021; Johnson et al., 2023).Similarly, pharmaceutical scientists will increasingly collaborate with AI systems in research and development, leveraging these tools to enhance drug design, predict pharmacokinetics, and streamline clinical trials (Tiwari et al., 2023). Incorporating AI education into existing pharmacy programmes is crucial in order to bridge this gap.Recent research demonstrating AI's capacity to successfully complete rigorous medical, legal, and business assessments have intensified debates about the implications of AI for the future of education and scholarly pursuits(Cain et al., 2023). Many AI-based education methods have not been described in pharmaceutical literature or tested for efficacy, despite their rapid growth and incorporation. Therefore, many authors in the literature stress that today’s pharmacy education cannot meet the needs of AI and that a fundamental and compulsory change in education should be undertaken (Jarab et al., 2023b; Malviya et al., 2023; Nair, 2024). Traditional pharmacy school curriculum covers practical principles like taking a full medication history, reconciling contradictory drug lists, and educating patients. Due to the digital transformation of the health care system and pharmacists' changing roles, assessing digital health literacy and collecting data on digital devices utilised in addition to pharmacological therapy will be a new focus (Clark et al., 2017). Although AI is increasingly used in pharmacy practice and research, there is little data on formal AI instruction and use in pharmacy education. This may be due to pharmacy educators not reporting or not using AI tools, or to slower acceptance in pharmacy education. The lack of a standardized AI curriculum in pharmacy education is a significant gap that needs to be addressed. Developing curriculum proposals specifically designed to train pharmacy students on AI would be a valuable contribution in that regard.

Understanding how today’s pharmacy students perceives AI, what they know and don’t know, and their comprehension of AI’s ethical dimensions is a crucial first step to developing effective AI curricula. Hence, in this study, we aim to examine undergraduate pharmacy student’s knowledge, perceptions regarding the possible influence of AI on pharmacy and also their opinions on the AI topics to be integrated into the pharmacy curriculum.

2. Materials and Methods

2.1 Study Design, Setting, and Population:

A cross-sectional survey was undertaken among undergraduate BPharm students at the School of Pharmaceutical Education and Research, JamiaHamdard, India, from February to April 2024. The approach adhered to the Checklist for Reporting Results of Internet E-survey. (Eysenbach, 2004).The BPharm is a four-year undergraduate degree in India, designed to provide students with a comprehensive foundation in pharmaceutical sciences. The curriculum encompasses various domains such as pharmaceutics, pharmacology, medicinal chemistry, and pharmacy practice. While the program includes theoretical instruction and laboratory work, it does not heavily emphasize experiential education, such as clinical rotations or internships, which are more common in some international pharmacy programmes. Given this context, the integration of AI into the BPharm curriculum could be particularly beneficial. It would allow students to engage with advanced technological tools and methodologies that are increasingly important in contemporary pharmacy practice. The study involved undergraduate pharmacy students, a population capable of providing informed consent independently. As such, no individuals deemed vulnerable were identified or excluded from participation. The study was designed to pose minimal risk, focusing on the perceptions and opinions of the students regarding AI in pharmacy profession and education respectively.Based on the study by Whicher and Wu (2015), the authors determined that the survey research involving pharmacy students' perceptions and opinions of AI posed minimal risk and did not necessitate ERB oversight. This determination was guided by established national regulations and the ethical principles of voluntary participation, informed consent, and data confidentiality. Therefore, it was determined that the participation of an Ethical Review Board was not required (Whicher & Wu, 2015).

The BPharm students were requested to complete an electronic survey through a message sent via Whatsapp Groups/Google mail groups of various classes. The survey remained accessible for a duration of 3 months, during which reminder messages were issued every month. Participation was optional and agreement for study participation was acquired through the initial page of the survey. Prior to the study, all participants were provided with detailed information regarding the objectives and characteristics of the research. They were also advised of their right to decline participation or withdraw from the study at any time. Furthermore, it was emphasised that the data obtained would be kept anonymous. We distributed a questionnaire to all 480 students enrolled in the BPharm program. Out of these, 245 students completed the survey, resulting in a response rate of 51.04%.

2.2 Designing of the Questionnaire:

This study builds upon the foundational work of Civaner and colleagues, who investigated perceptions and opinions about AI among undergraduate medical students (Civaner et al., 2022). Given the distinct context of pharmacy education, we have adapted and expanded their framework to better address our objectives. Specifically, we have redefined and focused on three key variables: Knowledge, Perceptions, and Opinions about AI in Pharmacy among BPharm students. To ensure the relevance and appropriateness of these variables for our study, initially we reviewed the survey items developed by Civaner and colleagues to ensure they were applicable to the context of pharmacy. This involved a thorough examination of the questions to confirm that they accurately captured the perceptions and opinions of our target population regarding AI in pharmacy. Then it underwent content validity testing by three experts in

pharmacy education and AI to review and endorse the questionnaire. Through an iterative process, many changes were made to the first draft of the questionnaire. Finally, we conducted a pilot study with 30 BPharm students to test the clarity, relevance, time needed for completion of our survey questions. Based on their feedback, we made necessary adjustments to enhance the validity of our questionnaire.

The valid questionnaire consisted of four sections: (1) demographic section; (2) knowledge section; (3) perception section; and (4) opinion section. The first section aimed to gather general demographic data including age, gender, and year of study. The second section assess the students' knowledge about the impact and role of AI in the healthcare system, particularly in pharmacy. Additionally, participants were asked about their exposure to AI training. All questions were closed ended and answered by multiple choices. The third section aimed to understand students' perceptions of AI's impact on the pharmacy profession and healthcare practice. These statements cover a broad spectrum of AI's potential effects on pharmacy practice, from improving accuracy and patient outcomes to negatively impacting professional relationships and trust. By capturing both positive and negative perceptions, the questions provide a comprehensive view of how students perceive AI's role in their future profession. This segment consist of twelve questions based on 5-point Likert Scale, which ranged from 1 (Strongly Agree) to 5 (Strongly Disagree). The fourth section gather students' opinions on the inclusion of AI-related content in pharmacy education. By focusing on specific applications and skills, the questions assess the students' opinions on the relevance and importance of AI training in their professional education. The inclusion of "Not Sure" allows for capturing uncertainty, reflecting the varying levels of familiarity and confidence in AI applications. This section consist of seven 3-point Likert scale questions, which ranged from 1 (should be included) to 3 (should not be included).

2.3 Statistical Analysis

Cronbach's Alpha was employed to assess internal consistency. Frequencies (n) and percentages (%) were used to summarize the responses generated. Prior to performing non-parametric tests, we assessed the normality of the data using the Shapiro-Wilk test (p=0.000). Therefore, perception scores between genders were compared using Mann-Whitney U test, whereas comparisons involving more than two groups were conducted using the Kruskal-Wallis H test. Moreover, Spearman correlation analysis was conducted between gender and perception score as well as between year of study and perception score (SPSS Inc., version 2). Statistically significant results were defined as having p-values less than 0.05.

The reliability of the items in the student's Perceptions and Opinions regarding the potential impact of AI in pharmacy was assessed using Cronbach's alpha. A value greater than 0.7 was considered acceptable. The reliability of the questionnaire was established by 12 questions that evaluated perceptions of AI (Cronbach's Alpha = 0.788) and 7 questions that assessed opinions on AI (Cronbach's Alpha = 0.812). An exploratory factor analysis (EFA) was conducted using principal component analysis and varimax rotation. A threshold of 0.50 was set for the minimum factor loading. The communality of the scale was assessed to ascertain the degree to which each dimension accounts for the variation, ensuring adequate levels of explanation. The results reveal that all communalities were above a threshold of 0.50.An essential step is to evaluate the overall significance of the correlation matrix by employing Bartlett's Test of Sphericity. This test calculates the statistical likelihood of observing strong correlations between specific components

of the correlation matrix. The results yielded a statistically significant outcome, with a chi-square value of $x2(n = 245) = 850.654$ ($p < 0.001$), indicating that the data is suitable for factor analysis. The Kaiser-Meyer-Olkin measure of sample adequacy (MSA), which assesses the suitability of the data for factor analysis, was 0.780. Data with MSA values of 0.700 are deemed suitable for factor analysis. The analysis resulted in a factor solution that identified three factors for the scale. These factors explained 58.30% of the variation in the data.

The Pattern Matrix of the factor structure of the Perceptions on the AI in Pharmacy (PAIP) scale is shown in table 3. The items in the scale have factor loadings ranging from 0.584 to 0.829. The factor dimensions that were obtained have been labelled as "Augmented Healthcare", "AI-Dehumanization", and "Information misuse". The three variables revealed in this exploratory factor analysis (EFA) are consistent with the theoretical proposition in this research. Factor 1 comprises components P2 to P6 and P12, which pertain to Augmented Healthcare (AH). Factor 2 combines elements P1 and P8 to P10, which illustrates the concept of AI-Dehumanization (AD). Factor 3 consists of two components, P7 and P11, which pertain to the concept of Information Misuse (IM). The factor loadings are displayed in table 1.

Table 1. Pattern Matrix of the PAIP Scale's factor structure

	Component		
	Augmented Healthcare	AI-Dehumanization	Information Misuse
1. Devalues the Pharmacy Profession.		.715	
2. Reduces errors in Pharmacy Practice.	.748		
3. Facilitates patient's access to the .669 service.			
4. Facilitates HCP's access to information..643			
5. Enable the HCP to make more accurate decisions.	.828		
6. Increase patient's confidence in medicine.	.596		
7. Facilitates patient education.			.710
8. Negatively affects the relationship of the HCP with the patient.		.816	
9. Damages the trust which is basis of the patient-HCP relationship.		.829	
10. Reduces the humanistic aspect of the pharmacy profession.		.698	
11. Violations of the professional confidentiality may occur more.			.605
12. Allows the patient to increase his .584 control over his own health.			

3. Results

3.1 Demographic Characteristics:

The questionnaire was filled successfully by 245 students. Out of the total, 148 individuals (60.4%) were male, while 97 individuals (39.6%) were female. The survey participants were divided into three age groups: 18-22 years (34.7%), 23-25 years (62%), and 26-30 years (3.2%). Moreover, the demographic profiles and professional information of the students are concisely shown in Table 2.

TABLE 2. The demographic characteristics of the students (n = 245).

Variables	Frequency (n)	Percentage (%)
Gender		
Male	148	60.4%
Female	97	39.6%
Age		
18-22	85	34.7%
23-25	152	62.0%
26-30	8	3.2%
Year of Study		
1st Year	34	13.9%
2nd Year	114	46.5%
3rd Year	39	15.9%
4th Year	58	23.6%

3.2 Knowledge of Students about AI:

In the subsequent phase of this investigation, we examined the level of knowledge that students have regarding AI. A majority of the students (54.7%) believed that AI serves as a tool to assist healthcare professionals (HCPs). Specifically, 33.8% disagreed with the notion that AI might replace HCPs such as pharmacists, while 11.4% agreed with this idea. Regarding the impact of AI's widespread use in India, 38.3% of students acknowledged the potential danger of job loss due to a drop in demand for their skills. In contrast, 39.2% believed that AI would enhance the abilities of HCPs. When asked about their training in AI, 59.2% of students reported not receiving any training on AI in pharmacy, whereas 23.2% indicated receiving limited training over the internet. Only 17.5% had received formal training. The results about knowledge are summarized in Table 3.

Table 3. Knowledge of students about AI

Variable	Frequency	Percentage
1.Do you think that Artificial intelligence will Replace the Healthcare Professionals like pharmacists in the healthcare system?		
A)Agree	28	11.4%
B)Disagree	83	33.8%
C)It is an assistant or tool that helps healthcare professionals	134	54.7%
2. What is your opinion, if artificial intelligence is widespread in India?		
A) Risk of losing jobs with the introduction of robots (Artificial intelligence) with the decrease in the need for employees	94	38.3%
B) Healthcare professionals will be better with the widespread use of artificial intelligence.	96	39.2%
C)The choice of specialization Field will be influenced by how artificial intelligence is used in that Field	46	18.8%
D)I don't know	9	3.6%
3. Have you received any formal training on artificial intelligence in pharmacy?		
A) Yes	43	17.5%
B)No	145	59.2%
C)Received limited training over the internet	57	23.2%

3.3 Perceptions of Students about AI:

For clarity, we have combined "Agree" and "Strongly Agree" responses into a single category referred to as "Agree." Similarly, "Disagree" and "Strongly Disagree" responses have been combined into a single category referred to as "Disagree."The perceptions of students towards AI

are presented in Table 5. The students exhibited a greater level of agreement with the "AI-Dehumanization" (Mean=2.82) subdomain compared to the "Information Misuse" (Mean=2.38) and “Augmented Healthcare"(Mean=2.19) subdomains. The majority of the students expressed positive perception towards AI in healthcare due to its potential to enhance HCP’s access to information (89.8%), improve patients' access to services (78%), decrease errors (69.8%), and assist HCPs in making more informed decisions (70.18%), whereas 65.6% believed it would enable patients to exert more control over their health. The participants were approximately evenly split in their deliberations on the concerns and risks associated with AI-induced dehumanisation in healthcare. 42.4% of respondents expressed neutrality regarding the idea that AI devalues the pharmacy professions, while only 19.9% agreed with this notion. Conversely, 34.3% expressed concern that AI-based tools could undermine the essential value of trust between patients and HCPs, and 31.4% agreed that AI would have a negative impact on the relationship between HCPs and patients. Meanwhile, 44.9% remained neutral on this matter. Moreover, a majority of the students (60.5%) expressed agreement with the notion that AI diminishes the humanistic element of the pharmacy profession. In the "Information Misuse" subdomain, students were distributed between positive and negative clusters. 63.7% of participants expressed the opinion that AI will improve patient education, while just a small percentage (6.1%) disagreed with the possibility of AI leading to more breaches of professional confidentiality. A Mann-Whitney U test was conducted to determine if there were differences in perception score (PAIP Scale Score) towards AI between males and females. Test revealed insignificant differences in the perception of males (Median=2.50, n=148) and females (Median=2.41, n=97), U=6586.00, z=1.09, p=0.27.To evaluate differences in perception (PAIP Scale Score) towards AI scores between four groups of BPharm students Kruskal-Wallis H test was performed: first-year, second-year, third-year, and fourth-year students. Median Perception Score were 2.58, 2.41, 2.50, and 2.41 for 1^{st} year, 2^{nd} year, 3^{rd} year and 4^{th} year students respectively.The test showed a statistically significant difference in perception scores between the different groups, χ^2 (3) = 9.57, p = 0.023.To identify which specific groups differed from each other, post hoc pairwise comparisons were performed using the Dunn-Bonferroni approach. There was a statistically significant differences in perception towards AI scores between first-year and second-year students (p = 0.003) and first-year and fourth-year (0.030). However, there were no significant differences between the other groups: first-year vs. third-year, second-year vs. third-year, second-year vs. fourth-year, and third-year vs. fourth-year (all $p > 0.05$). Results are summarized in table 4.Further, to investigate potential relationships between demographic variables and perception scores, a Spearman correlation analysis was conducted for gender and year of study. The results indicated no statistically significant correlation between gender and perception scores (Spearman’s rho = -0.070, p = 0.274) or between year of study and perception scores (Spearman’s rho = -0.061, p = 0.343). These findings suggest that, within this sample, neither gender nor year of study significantly influenced students' perceptions of AI.

Table 4: Kruskal-Wallis H Test and Dunn-Bonferroni Post Hoc Analysis for Year-wise Differences in Perception Scores

Year Group	Median PAIP Score	$\chi^2(3)$	p-value(Kruskal-Wallis)	PostHoc p-value
1st Year	2.58	9.57	0.023	
2nd Year	2.41			
3rd Year	2.50			
4th Year	2.41			
1st Year vs. 2nd Year				0.003*
1st Year vs. 3rd Year				0.210
1st Year vs. 4th Year				0.030*
2nd Year vs. 3rd Year				0.126
2nd Year vs. 4th Year				0.503
3rd Year vs. 4th Year				0.397

Table 5. Perceptions of the students about AI

Variables	Strongly Agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly Disagree n (%)
Artificial intelligence devalues the pharmacy profession	18 (7.3%)	31 (12.6%)	104 (42.4%)	78 (31.8%)	14 (5.7%)
Artificial intelligence reduces errors in pharmacy practice	55 (22.5%)	116 (47.3%)	56 (22.9%)	18 (7.3%)	0 (0%)
Artificial intelligence facilitates patients' access to the service	46 (18.8%)	145 (59.2%)	43 (17.5%)	9 (3.7%)	2 (0.8%)
Artificial intelligence facilitates healthcare professionals' access to information	65 (26.5%)	155 (63.3%)	20 (8.2%)	5 (2%)	0 (0%)
Artificial intelligence enables healthcare professionals to make more accurate decisions	47 (19.18%)	125 (51%)	59 (24.1%)	14 (5.7%)	0 (0%)
Artificial intelligence increases patients' confidence in medicine	29 (11.8%)	86 (35.1%)	101 (41.2%)	27 (11%)	2 (0.08%)
Artificial intelligence facilitates patient education	37 (15.1%)	119 (48.6%)	77 (31.42%)	12 (4.9%)	0 (0%)

Artificial intelligence negatively affects the relationship between healthcare professionals the patient	20 (8.1%)	57 (23.3%)	110 (44.9%)	56 (22.8%)	2 (0.08%)
Artificial intelligence damages the trust which is the basis of the patient-healthcare professional's relationship	24 (9.8%)	60 (24.5%)	97 (39.6%)	56 (22.6%)	8 (3.2%)
Artificial intelligence reduces the humanistic aspect of the pharmacy profession.	32 (13.1%)	116 (47.4%)	55 (22.5%)	38 (15.5%)	4 (1.6%)
Artificial intelligence violations of professional confidentiality may occur more	23 (9.4%)	91 (37.2%)	116 (47.4%)	11 (4.5%)	4 (1.6%)
Artificial intelligence allows the patient to increase his control over his health	24 (9.7%)	137 (55.9%)	54 (22.1%)	27 (11.1%)	3 (1.2%)

3.4 Opinions about AI:

A majority of respondents (80%, n = 196) expressed agreement that the academic curriculum should incorporate knowledge and skills related to AI. Almost 80% of students believe that incorporating AI as a tool to minimise medication errors is necessary, while 77.1% believe that training to address and resolve ethical issues associated with AI applications should also be included. In addition, when the study participants were surveyed about their agreement with the idea of having a simplified lecture on AI, computer use, coding, and Python language, 79.8% of the students expressed their support for its inclusion. 61.6% (n=151) of respondents expressed the belief that AI apps aimed at enhancing patients' ability to manage their own health should be incorporated. Moreover, 76.3% (n = 187) of students expressed support for the inclusion of AI in research, while 70.6% (n = 173) agreed to incorporate AI in emergency responses. The students' opinions about AI are provided in Table 6.

Table 6. Opinions of students about AI.

Variable	**Should be Included, n (%)**	**Not-Sure,n (%)**	**Should not be Included,n (%)**
Knowledge and skills in Artificial intelligence	196 (80%)	40 (16.3%)	9 (3.6%)
Artificial intelligence (AI) as an application for reducing medication errors	194 (79.8%)	45 (18.2%)	9 (3.6%)
Training to prevent and solve ethical	189 (77.1%)	41 (16.8%)	15 (6.1%)

problems that may arise with Artificial intelligence (AI) applications			
A simplified lecture on Artificial intelligence, Computer use, Coding, Python language	194 (79.8%)	42 (17.1%)	9 (3.6%)
Artificial intelligence (AI) applications that will increase patients' control over their health	151 (61.6%)	81 (33%)	13 (5.3%)
Artificial intelligence (AI) in scientific research	187 (76.3%)	48 (19.6%)	10 (4%)
Artificial intelligence (AI) assisted emergency responses	173 (70.6%)	55 (22.4%)	17 (6.9%)

4. Discussion

This study examined the perceptions of BPharm students regarding the impact of AI on the pharmacy profession and healthcare practice. Overall, students perceived AI as a supportive tool for healthcare professionals (HCPs), improving access to information, aiding in decision-making, and reducing errors. Nevertheless, concerns about AI's potential to reduce the humanistic aspects of pharmacy and ethical issues, such as confidentiality risks, were noted. A significant number of students advocated for integrating AI education into the pharmacy curriculum, emphasizing the need for both technical skills and ethical training. Furthermore, while no significant gender differences were observed in AI perceptions, variations across academic years suggested that perceptions may evolve with greater exposure and knowledge.

In this study, we investigated the perceptions of BPharm students regarding the potential impact of AI on the pharmacy profession and healthcare practice. They viewed AI as a supportive instrument that could enhance HCPs' access to information, aid in making more precise decisions, and enhance patients' access to healthcare. Consistent with our results, a similar study conducted among pharmacy students and faculty members found that 96.2% of respondents believed AI could improve patient care and pharmacy services (Hasan, Jaber, Tabbah, et al., 2024). Some studies have expressed concerns about AI potentially displacing jobs in healthcare. For example, Teng et al., (2022) expressed concerns about the possibility of job displacement caused by AI among Canadian students (Teng et al., 2022). However, most students in our study saw AI as a tool that supports rather than replaces healthcare personnel.This discrepancy may reflect differences in regional healthcare systems and the level of AI integration across countries. In India, where AI adoption in healthcare is still developing, students may see AI as an opportunity to improve healthcare access and support existing workforce capabilities. Conversely, in countries like Canada, where healthcare systems may already utilize AI technologies to a greater extent, concerns about job displacement may be more pronounced.Our findings further align with Hassani et al. (2020), who reported that AI is primarily seen as a tool to enhance human capabilities in healthcare rather than as a replacement for HCPs (Hassani et al., 2020).

In our study, 69.8% of students indicated that AI could help reduce errors in pharmacy practice. This is supported by Roosan et al. (2022), who found that pharmacy students commonly perceived AI as a means to minimize prescription errors and improve healthcare access,

reinforcing the view of AI as a safety-enhancing technology (Roosan et al., 2022). Similarly, Rauschecker et al. (2020) reported that 65% of medical students believed AI would benefit healthcare by reducing errors and enhancing decision-making capabilities (Rauschecker et al., 2020). Additionally, Cheng et al. (2020) found that 72% of clinical experts believed AI could improve diagnostic and treatment recommendations (Cheng et al., 2020), a sentiment echoed by 70.18% of our respondents who felt that AI helps HCPs make better judgments. This optimism was similarly reflected in Jarab et al. (2023), who found that U.S. pharmacy students were optimistic about AI's potential to improve efficiency and precision in pharmacy practice(Jarab et al., 2023c).These consistent findings across numerous research imply that healthcare students and professionals appreciate AI's potential to enhance treatment outcomes. The research findings confirmed that prior studies performed in many domains suggest that pharmacy students and experts see AI as a beneficial instrument in the healthcare sector.

Despite the positive outlook, the study also suggests anxieties surrounding the potential downsides of AI. Notably, 60.5% of students expressed that AI might reduce the profession's humanistic aspects, a concern echoed by Syed and Al-Rawi (2024), where half of the pharmacy students felt that AI diminishes the humanistic aspects of pharmacy. Additionally, our study found that 20% of students believed AI devalues the pharmacy profession, while 42.4% remained neutral. This neutral stance was similarly observed by Syed and Al-Rawi (2024), where nearly 30% of pharmacy students were undecided on whether AI devalues the medical profession (Syed & Al-Rawi, 2024). These concerns may stem from the fear that AI could replace the empathetic, patient-centered interactions that are core to the pharmacy profession. Saheb et al., (2021) also observed that students worried about AI depersonalizes healthcare and damages patient-provider trust (Saheb et al., 2021). This sentiment was further supported by Buabbas et al. (2023), who noted that despite AI's technical advantages, maintaining strong patient-provider connections remains a priority among healthcare students.(Buabbas et al., 2023). Confidentiality and data security also emerged as prominent concerns in our study. While 37.2% of students agreed that AI poses confidentiality risks, 47.4% remained neutral on this issue. Similar concerns were documented by Akhmetova and Harris (2021), where European students expressed anxiety over AI's potential to misuse sensitive information and cause dehumanizing effects in healthcare (Akhmetova& Harris, 2021).Syed and Al-Rawi (2024) also found that 36% of pharmacy students were neutral, while 20.4% agreed that AI could violate professional confidentiality standards (Syed & Al-Rawi, 2024).

We also examined the students' opinions on the need for specific educational topics to be integrated into the pharmacy curriculum. Our research results show that just 17.5% of the students had formal AI training, and only 23.2% received limited training over the internet, matching worldwide pharmacy education trends. This finding aligns with global trends in pharmacy education, as evidenced by Hasan et al. (2024), who found that only a minority (18.6%) of pharmacy students worldwide had received formal training in AI technology (Hasan, Jaber, Tabbah, et al., 2024). The limited AI education available in pharmacy programmes has led researchers, such as Charow et al. (2021), to advocate for curriculum updates that would equip students with the skills needed to address future healthcare challenges involving AI (Charow et al., 2021a).In our study a majority (80%) of students agree that their curriculum should include knowledge and skills in AI. This mirrors findings from a recent survey where 72% of international undergraduate pharmacy students from various institutions held favorable views toward AI and expressed strong interest in learning more about the technology(Busch et al.,

2024). Moreover, almost 77% of the students believe training on ethical issues surrounding AI applications is necessary. This highlights a crucial aspect often overlooked in the discussion of AI integration. It aligns with the recommendations made by Abramoff et al., (2023) who emphasize the importance of ethical frameworks and responsible implementation of AI in healthcare (Abràmoff et al., 2023). The lack of rules and regulations to guarantee data security has significantly impeded the integration of AI in patient care and education (Charow et al., 2021b).

The present research concluded that there was no statistically significant difference in the perceptual assessments of AI between male and female BPharm students, as shown by the Mann-Whitney U test. These results are consistent with the research conducted by Cirillo et al., (2020) and Esmaeilzadeh (2021), who found no noticeable differences between genders in how healthcare AI is perceived (Cirillo et al., 2020; Esmaeilzadeh, 2020). However, contrasting studies by Sobieraj and Krämer (2020) and Sohn and Kwon (2020) observed that women tend to have lower trust in AI, potentially due to the influence of traditional gender stereotypes affecting technology adoption(Sobieraj& Krämer, 2020; Sohn & Kwon, 2020). This discrepancy could be explained by the specific context of pharmacy education, where both male and female students receive similar exposure to AI concepts, thus leveling their perceptions. Further research is needed to explore whether these differences persist in real-world healthcare settings beyond the academic environment. Despite these contrasting views, our study's findings support the idea that gender has little influence on AI perception among pharmacy students, suggesting that gender-specific adjustments in educational interventions may not be necessary. This aligns with broader trends in modern educational settings where gender differences in technology adoption are decreasing, pointing toward a unified approach in designing AI education for healthcare.

The Kruskal-Wallis H test indicated significant variations in perception scores across four-year BPharm students. The post hoc study revealed notable differences between first year and second-year students, as well as between first-year and fourth-year students. This could be attributed to the progressive nature of the pharmacy curriculum. As students advance through the program, their exposure to complex topics, including AI and its applications in pharmacy, likely increases, leading to greater knowledge and more developed perceptions. Educational theories suggest that the depth of knowledge and the complexity of cognitive processing evolve over time, which could explain why first-year students differ significantly from their senior counterparts in their perceptions of AI (Anderson et al., 2001; Biggs et al., 2022). Furthermore, the differences between first and fourth-year students could also reflect the cumulative effect of experiential learning, which is more prevalent in the later years of the pharmacy program(Kolb, 1984).Additionally, our findings align with those of Chai et al. (2020), who observed that students in the early years of their education often display a more positive or neutral attitude toward AI, whereas senior students, exposed to a more rigorous curriculum, develop a more critical perspective on AI's functions and applications(Chai et al., 2020). They also proposed that with an increasingly complex curriculum, people might acquire a more astute perspective about the functions and applications of artificial intelligence (Chai et al., 2020).These findings highlight the importance of a progressively structured AI curriculum. Introducing foundational AI concepts in the first year, followed by more complex and applied topics in later years, could help bridge perceptual gaps across student cohorts. For instance, first-year students could benefit from basic AI literacy and its general applications in healthcare, which would establish a baseline understanding. In contrast, more advanced years could focus on specific AI applications

in pharmacy, AI ethics, and clinical case studies. Additionally, practical learning opportunities in the fourth year, such as internships or AI-related projects, could provide hands-on experience that reinforces theoretical knowledge. By structuring AI education to build progressively, the curriculum could foster a consistent and cohesive understanding of AI's potential in healthcare among students, preparing them to engage effectively with AI technologies in their professional lives.

To further explore whether demographic factors such as gender and year of study impact perceptions of AI, we conducted a Spearman correlation analysis. The analysis revealed no statistically significant correlations between gender and perception scores or between year of study and perception scores. This finding suggests that perceptions of AI among pharmacy students are relatively consistent across genders and different stages of their academic progression. The lack of a significant relationship may indicate that perceptions are influenced more by factors unrelated to demographic characteristics, such as personal exposure to technology, interest in AI, or the general academic environment. These results align with previous studies such as Cirillo et al., 2020; Esmaeilzadeh, 2021, that have also found minimal demographic impact on AI-related attitudes (Cirillo et al., 2020; Esmaeilzadeh, 2020). Future studies could investigate additional factors, such as prior exposure to AI or technology outside the curriculum, to identify more specific influences on students' views of AI.

Integrating AI into pharmacy education and practice has the potential to improve healthcare delivery, minimize errors, and increase patient outcomes. However, there are still lingering ethical and dehumanization concerns that have not been overcome. To properly address these challenges, a thorough education and training program is necessary. Pharmacy students are requesting AI-related courses to adequately prepare the next generation of pharmacists for a healthcare future that AI largely influences.

5. Recommendations

To enhance pharmacy practice and education with AI, we recommend incorporating AI literacy into the pharmacy curriculum, providing hands-on training with AI tools, and fostering interdisciplinary collaboration to explore the intersection of AI and pharmacy. AI can improve medication management, operational efficiency, and clinical decision support. AI can be instrumental in creating adaptive learning platforms tailored to pharmacy students and professionals. Such tools can ensure that pharmacy students are well-prepared to meet the demands of modern pharmacy practice. However, ethical concerns such as data privacy, bias, transparency, and informed consent must be addressed. Robust data protection measures should be implemented to safeguard patient information, and strategies to identify and mitigate biases in AI algorithms should be developed. Transparency in AI decision-making processes and obtaining informed consent from patients are also essential to ensure ethical practice. Moreover, AI should be viewed as a tool that supports, rather than replaces, the expertise of pharmacists. This will help maintain the trust of patients. By addressing these concerns and integrating practical AI training, we can prepare pharmacy students to leverage AI's benefits while upholding ethical standards.

6. Limitations

This study, conducted through an online survey method, has several limitations that must be acknowledged. First, the use of a convenience sample may introduce sampling bias, limiting the generalizability of our findings beyond the specific population of BPharm students at our institution. The absence of comparison with a national cohort means our findings may not fully represent all pharmacy students in India. Future studies should consider randomized sampling methods and include data from multiple institutions to enhance generalizability. Second, the study collected limited demographic information, including age, gender, and year of study. Additional demographic factors, such as socioeconomic background, academic performance, and prior exposure to AI, could further inform our understanding of how different factors shape perceptions of AI. Third, this study relied primarily on quantitative data from Likert-scale questions, which may not capture the full range of students' nuanced views and concerns about AI. Integrating qualitative data through interviews or open-ended questions in future research could provide a more in-depth perspective. Fourth, we acknowledge the possibility of confounding variables. Factors like students' prior exposure to AI outside the academic setting or previous knowledge of AI may influence their perceptions but were not accounted for in this study. Future research could address these potential confounders to better isolate the effects of the academic curriculum on students' perceptions.

Fifth, given the anonymous nature of the survey and the lack of additional demographic or personal data, we were unable to perform a detailed comparative analysis of respondents versus non-respondents. This constraint limits our ability to understand potential biases or differences between these groups. Another limitation of our study is the lack of data on students' previous healthcare experience. While we recognize that prior healthcare experience could significantly influence students' perceptions and opinions about AI in pharmacy, our study focused primarily on their current educational context. Moreover, while participants were divided into three specific age groups to simplify data analysis and align with standard practices in survey research, no specific analysis was performed based on age. This approach aimed to facilitate trend identification and pattern recognition, reflecting different stages of the BPharm program and varying levels of exposure to the curriculum and practical experiences. However, the absence of age-based analysis restricts the depth of our findings.Additionally, it is challenging to ascertain the competency level of most respondents, particularly second-year students in our study. This limitation suggests that our findings may not fully capture the competency variations among students at different stages of their education.

Although we were able to frame 12 questions for the desired questionnaire about perceptions and achieve satisfactory results in terms of factor analysis and reliability, the absence of another established measurement tool on this subject and the lack of re-testing hindered further validation studies. There is a need for studies designed in a more homogeneous sample.

7. Conclusion

This study highlights pharmacy students' generally positive perception of AI as a supportive tool in healthcare, emphasizing its potential to improve decision-making, reduce errors, and enhance patient care. However, significant gaps in specific knowledge areas, such as AI's technical aspects and its ethical implications, were evident. Furthermore, while students recognize the potential benefits of AI, there remains a cautious approach due to concerns about dehumanization and ethical issues. These findings suggest that integrating AI education into pharmacy programmes should not only focus on technical skills but also address the broader implications of AI in healthcare.The observed differences in AI perceptions across academic years suggest that a progressively structured curriculum could help students develop a balanced understanding of AI's benefits and limitations. Integrating foundational AI concepts in early years and advanced, application-focused topics in later years—alongside practical experiences—may prepare pharmacy students to engage effectively and ethically with AI technologies in their professional roles. By addressing these educational needs, pharmacy programmes can equip graduates with essential competencies for a healthcare landscape increasingly shaped by AI. Future research should consider longitudinal studies to assess the long-term impact of AI education on students' preparedness to use AI in practice.

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