



# Systematic Quantitative Assessment of AI Competency among Emerging Pharmacy Professionals: Detailed Analysis of Knowledge Acquisition, Practical Implementation, and Ethical Considerations

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## ABSTRACT

**Purpose of the Study:** Artificial Intelligence (AI) is reshaping industries by enhancing efficiency, decision-making, and automation, particularly in healthcare. This study evaluates the preparedness and understanding of pharmacy students regarding AI integration in professional practice, focusing on their attitudes, knowledge levels, and concerns about AI's impact on healthcare and the pharmacy sector.

**Background:** The potential of AI to transform healthcare, including pharmacy practice, is substantial. Understanding pharmacy students' readiness to work with AI is critical to aligning educational programs with future industry demands.

**Methodology:** A nationwide survey was conducted among pharmacy students, excluding faculty and recent graduates. Data were collected via in-person and online questionnaires, with expert validation and pilot testing to ensure reliability. A sample size of 406 students was chosen to achieve statistical robustness, focusing on demographics, AI knowledge, and perceptions of AI in pharmacy practice.

**Results:** The survey revealed a demographic predominance of female students (70%) and a majority within the 22-25 age range, with 60.5% in senior pharmacy years. Knowledge of AI was moderate, with 35.5% of respondents self-assessing their knowledge as mid-range and 83.7% utilizing AI for educational purposes. Perceptions were largely positive, with 75.4% recognizing AI's benefits, though concerns about job displacement and ethical issues persisted. Notably, 71.4% advocated for the inclusion of AI courses in the pharmacy curriculum, indicating a strong awareness of AI's relevance and a need for improved training.

**Conclusions:** The study underscores AI's transformative potential in pharmacy and identifies gaps in practical experience and training. While students view AI positively, addressing ethical concerns like job displacement is essential. Integrating comprehensive AI training into pharmacy curricula is vital to prepare future professionals to navigate AI's complexities responsibly.

## INTRODUCTION

Artificial Intelligence (AI) integration has become a revolutionary force and imparted a broad landscape in the constantly changing healthcare sector, changing the dynamics of patient care and medical practice. This evolution signifies a significant shift in our interaction with knowledge and information as well as a change in technological capabilities. AI is essential to healthcare for a variety of reasons. The primary rationale is that "healthcare systems can become smarter, faster, and more efficient in providing care to millions of people worldwide" [1]. This will lower healthcare expenses while simultaneously giving people high-quality care. In the field of healthcare, artificial intelligence is genuinely the wave of the future, revolutionizing the way patients receive high-quality treatment while reducing costs for providers and enhancing patient outcomes.

The viewpoints and attitudes of upcoming healthcare professionals are crucial in this paradigm change. Pharmacy practice is one of the widespread emerging fields in the healthcare sector which plays a versatile role from drug management to patient interaction. By enhancing medicine administration, optimizing productivity, and enhancing patient outcomes, artificial intelligence is transforming the way pharmacists provide healthcare. The day to day developing potential, challenges and capacity of AI has influenced the pharmacy settings in the past years [2] AI is being used by healthcare organizations to enhance the effectiveness of many processes, ranging from back-office work to patient care [3]. Automated dispensing, various intelligence technique in drug discovery has now enable the pharmacist to engage with the more patients while uplifting their health benefits. The growth of telemedicine the practice of treating patients from a distance has demonstrated the potential for AI application [4]. Pharmacy professionals may now make precise, evidence-based healthcare decisions with the use of tools and systems that are integrated with AI technologies. Pharmacists can evaluate a vast amount of patient data, such as medication profiles, lab results, and medical records, by utilizing AI algorithms and machine learning. This helps them spot possible drug interactions, evaluate the efficacy and safety of medications, and provide well-informed recommendations based on the needs of specific patients [2].

Artificial intelligence (AI) is one of the fastest-evolving technologies in medicine and is also transforming the

pharmacy industry by altering the way pharmacists perform their duties. This includes improving patient safety and treatment outcomes, streamlining operations, and offering personalized care. Artificial intelligence (AI) systems have the potential to track a patient's adherence to their prescribed medication schedule and send personalized alerts and reminders to encourage compliance, ultimately leading to better treatment outcomes and medication compliance [5].

With rapid advancements in the healthcare sector, the number of prescriptions, complex drug regimens, and administrative tasks has increased noticeably. As a result, there is an increasing demand for advanced technological solutions that can assist healthcare professionals in their daily responsibilities and optimize healthcare service delivery. AI is used in target identification, hit identification, absorption, distribution, metabolism, elimination, toxicity prediction, lead optimization, and drug repositioning, among other phases of the drug discovery process.

Promising prospects have been observed in the application of AI in several domains within the pharmaceutical practice field. However, to fully utilize AI technology, there are still research gaps that must be filled. There are major challenges that need to be overcome, like the high cost of implementation, safety issues, regulatory constraints on data interchange, and lack of human interaction [6]. The most crucial element is comprehending the influence of AI services on financial and clinical results and implementing them fully within current pharmaceutical systems. Upgrading medical education to focus on AI, involving stakeholders, funding R&D, developing safe machine learning techniques, and carefully integrating AI to complement pharmacy staff rather than replace them are some strategies to promote acceptance [7]. Considering that some pharmacists could be hesitant to employ AI, extensive education and training might be required to build trust in AI-driven processes [8]. AI indicates a promising future for the pharmacy sector. It is necessary to conduct more study to fully comprehend the potential and constraints of AI technology, as well as to establish clear rules for the safe application and assessment of AI in real-world contexts. AI technology's capabilities will grow as it advances, enabling more sophisticated and accurate solutions to be applied to pharmacy practice. Innovation will be sparked, and AI technologies will be improved to suit pharmacy needs through collaboration

between pharmacists, AI developers, and health care professionals [9].

Like many students, pharmacy students may have a lot of misconceptions and concerns about AI and its potential impacts on healthcare. The major reasons of the misconceptions might be due to lack of understanding and acknowledgment on the first hand. This study aims to assess pharmacy students' comprehension of artificial intelligence (AI) by investigating their views, knowledge, and preparedness to incorporate AI into their future practice.

This study aims to assess pharmacy students' comprehension and readiness regarding AI by exploring their views, knowledge, and preparedness to integrate AI into future practice. This work highlights the importance of AI literacy in pharmacy education to bridge gaps and build trust in AI applications, ultimately preparing students for a technologically advanced healthcare landscape.

## METHODOLOGY

### Study population

Our research endeavors to delve into the unique experiences and perspectives and knowledge of pharmacy students across the nation. In this research paper, our study population focuses on pharmacy students currently enrolled in colleges nationwide. We specifically exclude faculty members and recent graduates from our sample. The exclusion of faculty members and recent graduates from our study sample is intentional and serves to maintain the integrity and relevance of our findings. While faculty members undoubtedly possess valuable insights, their perspectives may differ significantly from those of current students, whose firsthand experiences are paramount in shaping the discourse surrounding pharmacy education. Likewise, fresh graduates, while possessing recent experiences within the academic realm, may have already transitioned into professional roles, potentially altering their perspectives and priorities by honing in on this demographic, we aim to understand the perspectives, experiences, and challenges faced by students within the pharmacy education landscape. This targeted approach allows us to gather insights that are pertinent to the current student body, shedding light on areas for improvement and innovation within pharmacy education at a national level [10].

### Ethical consideration

It's crucial to emphasize that participation in our study was entirely voluntary, with no coercion or pressure exerted upon students to complete the forms. This voluntary nature of participation ensures that students engage with the questionnaire willingly, without feeling obligated or unduly influenced. Furthermore, anonymity was rigorously maintained throughout the data collection process, safeguarding the privacy and confidentiality of participants. By anonymizing responses, we uphold the principle of confidentiality, reassuring students that their input will not be linked back to their identities. This fosters a sense of trust and openness among participants, encouraging candid and honest responses. Additionally, informed consent was obtained from all participants, providing them with clear information about the purpose of the study, the voluntary nature of participation, and how their data would be used. By conscientiously addressing these ethical considerations, we uphold the integrity and validity of our finding [11].

### Sampling

Sampling is settled by using power calculation to secure that our study is statistically strong to evaluate significant effect or differences. It will give our study true results and avoid false result and conclusions [12]. As this is one of the crucial steps so extraordinary safety measure were taken, to determine the required sample size for our study, several essential factors are considered. These included the effect size, alpha level, power, population standard deviation, desired level of precision, research design and methodology, statistical analysis plan, anticipated participant attrition rate, sampling strategy, and the potential for multiple comparisons or testing.

Through power calculation techniques, it is found that a sample size of 400 would be appropriate, considering the number of universities offering PharmD programs. This calculation was based on a 5% margin of error, a 95% confidence level, and an assumed response distribution of 50%. These parameters ensure that our sample size is sufficiently robust to produce reliable and valid results for the study [13].

### Data Collection

The methodology for data collection encompassed a multifaceted approach. Initially, surveys were conducted in person within a selection of universities situated across Karachi, ensuring a diverse

representation of perspectives within the city. Additionally, an extensive online questionnaire was deployed, targeting participants nationwide via the expansive reach of the internet. To maximize outreach and engagement, a strategic utilization of popular social networking sites was undertaken. Specifically, platforms such as WhatsApp, Instagram, Facebook, and LinkedIn were harnessed to disseminate the questionnaire widely, thereby facilitating participation from a broad spectrum of respondents spanning different demographics and geographical locations across Pakistan. This comprehensive strategy aimed to ensure robust data collection and a comprehensive understanding of the subject matter under investigation [14].

### Questionnaire

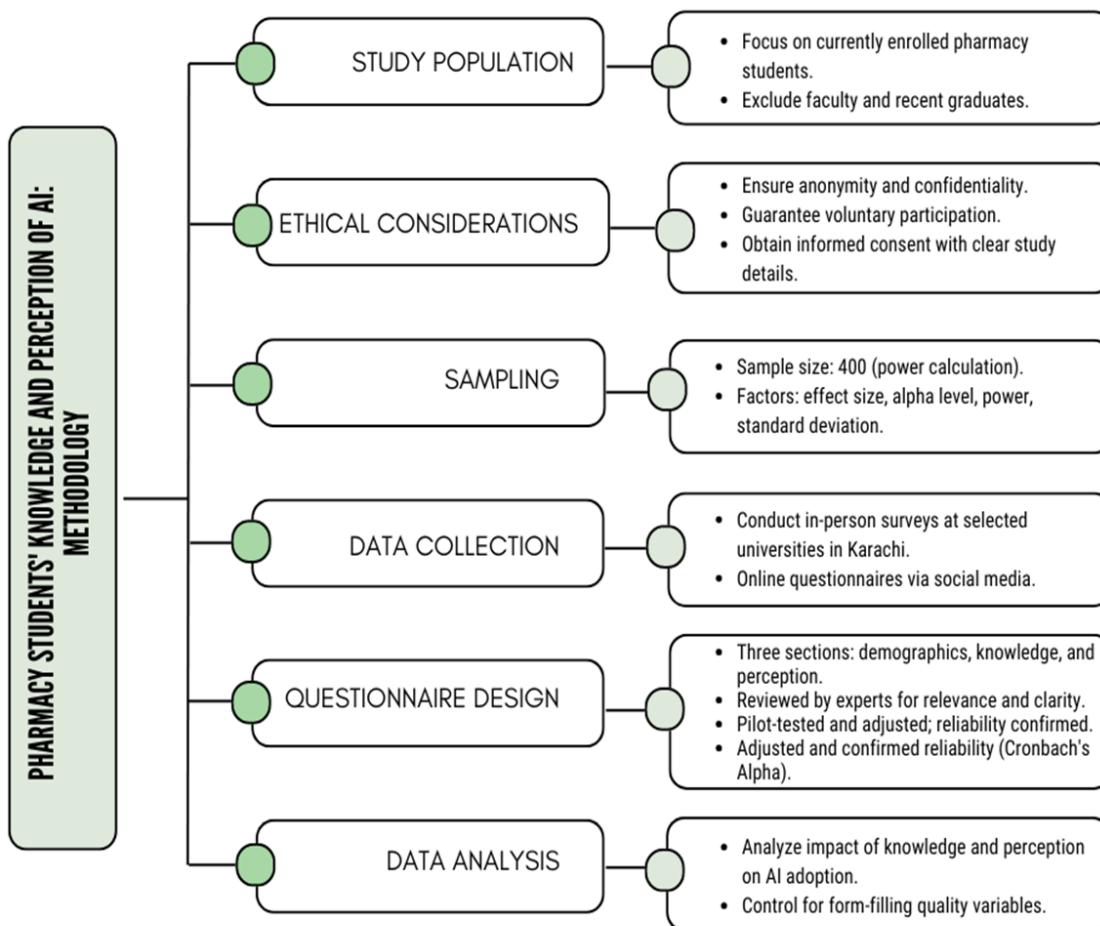
The questionnaire aimed to assess the knowledge and perception of pharmacy students in Pakistan towards artificial intelligence (AI). It was structured into three sections: demographics of the participants, knowledge, and perception. The questionnaire comprised 16 questions, with 6 dedicated to assessing knowledge and 10 to perception. It included a mix of multiple-choice questions as well as open and closed-ended questions [15]. To ensure the validity and reliability of the questionnaire, it was initially reviewed by two expert professors from Jinnah Sindh Medical University, who have extensive experience in conducting cross-sectional studies. These experts excluded 2 questions and altered 5 others to improve the questionnaire's relevance and clarity.

Subsequently, a pilot test was conducted with 30 participants from Jinnah Sindh Medical University who were not included in the final study sample. This pilot test aimed to evaluate various aspects of the questionnaire, such as the time required to complete it, its suitability, flow, level of difficulty, and clarity. Based on the feedback received from the pilot test participants, further alterations were made to 3 questions to minimize the time needed to answer and enhance their clarity. The reliability of the questionnaire was evaluated by calculating Cronbach's Alpha coefficient using responses from 30 randomly selected undergraduate pharmacy students. The results demonstrated an acceptable level of internal consistency, confirming the questionnaire's reliability for the main study. Specifically, the Cronbach's Alpha coefficient for the knowledge section

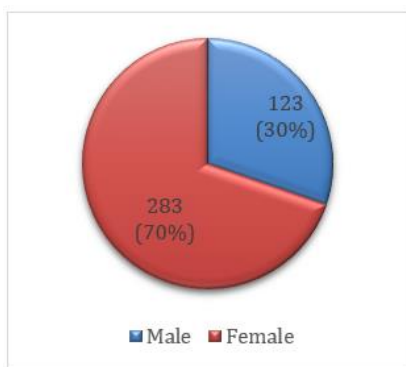
was 0.82, while the perception section had a coefficient of 0.76 [16-17].

### Data Analysis

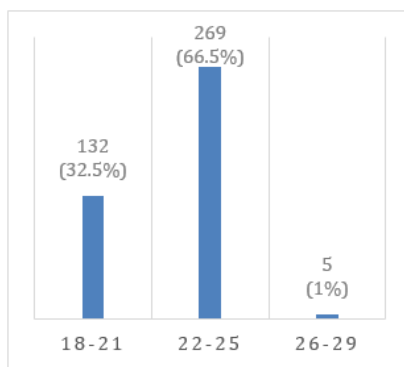
This multivariate study investigates the complex relationships between two independent variables - knowledge and perception - and one dependent variable, Pharm-D students, with undergraduate Pharm-D students serving as a control variable. The knowledge variable is comprised of three dimensions: previous knowledge, which refers to students' prior understanding of AI concepts and applications; current knowledge, which encompasses students' awareness of recent AI advancements and developments; and exposure to current technology, which assesses students' familiarity with AI-powered tools and platforms in healthcare and pharmacy settings. The perception variable is also multidimensional, capturing students' attitudes, beliefs, and opinions about the impact and role of AI in various fields of pharmacy, including clinical pharmacy, pharmaceutical sciences, and community pharmacy. By examining the interplay between these two independent variables and the dependent variable, Pharm-D students, while controlling for the influence of undergraduate Pharm-D students, this study aims to provide a nuanced understanding of how students' knowledge and perceptions of AI influence their adoption and utilization of AI in pharmacy practice, including their willingness to use AI tools, their confidence in AI-driven decision-making, and their overall attitudes towards the integration of AI in pharmacy education and practice. Additionally, the study accounts for an extraneous variable - the quality of form filling instructions and support - which may affect students' ability to accurately complete forms and potentially influence their responses. The inclusion of undergraduate Pharm-D students as a control variable allows for the isolation of the relationships between knowledge, perception, and AI adoption, while accounting for potential variations in AI familiarity and exposure among students at different stages of their pharmacy education and training. Furthermore, the study's design acknowledges the potential impact of extraneous variables, such as form filling instructions and support, on students' responses and takes steps to mitigate their influence, ensuring a more rigorous and reliable investigation [17].



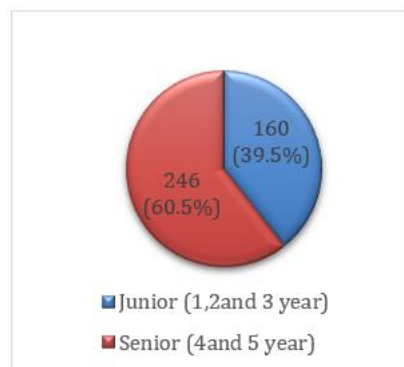
**Figure 1.** Methodology framework for assessing pharmacy students' knowledge and perceptions of AI, detailing study population, ethical considerations, sampling strategy, data collection approach, questionnaire design, and data analysis methods. This structured approach ensures reliability and comprehensive insights into AI adoption among future pharmacy professionals.



**Figure 2.** Gender



**Figure 3.** Age group



**Figure 4.** Year in school

## RESULTS

### Demographics

The demographic profile of the survey respondents reveals a notable gender imbalance, with females constituting the majority at 70% and males at 30% as shown in figure: 2. The age distribution shows that the largest group of respondents falls within the 22-25 age range, accounting for 66.5% of the total. This is followed by the 18-21 age group, which makes up 32.5%, while only 1% are aged 26-29 represented in figure: 3. Regarding their academic standing, a greater proportion of respondents are in their senior years (4th and 5th years) at 60.5%, compared to 39.5% who are in their junior years (1st, 2nd, and 3rd years) figure: 4. This demographic composition indicates that the majority of respondents are young adults and more advanced in their pharmacy education, which may influence their perceptions and experiences with AI in the field.

### Knowledge

The data collected from 406 respondents provides a comprehensive overview of their knowledge and

engagement with artificial intelligence (AI). When asked to rate their knowledge of AI, the majority of participants placed themselves in the mid-range, with 35.5% selecting option 3 and 22.7% selecting option 4. The mean rating was 81.2, with a standard deviation of 36.97, indicating a moderate level of self-assessed AI knowledge across the group. Regarding their technology friendliness, most respondents considered themselves quite adept, with 37.9% rating themselves at level 4 and 34.5% at level 3. The mean for this question was also 81.2, but the standard deviation was higher at 56.36, suggesting a broader variation in responses. When asked about practical experience with AI, 31% of respondents had implemented AI models or participated in AI projects, while 69% had not. The mean response for this question was notably higher at 203, with a substantial standard deviation of 77, reflecting diverse levels of hands-on AI experience. The use of AI software for educational purposes was prevalent among respondents, with 83.7% indicating usage. This question also had a mean of 203, but the highest standard deviation observed at 137, highlighting significant variation in responses.

**Table 1. Pharmacy Students' Knowledge of AI in Practice, Education, and Ethics.**

S.NO	KNOWLEDGE					
	Items	Options	Percentage	Frequency (n=406)	Mean	Standard Deviation
1	Rating of knowledge in the field of Artificial Intelligence (AI).	1	11.30%	46	81.2	36.97
		2	20.20%	82		
		3	35.50%	144		
		4	22.70%	92		
		5	10.30%	42		
2	Rating of level of technological proficiency.	1	3%	12	81.2	56.36
		2	15.80%	64		
		3	34.50%	140		
		4	37.90%	154		
		5	8.90%	36		
3	Implementation of any AI models or participation in AI projects.	Yes	31%	126	203	77
		No	69%	280		
4	Usage of AI software for educational purposes.	Yes	83.70%	340	203	137
		No	16.30%	66		
5	Perspective on the primary goal of Artificial Intelligence (AI).	Automation of Tasks	7.90%	32	81.2	93.54
		Problem Solving	10.80%	44		
		Mimicking Human Intelligence	6.90%	28		
		Improving Human Life	8.40%	34		
		All of the above	66%	268		

**Table 2. Pharmacy Students' Perceptions of AI in Practice, Education, and Ethics**

S.NO	PERCEPTION					
	Items	Options	Percentage	Frequency(n)	Mean	Standard Deviation
1	AI have a positive impact on the field of pharmacy.	Yes	75.40%	306	135.33	122.53
		No	5.90%	24		
		Unsure	18.70%	76		
2	AI ever be capable of replacing pharmacists.	Yes	21.20%	86	135.33	64.19
		No	55.70%	226		
		Unsure	23.20%	94		
3	Pharmacists need to be skilled in using AI tools and interpreting AI-generated data.	Yes	74.40%	302	135.33	120.71
		No	4.90%	20		
		Unsure	20.70%	84		
4	AI reduce educational opportunities for developing "clinical judgment" and "practical skills" among trainee pharmacists.	Yes	55.70%	226	135.33	66.15
		No	17.20%	70		
		Unsure	27.10%	110		
5	AI-based technology cumbersome and irritating, and does it affect your confidence or induce anxiety while using	Yes	48.30%	120	135.33	44.61
		No	29.60%	196		
		Unsure	22.20%	90		
6	Including a specific course on AI and its role in pharmaceutical sciences in the national pharmacy curriculum	Yes	71.40%	290	135.33	109.56
		No	12.30%	50		
		Unsure	16.30%	66		
7	Rating of confidence in working alongside AI.	1	5.40%	22	81.2	54.34
		2	15.30%	62		
		3	43.80%	178		
		4	24.10%	98		
		5	11.30%	46		
8	Rating of eagerness to learn about AI.	1	3%	12	81.2	51.10
		2	7.40%	30		
		3	32.50%	132		
		4	24.10%	98		
		5	33%	134		
9	Potential impact of AI on the role of pharmacists in the future.	AI can be used to automate many of the tasks that pharmacists currently perform	24.10%	98	101.5	66.06
		AI can be used to develop new drugs and treatments	9.90%	40		
		Improve the accuracy of clinical decision-making	14.30%	58		
		All of the above	51.70%	210		
10	Thoughts on the ethical implications of using AI in the field of pharmacy.	Biasness in the selection of treatment	8.40%	34	101.5	66.87
		Accountability who will be responsible for the decision made by AI.	22.20%	90		
		Privacy of the patient data can't be maintained	17.20%	70		
		All of the above	52.20%	212		

Finally, when queried about the primary goal of AI, a significant majority (66%) believed it encompassed all listed purposes, including automation of tasks, problem-solving, mimicking human intelligence, and improving human life. This question had a mean of 81.2 and a standard deviation of 93.54, illustrating a strong consensus on the comprehensive role of AI. Overall, the data suggests that while there is a solid base of knowledge and technological comfort among respondents, practical experience with AI varies widely. Additionally, there is a strong recognition of the multifaceted goals of AI, particularly in its potential to broadly enhance human activities [18].

### Perception

The survey results reveal insightful perceptions about AI's role and impact on pharmacy among 406 respondents. A significant majority (75.4%) believe that AI will positively impact the pharmacy field, with a mean response rate of 135.33 and a standard deviation of 122.53, indicating broad agreement despite some variability. Conversely, only 5.9% foresee no positive impact, and 18.7% remain unsure. When considering AI's potential to replace pharmacists, 55.7% of participants disagreed, although 21.2% thought it possible, and 23.2% were unsure, reflecting a mixed outlook on AI's future dominance in the profession. Regarding the necessity for pharmacists to be skilled in AI, 74.4% affirmed its importance, suggesting a strong recognition of AI's growing relevance in their field. Only 4.9% disagreed, while 20.7% were unsure. Additionally, over half of the respondents (55.7%) expressed concerns that AI might reduce educational opportunities for developing clinical judgment and practical skills, though 17.2% disagreed and 27.1% were uncertain, highlighting a significant area of apprehension.

The data also indicates a substantial portion of respondents (48.3%) find AI technology to be hectic and anxiety-inducing, with 29.6% disagreeing and 22.2% unsure, suggesting a need for better integration and training. Reflecting the perceived importance of AI education, 71.4% supported the inclusion of AI courses in the national pharmacy curriculum, while 12.3% opposed and 16.3% were uncertain. Confidence in working alongside AI varied, with the highest percentage (43.8%) rating their confidence at level 3, followed by 24.1% at level 4. Additionally, enthusiasm for learning about AI was high, with 33% rating their keenness at level 5 and 32.5% at level 3. When

considering AI's future impact, 51.7% agreed that AI would encompass task automation, drug development, and improving clinical decision-making, while 24.1% focused on task automation alone.

Finally, ethical concerns regarding AI in pharmacy were prominent, with 52.2% acknowledging multiple issues such as treatment bias, accountability, and patient data privacy. This broad agreement, coupled with significant standard deviations, suggests diverse yet strong apprehensions about AI ethics in the pharmacy domain. Overall, the data reflects a nuanced perspective, acknowledging AI's potential benefits while highlighting areas of concern and the need for education and ethical considerations [19].

## DISCUSSION

Artificial Intelligence (AI) is revolutionizing various fields, including pharmacy and health professions, by enhancing efficiency, accuracy, and decision-making processes. In pharmacy, AI can aid in drug discovery, personalized medicine, and patient care optimization. Understanding demographic trends is crucial because it helps identify the segments of the population that are more receptive to AI and those that may need more targeted educational interventions. Knowledge levels among professionals indicate the current state of AI literacy and the areas where training is needed most. Ethical concerns, such as AI's impact on job displacement and educational opportunities, must be addressed to ensure responsible and equitable AI integration. By comprehensively understanding these factors, we can better prepare for the challenges and opportunities that AI presents, fostering a workforce that is both technologically adept and ethically aware.

Our research, which revealed a significant female majority (70%) and moderate AI knowledge (mean rating: 81.2), aligns closely with previous studies by Jha et al., who also observed similar demographic trends and knowledge levels among health professions students [20]. Additionally, Gerlich's study corroborates our findings by highlighting a demographic imbalance with a female majority, further emphasizing the influence of demographics on AI acceptance [21]. Both our research and the studies by Jha et al., and Gerlich indicate a moderate level of AI knowledge and tech-savviness among respondents, stressing the need for improved AI education [20-21]. A significant portion of our respondents (83.7%) reported using AI for educational purposes, a higher percentage than Jha et al.'s 44.2%, yet both studies



highlight the critical need for practical AI training, given that only 31% of our participants had practical AI experience [20]. This mirrors the findings from pre-service teachers' studies, which also revealed a gap between theoretical knowledge and real-world application. Consistent with Ejaz et al.'s findings, our study showed a perceived positive impact of AI on pharmacy (75.4%) and the necessity of AI skills (74.4%) [22]. Similarly, both our research and Gerlich's study observed positive attitudes towards AI's impact in specific fields such as pharmacy and education [21-22]. However, these optimistic views are tempered by ethical concerns and mixed opinions regarding AI's potential to replace jobs, an issue noted across all studies.

These insights collectively underscore the imperative for enhanced and ethically mindful AI education across various professions. The recurring theme of ethical concerns about AI reducing educational opportunities and job displacement highlights the need for a balanced approach in AI training, ensuring that professionals are not only skilled in AI applications but also prepared to navigate the ethical challenges associated with AI integration. The positive perception of AI among pharmacy students suggests a readiness to embrace technological advancements in their future careers. This readiness is crucial as the healthcare industry continues to evolve with AI-driven innovations. Educational institutions can leverage this positive attitude by incorporating more AI-related content into pharmacy curricula, ensuring that students are well-prepared to utilize these technologies effectively. Additionally, the findings suggest that future pharmacists are likely to advocate for and adopt AI tools in their practice, potentially leading to more widespread use of AI in the pharmaceutical industry. This could enhance the overall quality of care provided to patients and improve operational efficiencies within pharmacies.

## CONCLUSION

This research has illuminated the pivotal role of Artificial Intelligence (AI) in reshaping pharmacy and health professions, revealing both opportunities and challenges associated with its integration. The findings reflect a moderate level of AI knowledge among respondents, alongside a notable female predominance, aligning with broader demographic and educational trends. This indicates a foundational understanding of AI, yet highlights significant gaps in

practical experience and advanced training. The study demonstrates that while AI is viewed favorably for its potential to enhance efficiency and accuracy, ethical concerns—particularly around job displacement and educational equity—must be addressed. These concerns emphasize the need for a balanced approach to AI adoption, ensuring that technological advancements do not compromise ethical standards or professional opportunities. Educational institutions play a crucial role in this transition by incorporating robust AI training into their curricula. By equipping future professionals with both the technical skills and ethical framework necessary to navigate AI's complexities, we can foster a workforce adept at leveraging AI's benefits while mitigating its risks. Ultimately, the successful integration of AI into pharmacy and health professions hinges on our ability to balance technological innovation with ethical considerations. This research underscores the importance of preparing professionals to not only harness AI's capabilities but also to address its broader implications responsibly.

## CONFLICT OF INTEREST

The authors confirm that there are no conflicts of interest or biases influencing this publication. The research was conducted independently, free from any financial or personal ties that could compromise its integrity.

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