

THE ROLE OF AI IN ENHANCING PHARMACY SERVICES: A QUANTITATIVE SURVEY APPROACH

*Mr. Pathan Abdulrahman, Ms. Pallavi Somthane**

Dr. D. Y. Patil College of Pharmacy Akurdi, Pune, Maharashtra

ABSTRACT:

Artificial Intelligence (AI) plays a transformative role in modern society, with intelligent modeling at its core, supporting information visualization, problem-solving, and informed decision-making across various domains. Among the most promising areas of AI application is the healthcare sector, which is currently facing mounting challenges in keeping pace with increasing demands, complex diseases, and rapid advancements in medical science. AI offers the potential to revolutionize healthcare systems by introducing innovative approaches in economics, diagnostics, treatment planning, and overall operational efficiency. In particular, AI is rapidly reshaping the pharmacy industry. Its ability to enhance the precision and efficiency of medication management, patient care, and pharmaceutical research is significantly improving clinical outcomes. By leveraging AI algorithms and machine learning models, vast amounts of healthcare data can be processed and analyzed to identify hidden patterns, predict patient responses, and optimize drug therapies. This leads to the advancement of personalized medicine, where treatments can be tailored to individual genetic profiles and health conditions. Furthermore, AI supports clinical decision-making by providing healthcare professionals with real-time insights and evidence-based recommendations. In drug discovery, AI accelerates the identification of new therapeutic compounds and the design of targeted medications, reducing the time and cost traditionally required in pharmaceutical development. Additionally, AI streamlines pharmacy operations, including inventory management, prescription processing, and adherence monitoring, enhancing overall workflow and patient safety. This review paper delves into the multifaceted applications of AI in pharmacy, highlighting how these intelligent systems are redefining the future of pharmaceutical care and transforming the healthcare landscape.

KEYWORDS:

AI, Type, History, Use of AI, Advanced techniques, Merit and Demerit, A case study, Survey, Future of AI.

INTRODUCTION: -

One of the main objectives of humanity is to manage the ever-changing world to our advantage, and this is especially true in fields like medicine and pharmaceuticals. These sectors focus on developing chemical substances to alleviate physical and mental suffering. Technological innovations, particularly in chemical and mechanical engineering, have been driven by the pharmaceutical industry, which is also a source of groundbreaking technologies. However, mechanical innovations that aid drug development, especially for human use, are desperately needed.1

AI is transforming the pharmaceutical and healthcare industries by replicating human cognitive functions like learning and problem-solving. It enhances drug discovery, formulation, and clinical diagnostics by analyzing vast data efficiently. In healthcare, AI aids decision-making, improves early diagnosis, and streamlines administrative tasks, reducing the workload for professionals and improving patient outcomes.²

AI is revolutionizing pharmaceuticals and healthcare by enhancing drug discovery, formulation, and diagnostics through data analysis. It aids in early disease detection, automates pharmacy operations, improves inventory management, and streamlines administrative tasks. AI-driven technologies like machine learning and natural language processing help identify early disease signs and analyze unstructured medical data for better diagnoses and treatment decisions. As AI advances, its role in healthcare and drug development will continue to expand, making it a crucial tool for the future of medicine and pharmacy.³

TYPE OF ARTIFICIAL INTELLIGENCE:-

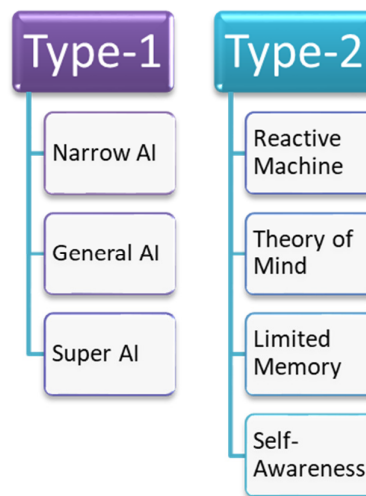


Fig. No. 1 Types of AI

Based on the calibre and their presence:

A1. Artificial Narrow Intelligence (ANI) or Weak AI: It specializes in specific tasks, such as facial recognition, driving a vehicle, practising chess, and managing traffic signals, among others.⁴

A2. Artificial General Intelligence (AGI) or Strong AI: It can mimic human capabilities and is often referred to as human-level AI. This type of AI can streamline human cognitive functions and handle unfamiliar tasks.

A3. Artificial Super Intelligence (ASI): It surpasses human intelligence and exhibits significantly greater activity in areas like drawing, mathematics, and space-related tasks, both in what's currently available and what's still in development.⁶

Based on presence (Four Primary Artificial Intelligence Type)

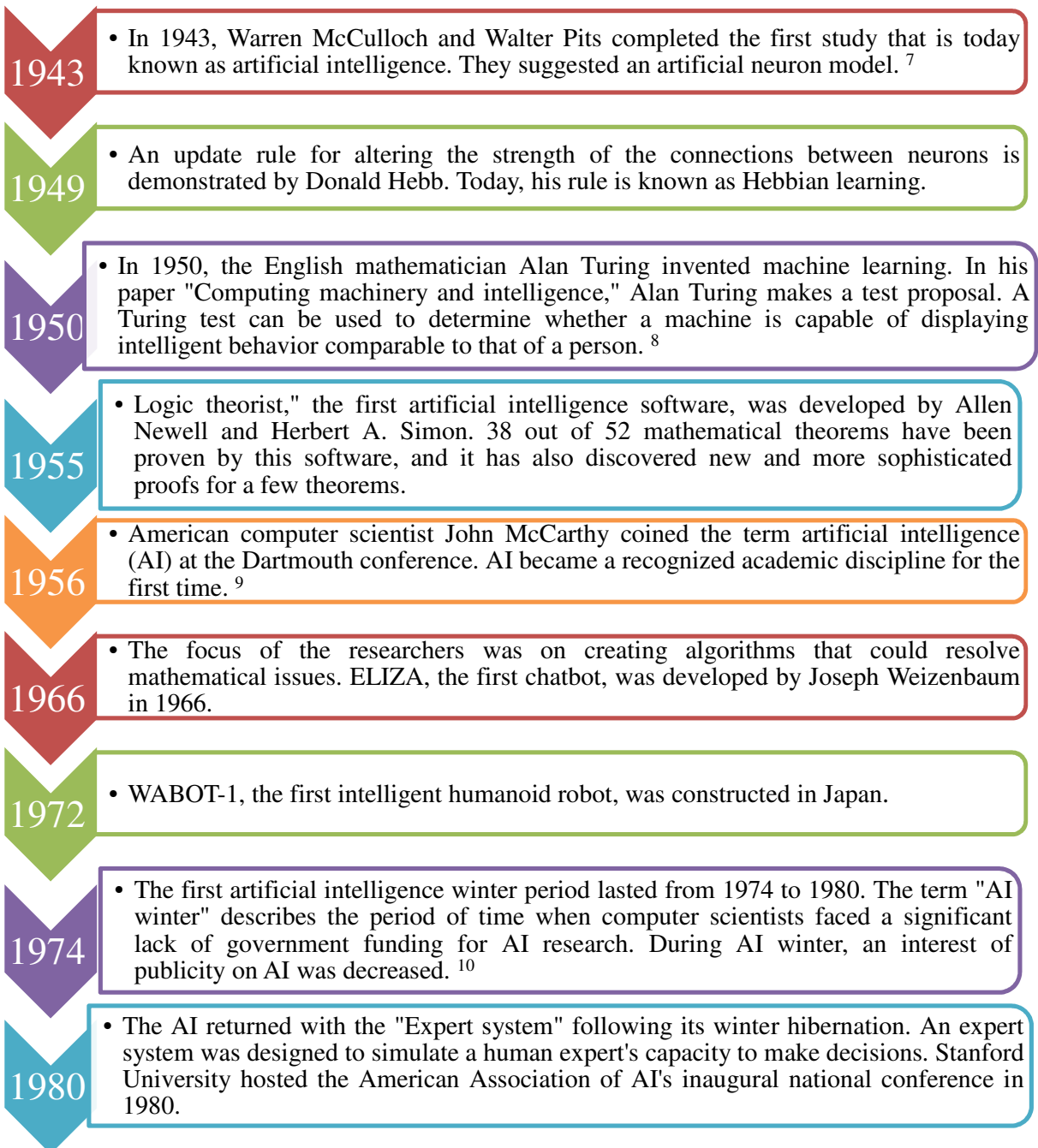
B1. Reactive Machine: It serves specific, single-purpose applications and lacks the ability to draw from past experiences due to the absence of a memory system. This category is referred to as reactive machines. Notable instances of these systems include IBM's chess program, which can identify chessboard pieces and make predictions.⁵

B2. Limited memory system: It possesses a constrained memory system that leverages past experiences to address various issues. In the context of autonomous vehicles, this system is adept at making decisions based on recorded observations, which are used for subsequent actions, but these records are not retained permanently.

B3. Theory of mind: It relies on the concept of "Theory of Mind," which implies that human decision-making is influenced by their unique thoughts, intentions, and desires. This kind of AI system does not currently exist.⁶

B4. Self-awareness: It possesses self-awareness, including a sense of self-consciousness. However, this type of AI system does not exist at this time.

HISTORY OF ARTIFICIAL INTELLIGENCE:-



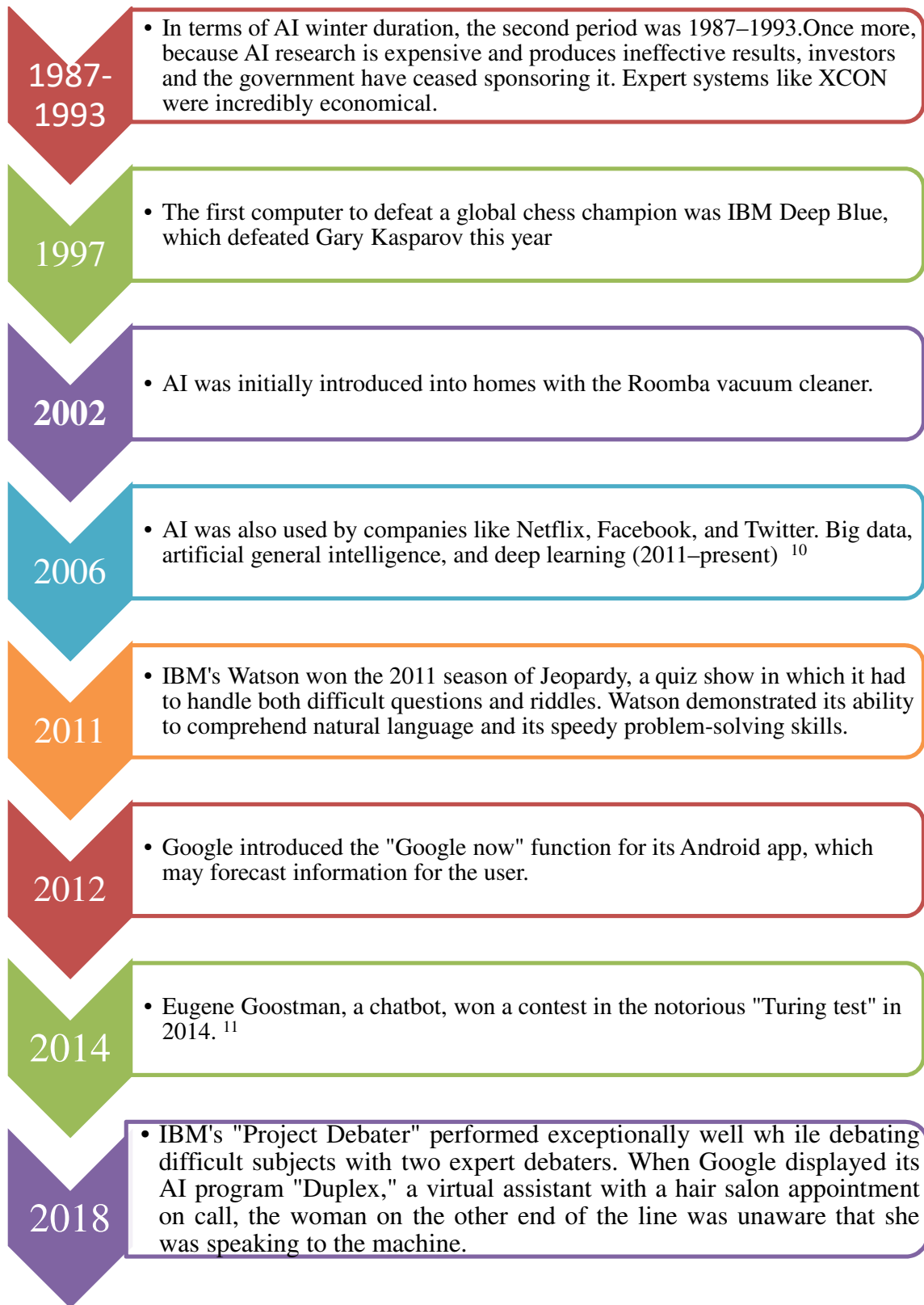


Fig. No. 2 History of AI

USES OF ARTIFICIAL INTELLIGENCE IN PHARMACEUTICAL DEVELOPMENT AND DELIVERY:-

1. Basic Scientific Research

Basic scientific research or a thorough grasp of human disease at the molecular level are typically prerequisites for pharmaceutical innovation. AI is being used to help a wide range of scientific research, including the development and assessment of scientific theories. Pharmaceutical discovery research also makes use of AI. One notable innovation was the application of AI to resolve the "protein folding problem," which is the question of how the amino acid sequence of a protein determines its three-dimensional atomic structure. The artificial intelligence company DeepMind declared in December 2020 that its AlphaFold2 system had developed a system that can accurately anticipate a protein's three-dimensional form, thereby solving the protein folding challenge.¹²

2. Pharmaceutical Discovery And Design

Artificial Intelligence (AI), particularly bioinformatics, has been utilized for decades in pharmaceutical design and discovery by analyzing vast biological data. AI helps identify relevant biomarkers or mutations associated with diseases, advancing knowledge for new pharmacological targets. Companies are building and purchasing data sets, including synthetic data, to train machine learning models for drug discovery. Synthetic data, though useful, has limitations, especially for rare diseases with limited experimental data. An example includes a genetic testing company that used data from 10 million individuals to identify potential medications, resulting in a licensed drug. However, ethical concerns arise over data privacy, regulatory oversight, and cybersecurity risks. AI is also employed to screen compounds, enabling researchers to explore a broader chemical space, identify biologically significant molecules, and "fail faster" in the discovery process, improving efficiency in finding new treatments.¹³

3. Preclinical Studies And Pharmaceutical Development

For use in preclinical research, scientists are also developing machine learning models to forecast a molecule's characteristics, like its toxicity or binding affinity to a target protein. Preclinical research has so far used animal models to mimic some parts of human disease, but not all of the disease may be replicated. With comparable or superior performance, machine learning models utilizing data from sufficiently relevant heterogeneous biological systems (such organoids or organs-on-a-chip) may eventually be able to replace animal models.¹⁴

4. Post-approval activities

Following approval, artificial intelligence (AI) may be utilized in pharmacovigilance to a limited degree. This includes automating the submission of individual case study reports to a drug regulatory body, like the US Food and Drug Administration. This is also how the Swedish Medical Products Agency has employed AI. Below is a discussion of additional possible uses of AI in pharmacovigilance. AI is being used more and more by pharmaceutical companies in

a variety of areas related to pharmaceutical manufacturing, such as process design (to cut down on waste and development time), advanced process control, process monitoring, fault detection (including using computer vision to detect irregularities in packaging), and trend monitoring (including customer complaints and reports of manufacturing-related deviations).¹⁵

Pharmaceutical firms are increasingly adopting AI to oversee the distribution and supply of medications, including keeping an eye on the cold chain for vaccine transportation. AI may also be used to predict demand, track and detect supply chain malfeasance, and foresee or identify shortages and stock-outs. Pharmaceutical businesses also utilize AI to build marketing plans, determine prices, and forecast where they can sell the most of a new drug. AI-based analysis of demographic, medical, prescription, and physician data is used to modify marketing techniques, particularly to increase engagement with health-care professionals through the use of social media, sponsored commercials, and mass emails.¹⁶

5. Clinical trials and regulatory approval



Fig. No. 3 Clinical trials and regulatory approval

AI plays a pivotal role in various stages of clinical development, enhancing the efficiency and accuracy of processes such as clinical trial design, patient recruitment, data analysis, and regulatory filings. It assists in designing trials by predicting outcomes using real-world data, electronic health records, and medical claims, optimizing site selection, dosing regimens, and clinical endpoints, and improving medication adherence to reduce attrition rates. However, the use of AI in medication adherence raises privacy concerns, especially if it is used without consent for surveillance.¹⁷

Moreover, AI aids in the creation of documents and reports required for drug development and regulatory submission, including statistical analyses, product characteristic summaries, and labels. Despite its capabilities, AI-generated content requires human oversight to prevent inaccuracies and ensure quality control. While AI has proven to be a valuable tool in clinical

development, its implementation is still under refinement, with ongoing discussions between researchers and regulators to address ethical, technical, and validation challenges.¹⁸

1. AI IN DISEASE DIAGNOSIS

In order to protect patients' health and provide a thoughtful treatment plan, disease analysis becomes essential. Inaccuracy caused by humans makes correct diagnosis difficult, and misinterpretation of the information produced makes the work complex and difficult. Because AI ensures precision and efficiency, it can be used for a wide range of purposes. Following a thorough review of the literature, applications of several technologies and approaches for the diagnosis of disease have been documented.¹⁹

2. AI IN OTHER CHRONIC DISEASES

Various computer programming techniques have led to the development of various computerized therapies. The behavioral and cognitive method, which uses joysticks or multiple-choice questions, is the main focus of the therapy. Intelligent computer-assisted instruction is a recently developed computer interaction that can potentially use other AI technologies, such as expert systems and natural language understanding.²⁰

3. AI IN DIGITAL THERAPY/PERSONALIZED TREATMENT

Within the raw datasheets, AI has the ability to extract a meaningful relationship that may be utilized for illness diagnosis, treatment, and mitigation. Numerous more recent methods for computational knowledge in this developing subject could be used in nearly every area of medical study. Solving complex clinical problems requires a great deal of knowledge acquisition, analysis, and application.²¹

FUTURE OF ARTIFICIAL INTELLIGENCE: -

AI is revolutionizing various industries, from automated transportation to healthcare and space technology. Companies like Google and Uber are leveraging AI for self-driving cars, enhancing mobility for disabled individuals and reducing accidents. AI is also transforming factory work by taking on hazardous tasks, while in customer service, it is expected to manage around 80% of tasks efficiently. In healthcare, AI is improving personalized health management by analyzing medical data and identifying symptoms. Additionally, AI aids in climate change forecasting through environmental technologies and data science.³⁰

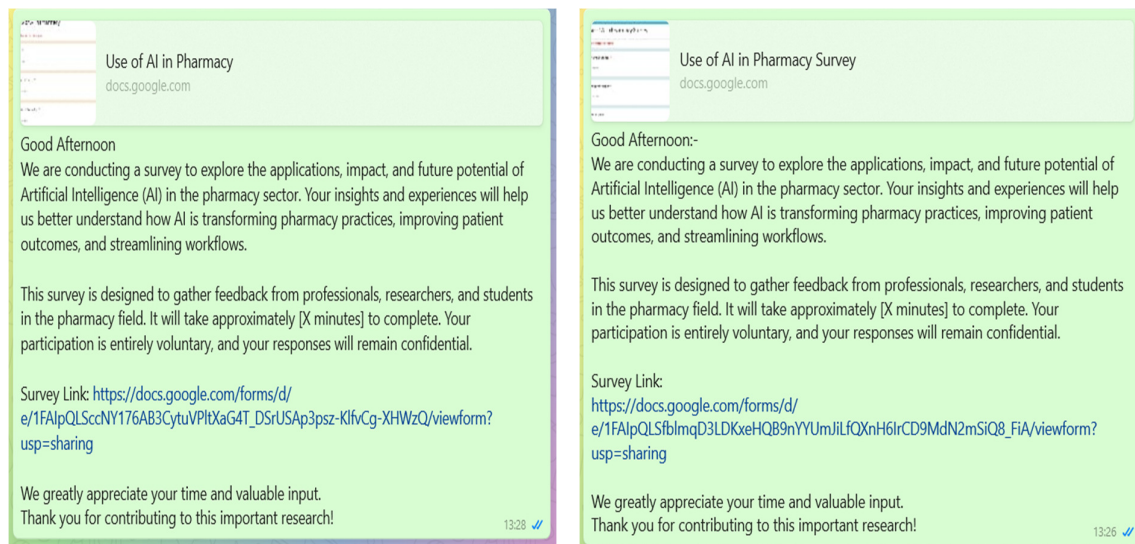
In the pharmaceutical and biotech industries, AI and machine learning are accelerating drug development by expanding the range of compounds available for research and improving patient selection for clinical trials. AI can help detect medication issues early, ensuring safety and effectiveness while reducing costs. The technology is also making advancements in cyborg technology, enhancing the functionality of artificial prosthetics. In space exploration, AI assists in monitoring orbital routes and optimizing launch strategies. Overall, AI has the potential to save lives, reduce expenses, and create innovative solutions across multiple fields, making its adoption crucial for future advancements.³¹

MATERIALS AND METHODS: -

Material	Details
Research Design	Research Approach: Descriptive or exploratory research design to understand The Role of AI in Enhancing Pharmacy Services : A Quantitative Survey Approach
Literature Review Sources	Previous studies, books, articles, and guidelines on Artificial Intelligence were reviewed to validate the survey design.
Survey Questionnaire	A structured questionnaire with a mix of closed and open-ended questions to collect data on Artificial Intelligence used in Pharmacy.
Survey Instrument/Tools	Design of the Survey: Structured questionnaire with a mix of multiple-choice, and open-ended questions focused on Artificial Intelligence used in Pharmacy.
Survey Platform	The online platform (Google Forms, Social Media, Mobile Apps), In-person was used to collect responses.
Sampling Method	Random Sampling or Purposive Sampling based on specific criteria (e.g., teachers, students).
Pilot Testing	A pilot study with a small group of participants to test the survey’s clarity, reliability, and validity before full deployment.
Participants	Target Population: Teachers, students, or educational administrators from specific institutions or programs (B. Pharmacy, M. Pharmacy, D. Pharmacy and Pharm.D.). Sample Size: Number of teacher participants: 30 Number of Students participants: 100 *(justification based on statistical power or population size)
Data Collection	Administer the survey through email, or online, ensuring ethical consent and confidentiality.
Data Analysis Software	<ul style="list-style-type: none"> Quantitative data: Statistical analysis using Excel (e.g., frequency of using specific Artificial Intelligence used in Pharmacy, distribution, percentage calculations were performed) Excel functions like pivot tables, charts, and graphs were used to summarize and visualize the data.
Consent Forms	Informed consent forms for participants, ensuring their voluntary participation and data confidentiality and adherence to ethical research standards.

Tab. No. 1 Materials & Methods

Consent Forms:



SURVEY: -

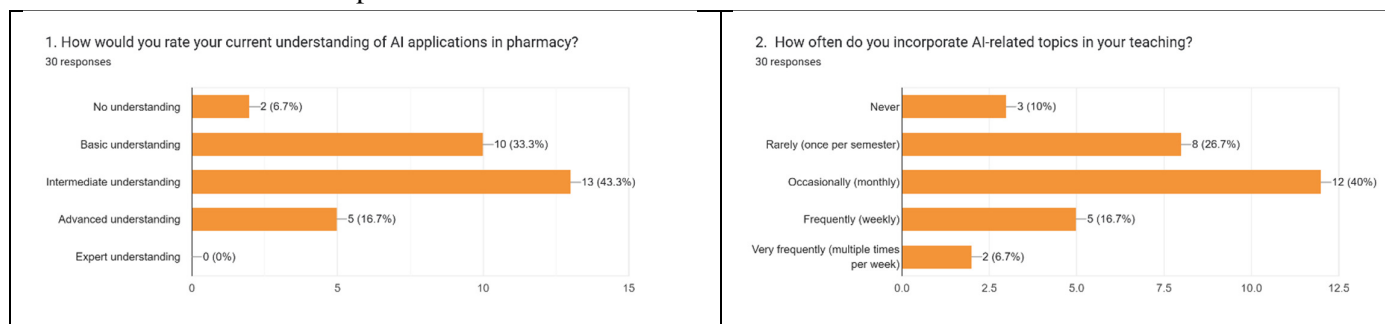
A survey is being conducted to assess the awareness, perceptions, and applications of AI among pharmacy students and faculty. The goal is to evaluate AI knowledge, attitudes toward its integration, and current usage in academic and clinical settings. Insights will help develop educational programs to equip students and faculty with AI skills. Participation will contribute to shaping the future of pharmacy education and practice in the AI era.

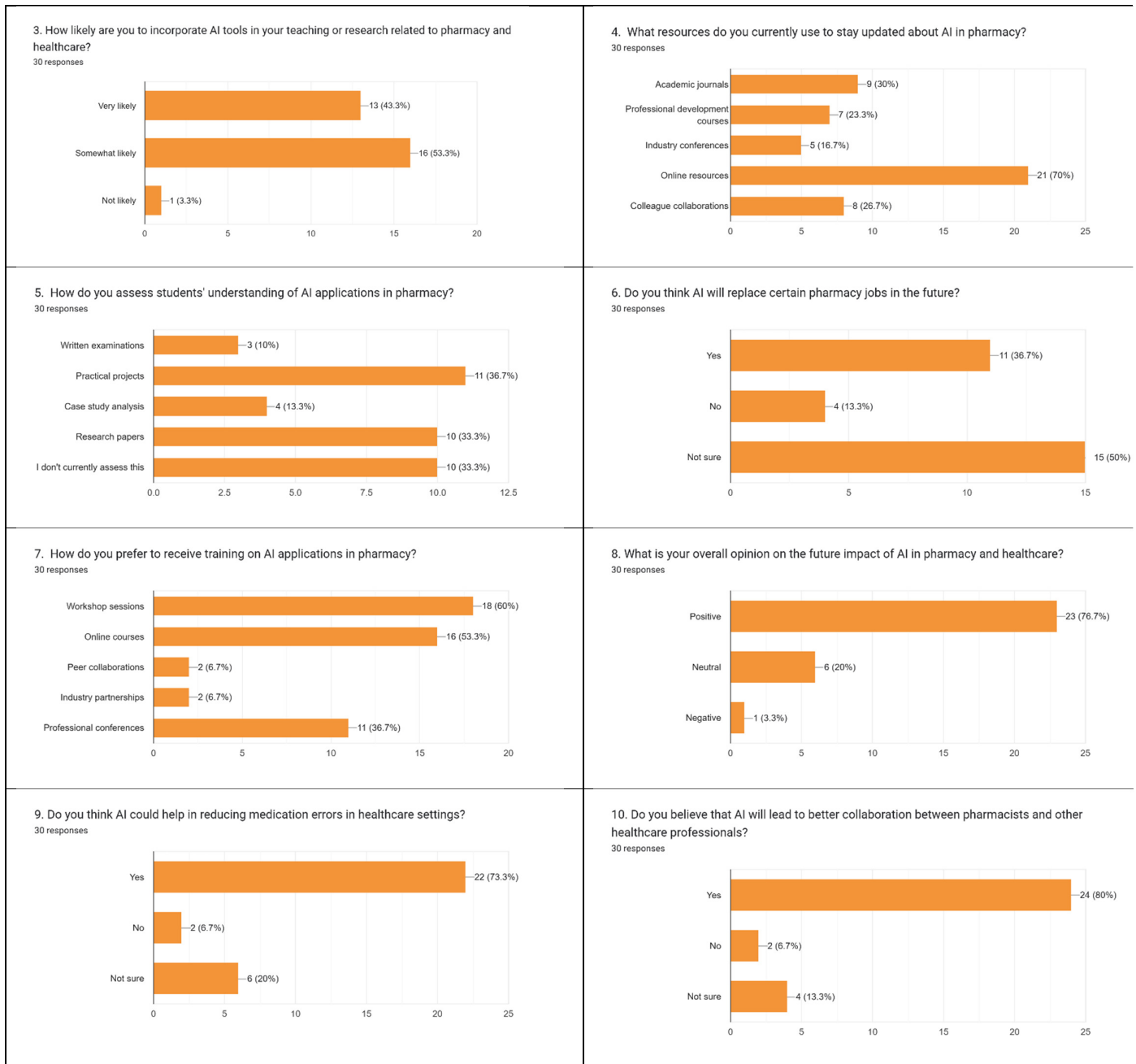
PERCEPTION OF TEACHING PROFESSIONALS ON USE OF AI IN PHARMACY

Pharmacy educators see AI as a transformative tool that enhances learning, research, and pharmaceutical practices. AI optimizes drug discovery, medication management, and clinical decision-making while improving operational efficiency and reducing errors. It enables real-time insights into drug interactions and patient care, fostering a data-driven educational approach. AI also supports personalized learning through interactive simulations and virtual platforms. Additionally, AI-powered telepharmacy and remote consultation tools modernize pharmacy practice. Overall, educators view AI as a catalyst for innovation, improving research, patient safety, and the learning experience.³²

Survey Questions: -

1. How would you rate your current understanding of AI applications in pharmacy?
2. How often do you incorporate AI-related topics in your teaching?
3. How likely are you to incorporate AI tools in your teaching or research related to pharmacy and healthcare?
4. What resources do you currently use to stay updated about AI in pharmacy?
5. How do you assess students' understanding of AI applications in pharmacy?
6. Do you think AI will replace certain pharmacy jobs in the future?
7. How do you prefer to receive training on AI applications in pharmacy?
8. What is your overall opinion on the future impact of AI in pharmacy and healthcare?
9. Do you think AI could help in reducing medication errors in healthcare settings?
10. Do you believe that AI will lead to better collaboration between pharmacists and other healthcare professionals?





Conclusion:

The perception of teaching professionals regarding AI in pharmacy is largely positive, highlighting its potential to revolutionize drug research, patient care, and education. While challenges exist, proactive steps such as AI integration in curricula, ethical considerations, and ongoing training can ensure a smooth transition into an AI-driven pharmaceutical landscape.

The survey on 30 faculty members of various colleges regarding the Perception of Teaching Professionals on the Use of AI in Pharmacy revealed a predominantly positive outlook. Most educators recognize AI's potential to enhance drug discovery, personalized medicine, and pharmacy education. While some express concerns about ethical implications and the need for

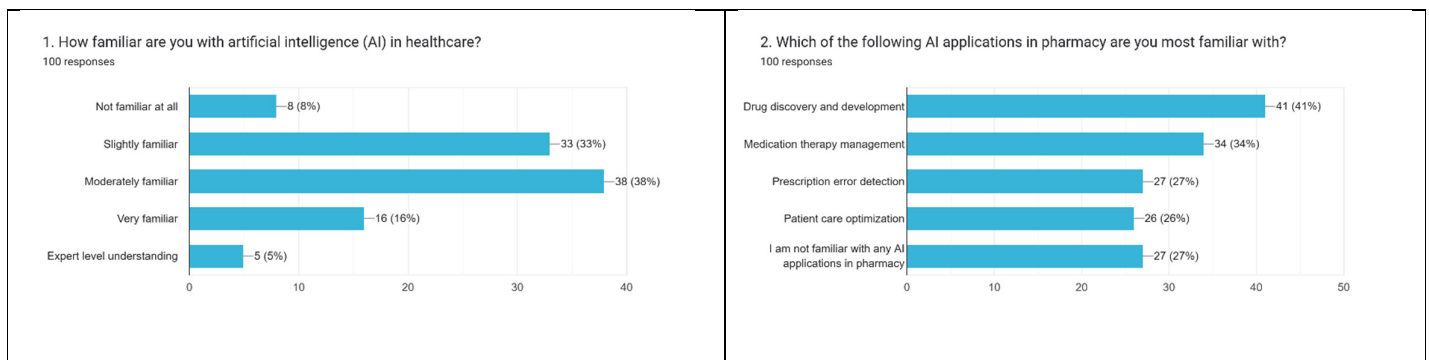
proper training, there is a strong willingness to integrate AI into teaching and research. The findings highlight the importance of continuous professional development and institutional support to maximize AI's benefits while addressing challenges. Embracing AI in pharmacy education can significantly improve learning outcomes and innovation in the field.

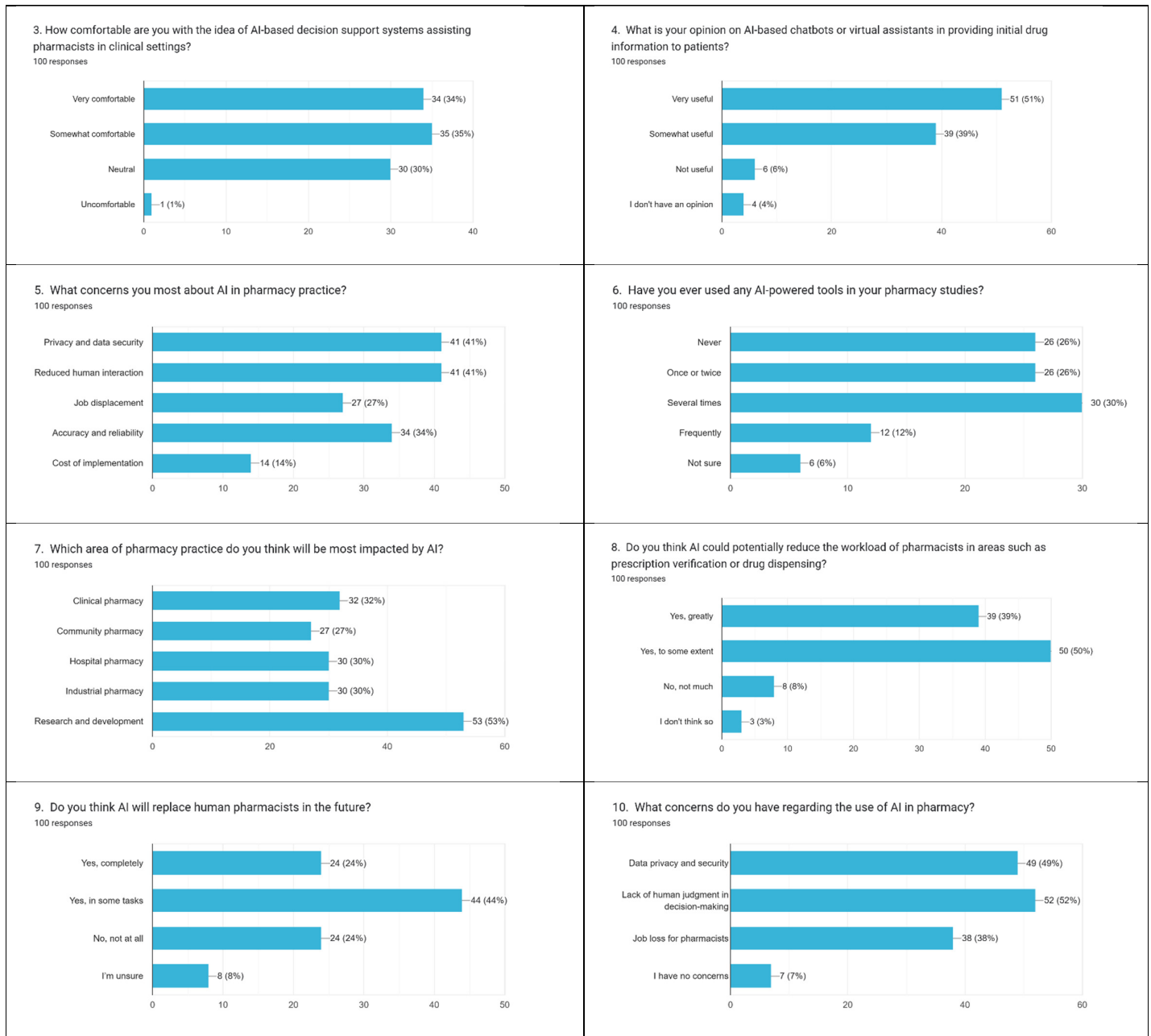
PERCEPTION OF STUDENTS ON USE OF AI IN PHARMACY

Pharmacy students have a highly positive perception of AI, recognizing its potential to revolutionize drug discovery, medication management, and patient care. They appreciate AI's role in automating pharmacy operations, reducing errors, and improving efficiency. AI-powered decision support systems aid pharmacists with real-time insights, while AI in pharmacovigilance enhances drug safety. Students also see AI-driven research and telepharmacy as vital for expanding healthcare access. Overall, they view AI as an innovative tool that enhances pharmacy practice without replacing pharmacists.³³

Survey Questions: -

1. How familiar are you with artificial intelligence (AI) in healthcare?
2. Which of the following AI applications in pharmacy are you most familiar with?
3. How comfortable are you with the idea of AI-based decision support systems assisting pharmacists in clinical settings?
4. What is your opinion on AI-based chatbots or virtual assistants in providing initial drug information to patients?
5. What concerns you most about AI in pharmacy practice?
6. Have you ever used any AI-powered tools in your pharmacy studies?
7. Which area of pharmacy practice do you think will be most impacted by AI?
8. Do you think AI could potentially reduce the workload of pharmacists in areas such as prescription verification or drug dispensing?
9. Do you think AI will replace human pharmacists in the future?
10. What concerns do you have regarding the use of AI in pharmacy?
- 11.





Conclusion:

The perception of students on the use of AI in pharmacy is largely positive, with a strong belief that AI will complement and enhance pharmaceutical practices. AI's contributions to drug discovery, medication management, patient care, and pharmacy operations are widely recognized. While challenges exist, students remain hopeful that AI, when implemented responsibly, will lead to improved healthcare outcomes. Preparing future pharmacists with AI knowledge and skills will ensure a smooth transition into this evolving field, paving the way for a more efficient and patient-centric pharmacy practice.

The survey conducted among 100 pharmacy students of various colleges reveals a largely positive perception of AI in the field. Most students recognize AI's potential to enhance drug

development, patient care, and research efficiency. While some express concerns about ethical implications and reliance on technology, the overall sentiment reflects enthusiasm for AI as a supportive tool rather than a replacement for human expertise. These insights highlight the need for AI-focused education in pharmacy curricula to maximize its benefits while addressing students' concerns.

SURVEY SUMMARY: PERCEPTION OF AI IN PHARMACY

1. Teaching Faculty's Perception

- **Awareness & Knowledge:** Most faculty members are aware of AI applications in pharmacy but vary in their depth of knowledge.
- **Potential Benefits:** They recognize AI's role in drug discovery, personalized medicine, and automating routine tasks like prescription processing.
- **Concerns:** Ethical concerns, data privacy, and the fear of AI replacing human expertise are common apprehensions.
- **Readiness for Integration:** Many faculty members support AI integration in the curriculum but stress the need for proper training and guidelines.³⁴

2. Students' Perception

- **Awareness & Interest:** Students show enthusiasm about AI in pharmacy, though some have limited understanding.
- **Potential Benefits:** They see AI as a tool for improving drug safety, reducing errors, and enhancing clinical decision-making.
- **Concerns:** Fear of AI replacing jobs, lack of human judgment in healthcare, and the need for AI literacy among pharmacy professionals.
- **Future Prospects:** Most students support AI-driven advancements and express interest in learning AI-related skills as part of their education.³⁵

MERIT OF AI TECHNOLOGY:-

- 1) **Error minimization:** AI helps to improve accuracy with more precision and reduce errors. Intelligent robots are dispatched to explore space because they are composed of metal bodies that are resistant to the harsh atmosphere.²²
- 2) **Difficult exploration:** The mining industry demonstrates the value of AI. The field of fuel exploration also makes use of it. Artificial intelligence (AI) technologies can explore the ocean by overcoming human mistake.²³
- 3) **Daily application:** AI is incredibly helpful for our everyday actions. For instance, long drives are a common use for GPS systems. Installing AI on Android devices makes it easier to anticipate what a user will enter. Additionally, it aids with spelling correction.²⁴
- 4) **Medical uses:** Generally speaking, doctors can use AI programs to evaluate patients' conditions and examine the negative effects and additional health hazards of the prescription. Application of AI algorithms, such as different artificial surgical simulators (e.g., brain, heart, and gastrointestinal simulations), can help trainee surgeons learn.²⁵

- 5) **No risk:** Working in hazardous environments, such as fire stations, has a significant danger of harming the staff members involved. Broken elements of the machine learning programs may be repairable in the event of an accident.²⁶
- 6) **Acts as aids:** AI technology has fulfilled a new role by providing round-the-clock assistance to both elderly people and children.
- 7) **Limitless functions:** There are no boundaries for machines. All tasks can be completed more quickly and precisely by emotionless machines than by humans.²⁷

DEMERIT OF AI TECHNOLOGY:-

- 1) **Expensive:** A significant amount of money is spent when AI is introduced. The cost-effectiveness of complex machine design, maintenance, and repair is high. For the R&D section, it takes a long time to design a single AI computer. Regular software updates are necessary for AI machines. The recovery and reinstallation of the machine take a lot of time and money..²⁸
- 2) **No replicating humans:** Artificial intelligence (AI)-enabled robots are thought to possess human-like thought processes and emotionlessness, which improves their ability to complete tasks more precisely and impartially. When new issues emerge, robots are unable to make decisions and report incorrect information.
- 3) **No improvement with experience:** With experience, human resources can be enhanced. On the other hand, AI-powered robots are incapable of learning from their mistakes. It is impossible for them to tell which person is diligent and which is not.²⁹
- 4) **No original creativity:** Artificial intelligence (AI) machines lack emotional intelligence and compassion. People are able to see, hear, feel, and think. They are able to employ both their thoughts and their creativity. The usage of machines cannot provide these features.
- 5) **Unemployment:** Large-scale unemployment could result from the pervasive use of AI technology across all industries. Because of the unfavorable unemployment, human workers may become less creative and productive.

CONCLUSION

The survey conducted among teaching faculty and students successfully highlights the immense potential of AI in pharmacy education and practice. The results reveal a strong awareness and positive reception of AI-driven technologies, with both faculty and students recognizing its transformative role in drug discovery, precision medicine, automated prescription validation, and patient counseling. Faculty members emphasize AI's ability to enhance pharmaceutical research, streamline administrative tasks, and improve medication management, while students express enthusiasm for AI-integrated learning modules and digital tools that offer real-time clinical decision support. The success of the survey also reflects a growing acceptance of AI as a crucial component in modern pharmacy education, with respondents supporting the integration of AI-focused coursework, workshops, and hands-on training programs.

The survey highlights AI's potential to transform pharmacy by improving supply chain management, reducing medication errors, and enabling predictive analytics for disease

management. Despite challenges like ethical concerns and data privacy, there is strong support for AI adoption. Academic institutions should collaborate with industry leaders to develop AI-based curricula and training, ensuring future pharmacists are prepared for the evolving healthcare landscape. Promoting AI literacy will enhance efficiency, accuracy, and innovation in pharmaceutical sciences.

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