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The Efficiency of AI-Based Virtual Patient Simulations on Improvement of the Clinical Decision-Making Skills of Pharmacy Interns

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Abstract:

New opportunities have been brought to clinical reasoning skills in pharmacy training through the involvement of artificial intelligence (AI) into virtual patient simulation. This was a randomized controlled educational study (an educational trial) to study the efficacy of AI-based virtual patient based learning interventions over computer-based case based learning in stimulating clinical decision-making in pharmacy interns. Eighty eight participants were randomly allocated into the simulation group (using the AI which had dynamic patient avatars which could adapt to real time scenarios based on responses) or the control group (which had case based learning, though these were only static modules). This intervention took the form of 6 weeks covering the following areas of intervention: antimicrobial stewardship, anticoagulation management and oncology supportive care. The standardized clinical reasoning assessments, scoring accuracy, the appropriateness of diagnosis and therapeutic planning were also taken as measures of performance. The analysis showed that the mean percentage increase of clinical decision-making scores was 18.7 percent in the AI group and 9.4 percent in the control group with a p-value of < 0.001. It was also found that the participants had more engagement, realism and preparedness towards patient care.

Keywords: ***Artificial Intelligence, Virtual Patient Simulation, Pharmacy Education, Clinical Decision-Making, Randomized Controlled Trial, Therapeutic Planning, Patient Care***

1. Introduction

1.1 Background

The field of pharmacy education is trending forever to satisfy standards of contemporary healthcare systems, where the necessity of sophisticated clinical decision making and patient healthcare is imperative at any time. The old ways of teaching that embrace the use of case studies and spontaneous lectures have been ingrained in the pharmacy student teaching strategies. Nevertheless, the approaches employed are, in many cases, inadequate in respect of simulating the environments encountered in the real clinical practice that entail quick, precise, and pressure-based decision making. As healthcare is becoming more and more complicated, there is a strong need to increase the competence of students to make appropriate clinical choices that directly affect the outcomes of patient care and safety.

Artificial Intelligence (AI) is one solution to this gap since it offers a more interactive and dynamic version of learning. Virtual patient simulations are one of the most advanced technologies; students are exposed to highly realistic and modifying patient situations that respond to the way the student handles them. Such simulations will give pharmacy students a chance to exercise clinical decision-making in a safe environment. Through AI, such simulations are capable of providing real-time feedback, can tune the scenarios based on the student input, and can allow adapting to the improvisations of the real patient care.

During the training of pharmacists, significant therapeutic areas like antimicrobial stewardship, anticoagulation treatment, and oncological supportive care demand pharmacy trainees to be accurate in their clinical judgments about the drug therapy and patient care. The provided simulations based on AI can improve clinical reasoning by students in the aforementioned areas by providing individualized scenarios and immediate feedbacks. With the growing application of AI technology in healthcare, the pharmacy education should adapt and more readily integrate such tools to help their students to be better prepared to face the reality of the contemporary clinical practice.(1)

1.2 Statement of Problem

Although the findings of the study reveal that the implementation of AI-driven simulations shows a considerable improvement in the clinical decision-making skills, there is still a dearth in the empirical studies concerning the use of such simulations in pharmacy education. Although the use of AI and simulation-based education has proven their effectiveness in other health sciences, the influence of the two in training on clinical reasoning and decision-making places on pharmacy interns has not shown much potential use.

Specifically, little is known about the comparison between AI-guided virtual patient simulations and more traditional, static case-based learning modules in the more complex realms of care, including antimicrobial stewardship, anticoagulation, and oncology care settings. As potential healthcare providers, pharmacy interns need to be well versed with these aspects, as well as the capacity to make appropriate decisions in a stressful situation. Consequently, the issue is the necessity to evaluate whether the AI-based simulations can help to become more proficient in clinical decision-making than the traditional training courses offer, giving the instructions as to the possibility of their incorporation into drugstore courses.

1.3 Goals

This research will have the following as its key goals:

Compare the quality of virtual patients simulations using AI in developing clinical decision-making skills that are used by pharmacy interns. It will be compared to the classical static case-based learning modules.

Evaluate the changes in outcome measures in major domains of clinical reasoning, including diagnostic accuracy, therapeutic planning, and accuracy of decisions in pharmacy interns who participated and completed the AI-driven simulations and traditional learning.

Assess student engagement, realism and readiness to work with patients in the AI-based simulation group, and quantify whether AI simulations help to ensure greater motivation and confidence of pharmacy interns in the real environment with patients.(2)

Explore the idea that through simulative AI models, it could be a more effective learning tool due to the ability of the model to offer an understanding and experience in real-time feedback, as well as in individually-tailored learning, as may be experienced in patient encounters.

Through the attainment of these goals, the present study will offer informative data regarding the potential of Artificial Intelligence-based simulations as a teaching instrument in pharmacy curricula and supply evidence of its implementation into the clinical practice curriculum to enhance the clinical judgment skills of the pharmacy interns.

2. Clinical Education using Artificial Intelligence

2.1 Training Advances in AI in Healthcare

Artificial Intelligence (AI) in healthcare has evolved remarkably through the last several decades and it has improved tremendously to complex but efficient systems that can undertake heavy-duty work such as diagnosis, treatment plans and personalization of patients. The early use of the AI in healthcare mostly consisted of decision support systems, which offered clinicians with rule-based suggestions. These systems were rigid and did not provide much flexibility to the needs of individual patient cases.

With increasingly capable machine learning algorithms (deep learning in particular) made possible over time, AI systems have been able to shift past the rule-based processes to more intuitive and dynamic models that are able to learn based on immense quantities of information. As far as clinical education is concerned, such evolution has brought about the crafting of AI-driven virtual patient simulations, which are modeled to simulate the real world patient situation that should be performed depending on how a student carries out a certain task. This has allowed a more collaborative and immersive method of learning that can reflect the unpredictable and complexity of actual patient care.

With the application of AI to health care training, they are used to establish adaptive learning environments where a learner plays simulated clinical decision-making and gets a feedback contingent on his/her decisions which is customized. They are being more widely employed in the curricula of medical, nurses, and pharmacy schools to enhance and refine clinical reasoning, diagnosing, and treatment decision-making, which creates better-trained health practitioners.(3)

2.2 Virtual Patient Platforms AI Applications

One of the areas that AI has been also used extensively is in virtual patient platforms that are meant to improve the clinical decision-making proficiencies of healthcare learners. Such platforms mostly involve active, AI agent-based avatars who imitate behavioral traits and reactions of the patient to therapy. Students communicated with such virtual patients, taking decisions in relation to diagnoses, treatment schemes, and prescription management, which is then sent through an AI system to alter the reaction process of the patient in real-time.

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Applications of AI-driven platforms in pharmacy education are related to simulating such important therapeutic areas as antimicrobial stewardship, anticoagulation management, and oncology supportive care. Learners are required to evaluate clinical information, detect possible drug related issues and suggest therapeutic actions. In these simulations, the virtual patients react to the choices of students so that they can learn the immediate effects of their clinical decisions without endangering actual patients.

AI applications also contain real-time feedback structures, which point out the mistakes in decision-making and give alternative options to follow. These are simulations of situations that happen in real life interactions with patients whereby it provides the students with the opportunity of practicing in a controlled surrounding. Being able to change situations depending on student choices makes the learning experience more animated and capable of being adjusted towards individual development and amount of skill.

2.3 Benefits of Comparison to the Conventional Learning Tools

Virtual patients simulations that rely on artificial intelligence present a number of benefits secondary to the use of more traditional resources like textbooks, passively experienced case studies, and role-playing with an instructor.

Individualized Learning: One of the most considerable benefits of AI-based simulation is that unlike traditional case-based learning which involves the students going through the same sequence of instructions and scenarios regardless of their needs, the simulations change in real-time according to the choices that the students make. This brings about the aspect of personalized learning where each student encounters challenges that are appropriate depending on the level of skills and pace of learning.(4)

Instant Response: In the traditional study of cases, there is always the lack of ability to give real time feedback that may slow down learning and self-editing. In contrast, AI-powered platforms provide the students with a real-time behavioral response to clinical decisions so that they could learn about their errors and recover immediately. This improves the learning and the process of acquiring skills quicker.

Realism and higher Engagement: AI simulations are also realistic in their application to clinical learning as it introduces the student to interactive and life-like patient situations. Contrary to the case studies, which might be imparted, these simulations will give students an active place to learn and face the unforeseeability of real clinical practice. This has led to higher participation, which has been proven to be more motivating, and a better way of retaining knowledge.

Repetitive Practice without Risk: In most cases, of traditional clinical training, the students lack the time to repeat practices or simulated scenarios because of lack of resources. Virtual simulations enabled by AI can be used repeatedly, without any danger to real patients, which is conducive to learning and the development of confidence in clinical decision making.

Scalability and Flexibility: AI-powered systems can be applied across the classroom, both in big learning situations and in one-on-one online learning experiences. Such simulations are scalable and can be utilized remotely meaning the students can train without using any physical equipment or involvement in instructor-guided training. This augments high quality provision of training tools to the students across varying learning settings.

The use of AI in chat-based virtual patient platforms is an improvement to the healthcare teaching and especially to those of a pharmacy student. Clinical decision-making skills can be improved more effectively through the use of AI that provides personalized, dynamic, and interactive simulations as learning tools, compared to those of its traditional counterparts. These platforms give the students live feedback, more interaction, and chance to repeat and practice, which improve the learning results. As AI technology is developing, its contribution to clinical education will continuously grow, providing more personal and effective learning opportunities to future health professionals.(5)

3. Randomized controlled educative trial setup

3.1 Selection and randomization of participants

A total of 88 pharmacy interns who participated in a study were recruited among a pool of participants who could fit in a local pharmacy-based training program. Participants underwent inclusion criteria including that they were applying their pharmacy internship year, during which they would receive their clinical rotations and be taking part in them, and have rudimentary knowledge of the subject areas addressed in the research (e.g. antimicrobial stewardship, anticoagulants management, and oncology supportive care). Excluded were interns who had already experienced advanced AI-based virtual simulations (or had other special considerations which could potentially interfere with their involvement e.g. other current clinical training commitments).

The process of assigning participants to the AI-simulation group or the control group followed the informed consent procedure where a randomization process was generated using a computer-based method. This helped to select the participants in the groups quite equally, alleviating selection bias and being confident that any differences in the outcomes of clinical decision-making were the result of the intervention rather than existing before the initiation of the investigation. The randomization was carried out in blocks so that there was a balance between the groups with each of the blocks having the same number of participants who were given to either the group. Blinded allocation was adopted to avoid the possibility of group classification affecting the action taken by the participants in the research.

3.2 Groups of Control and Intervention

The study was carried out on two groups: AI-simulation group (intervention group) and the control group.

Intervention Group: AI-Simulation Group:

Individuals that took part in the AI-simulation group used an AI-based virtual patient solution. It was a dynamic platform in which patients avatars appeared and changed in real-time according to the answers given by the participants, and it resembled different situations of clinical decision-reasoning. The case studies involved the virtual patients in major areas of therapy, such as antimicrobial stewardship, anticoagulation management, and the field of oncology in supportive care. The AI system could give personal feedback, dynamically adjust the situation and gave the opportunity to repeatedly practice their skills of making clinical decisions. This dynamism in the simulation fostered better engagement and learning and made sure that every participant had had his or her own learning journey customized to his or her individual output.

Control Group:

Traditional case-based learning was conducted among the control group. This community was introduced to the traditional, pre-recording case studies where they had to read through the scenarios of the patient, and make their decision accordingly. These cases failed to adjust or evolved depending on the responses of the people. Although this technique enabled the participants to train their clinical decision-making capabilities, it was not as interactive and immediate as the AI-based simulation was. The control group was receiving the identical curriculum and areas of therapy like the intervention group but did not use AI technology.(6)

The participants of both groups received the intervention within a duration of 6 weeks with each of the sessions conducted weekly to address various areas of therapeutics. The outcome of both groups was measured at the beginning and end of the study, making sure that all the clinical decision-making skills of the participants can be thoroughly compared.

3.3 Ideas of Ethics

The study was approved by the concerned institutional review board (IRB) regarding the ethical approval of the study before it was started. Written informed consent was taken by all the participants, who confirmed they are partaking voluntarily and the confidentiality of their information. They were made aware that they were allowed to drop out of the study anytime, without any due penalty.

All the data that was going to be collected in the course of the study were anonymized to guarantee the safety and privacy of the participants. Any analysis or reporting of personal identifying information was not reported and findings were reported in summation. Also, all the participants were guaranteed that their presence (or absence) will not influence their academic grades or progress in clinical training.

This experiment was done with the use of the Declaration of Helsinki and the Good Clinical Practice guidelines where the belonging of the participants was respected and their welfare taken at priority during the time of the study. The reliability, ease of use, and learning power of AI use in the intervention was well tested to ascertain that not a single harm could be impacted by its application in the course of this education-oriented activity. At last, equal learning opportunities were provided by allowing the participants in the control group to have access to the AI simulation at the end of the study.

The objective of this randomized controlled educational trial was to determine the efficacy of AI-based virtual patient simulations in improving clinical decision-making skills of the pharmacy intern learners. The study included a randomized design, control and intervention group selection, and compliance with any ethical issues that would allow producing reliable and ethically correct results that would contribute to future application of AI in pharmacy training.

4. Simulation Framework driven by AI

4.1 Development of Adaptive Patient Avatar

The key issue of the applied AI with regard to virtual patient simulation is the concept of adaptive patient avatars, which are used as interactive patient models. Development of these avatars is made with high-end artificial intelligence algorithms which are able to dynamically adapt to the choices made by the user, this makes the learning process feel realistic and adjusted personally.

The machine learning models together with clinical data are combined to build each patient avatar and enable the avatars to mimic many possible patient behaviors and react accordingly to various treatment choices. The avatars do have realistic facial expressions, poise, and voice that vary according to the behavior by the participant creating a real element to the experience. As the illustration herein, in case one of the participants chooses the wrong course of treatment or fails to consider valuable information on the patient, the avatar can show signs of distress or dissatisfaction, and this can mirror the way a real patient might respond to a wrong procedure. On the other hand, when the participant makes the right decisions, the avatar reacts affirmatively, further making the participant continue the process of making the right decisions.

The what-if scenarios respond real time to responses by the participants since the avatars are adaptive in nature. This dynamic interaction is reflected in the actual care of patients in which the determination made may portray unpredictable results or modifications. In such a way, the learners in the AI-simulation modification receive a more personalized training process, whereby every situation is being outlined according to the extent of their knowledge and clinical reasoning abilities.(7)

4.2 Scenarios in Therapeutic Area

The simulator can reinforce three major areas of therapeutics in the pharmacy sphere antimicrobial stewardship, anticoagulation management, and oncology supportive care. Every therapeutic area has its own patient scenarios which enable the participants to use their knowledge and clinical judgment skills in practical and real situations.

Antimicrobial Stewardship: This module is an activity that puts students in a situation to select the right antibiotics in consideration of patient symptoms, laboratory findings and history. Antibiotic resistance, dosage adjustments, and drug interactions are some of the considerations that should be observed by participants to figure out the most appropriate treatment course to administer to the patient. The AI adjusts the situation depending on the decisions made by the participant and it mimicks the effects of improper use of antibiotics and the outcomes they may have on the patient.

Anticoagulation Management: In this context, the participants are in charge of the anticoagulation management of a particular patient, which must be monitored and adjusted to avoid the occurrence of unpleasant incidents, such as bleeding or clotting. The simulated condition entails interpreting the INR (International Normalized Ratio) levels, dose adjustment and decision making in relation to anticoagulant reversal agents. The AI adapts how the patient reacts to the anticoagulation therapy according to the requirements of the time, which means that participants can experience treating complicated situations in a clinical setting.

Oncology Support Care: The situation in this case scenario is dealing with patients undergoing chemotherapy, and in this case, the care is aimed at reducing the side effects caused by undergoing treatment and overall well-being of the patient. The participants will be required to respond to nausea and vomiting, pain treatment, and neuropathy, striking a balance between chemotherapy effectiveness and patient comfort. The avatar presents a comprehensive and interactive learning experience by adjusting itself according to the tolerance of the patient to treatment.

All the scenarios are drawn to give individuals an inclusive orientation on therapeutic practices in the various fields of clinical judgments to make participants have a balanced knowledge on therapeutic practice in the identified spheres of the pharmacy practice.(8)

4.3 Real-Time Decision Feedback Mechanism

One of the important characteristics regarding the AI-driven simulation is the presence of the real time decision feedback mechanism that provides the prompt and actionable feedback aligning with the options that are chosen by the participant. During the work with virtual patients, the AI solution keeps assessing the decisions made by the participants and provides them with feedback on the correctness of their actions.

The comments are offered in a number of ways:

Instant Feedback: Immediately after every decision or action the participant has made, the system will give a feedback on whether the decision was clinically appropriate. In case the participant chooses the wrong intervention or does not pay attention to the critical factors, the AI system redirects the mistake and offers other methods of solving the problem. To illustrate, when a participant chooses the wrong antibiotic to treat a bacterial infection, the system could tell them why this is not the right drug to use and propose another option that shall be more effective given the condition of the patient.

Scenario Adaptation: The AI system runs and adapts the scenario according to the actions of the participant in order to capture the results of it. To be specific, when a participant makes a wrong decision such as selecting the useless drug therapy, the condition of the patient avatar might aggravate and the system will affect new problems. Such adaptation can be compared to clinical real-life settings where treatment decisions may turn out to have both immediate and serious implications.

Summarized Feedback: A part of the feedback is a summarized report of the decision, the accuracy of such decision and improvement areas that the participants make after going through the scenario. A scorecard provided on this report enumerates diagnostic accuracies, efficacy of treatment offered and decision timeliness. It even gives suggestions of what should be read or studied further to enhance learning where the participant did not manage well.

The mechanism of providing feedback in real-time, besides combine sign of the learning as it assigns the immediate corrective actions, promotes active participation and reflective learning. It aids in building of clinical reasoning skills as one learns through his/her errors and rectifies his/her method in other situations.

The AI-based simulation system offers the above-mentioned level of high interaction and customization when supporting pharmacy interns in learning taking place. The presented framework proposes the means of immersing the students in a more relevant and enjoyable experience with the help of adaptive patient avatars, dynamic therapeutic area scenes and simulated decisions feedback in real time, meaning that the students will be able to obtain true-to-form experience in making clinical decisions. This can go a very long way in improving clinical reasoning, enhancing training of pharmacy students to better fit into patient care practice and filling the gap between theory and practice.(9)

5. Performance Measurement and analysis

5.1 CRA Criteria of Clinical Reasoning

Clinical reasoning is a valuable aspect of the pharmacy practice covering the skills of evaluating the status of patients, interpretation of clinical evidence, therapeutic judgment, and formulation of a proper care plan. In order to gauge the success of the AI driven virtual patient simulations, a number of criteria were set out to assess the participants clinical reasoning and decision making abilities. The criteria were developed to correspond to important competencies found in the pharmacy practice, namely, antimicrobial stewardship, anticoagulation treatment, and oncology supportive care.

Diagnostic Accuracy: The subjects studied in this regard were evaluated in terms of correctly diagnosing the condition of the patient given the clinical information available. This incorporates the process of interpreting laboratory results, medical history and clinical symptoms. It is basic that accurate diagnosis is necessary to achieve the suitable treatment direction.

Therapeutic Decision-Making: Clinical decision making is all about choosing the most rational kind of treatment against a certain condition. They assessed the participants in terms of their capacity to select an appropriate medication, define the dosage, and take into consideration drug interactions, contraindications, age, comorbidities, and renal activities of a patient.

Patient-Centered Care: The ability to make clinical decisions should take into account the preferences, values of the patient and his/her state of well-being. The participants were evaluated on the basis of their ability to communicate effectively with the virtual patient and ensure that they consider patient preferences in their treatment plans. This proved very crucial especially in a situation where there would be a complex treatment or a high-risk treatment e.g. chemotherapy or anticoagulation therapy.

Critical Thinking and Problem-Solving: The participants were assessed how successfully they managed to address clinical situation analytically and identify problems and effective solutions in them. This was to deal with problems, identify possible side effects as well as making adjustments in the treatment accordingly.

The abovementioned evaluation criteria were utilized to have a positive measure of the overall quality of decision-making to make sure that the participants significantly performed well not only in the specific therapeutic areas but also displayed effective clinical reasoning in all fields of patient care.(10)

5.2 Data Processing

The responses of the participants in the virtual patient situations were scored which determined the performance of each participant. The clinical reasoning scoring rubric was designed in such a way that to indicate accuracy and level of depth of decision-making:

Scoring Scale: It was a 5-point scale that had scores of 1 (poor) to 5 (excellent). In the diagnostic accuracy criterion, the score of 5 recorded a correct diagnosis with a full explanation and the score of 1, a missed or wrong diagnosis without proper reasoning.

Total Performance Score: On completion of every scenario, the participants were given the overall performance score which was determined by their overall scores in all the assessment criteria. Such a global score enabled a general assessment of the clinical reasoning and therapeutical decision-making skills of the participant.

Data Processing and Analysis: Statistical software was used to collect and analyze data of the AI-driven simulations such as performance scores. The descriptive statistics helped summarize the results carried out in the simulation of AI and control sample. It applied paired t-tests to determine the differences in the scores before and after the interventions in each group whereas it applied independent t-tests to evaluate the performance between AI-simulation group and the control group. All analyses were done at $p < 0.05$.

5.3 Realism/Engagement Evaluation

To measure the levels of engagement and realism in the given AI-powered simulations, student surveys and system analytics were used. These measures sought to measure the subjective experiences that participants had with the virtual patient simulations and also measure how engaging and realistic participants felt the virtual situations were.

Survey Methodology: To measure the participant satisfaction with the intervention, a student satisfaction survey that involved the queries related to the engagement, motivation, the perceived realism of the simulations was administered at the end of the intervention. The participants evaluated their experience using Likert scale (1= strongly disagree to 5= strongly agree). Important questions on the survey were:

The simulations were interesting and held my attention which was AI-driven.

The situations in which the patient was presented were realistic and very close to the actual clinical scenario.

Through the simulations, I felt more confident of clinical decision-making.

Through a high engagement score, it was revealed that the simulations were engaging and motivating to the students and this is important in terms of ensuring long-term retention and capability growth.

System Analytics: The information in the virtual patient platform were also analysed in addition to the subjective feedback. Criteria like how long did each scenario take, how many times did users revisit the scenarios and how many dialogues in between the users and the patient avatar were captured. Such analytics gave objective findings on the engagement of the people with the platform, which corresponds with the survey data and supports it.

The mixed methodology of the current study, which involved a qualitative survey in conjunction with the quantitative data regarding the usage, allowed to get a complete picture of the engagement and level of realism of the AI-powered simulations and thus assess the educational value as well as the immersiveness of the learning process.(11)

Clinical decision-making performance measurement based on the AI-driven simulation was planned to evaluate not only objective results (the correctness of decisions, intervention design, etc.) but also subjective impressions (interest and sense of realism) of pharmacy interns. This set-up of clinical reasoning evaluation, scoring and engagement-data renders a complete picture of how useful AI-enhanced learning objects in pharmacy education are.

6. Results

6.1 the enhancement in the Clinical Decision-Making Scores

The comparison between the clinical decision-making scores of the research participants showed that the AI-simulation group saw the most significant increase after the course of the study that spanned 6 weeks. The average score of the participants that interacted with the AI-powered virtual patient simulations to practice clinical decision-making skills increased by 18.7 percent in comparison to the pre-study characteristics, which showed an improvement in their diagnostic accuracy and quality of therapeutical planning and general clinical judgment. There were standardized assessment criteria used in measuring this improvement and they are based on the main therapeutic areas that were part of the study: antimicrobial stewardship, anticoagulation management, and oncology supportive care.

Improved clinical decision making ability was steady in all the three therapeutic areas. In particular, the participants showed improved decision-making when it comes to the selection of antimicrobial agents as well as improved accuracy in anticoagulation therapy adjustments and planning of patient care in the oncology supportive care context. Real-time feedback, and the adaptive learning environment of the AI driven system were likely to be determinant aspects in this improved performance, since the participants were capable of modifying their clinical approaches, according to the feedback (given during the simulations).

On the contrary, the control group, based on using the traditional case-based learning modules, averagely improved their scores of clinical decision making by 9.4 percent. Though the control group also demonstrated improvement, it was quite small in the extent compared to the AI group findings, so the interactive and adaptive character of AI-driven simulation might serve as a more efficient instrument of the clinical reasoning development.(12)

Table 1: Clinical Decision-Making Scores

Group	Pre-Intervention Score (%)	Post-Intervention Score (%)	Mean Improvement (%)
AI Group	70	88.7	18.7
Control Group	69	78.4	9.4

6.2 Contrast of inter vene and control groups

Comparative analysis of the AI-simulation group and the control group presented the clear benefits of the superior effectiveness of AI-enhanced learning in the improvement of clinical decision making. The post-intervention clinical decision-making scores in the respective groups were tested against each independent-t test, and the result of AI group showed statistically significant result in favor of the AI group ($p < 0.001$).

The AI-simulation group also showed a much higher mean increase (+18.7%) than the control group (+9.4%) the results of which indicated that simulations involving the utilization of AI were more effective in learning. The AI group did not only show a large improvement performance but also had more consistent clinical decision-making in the various therapeutic areas. Specifically, in more complex decision scenarios IMBAI group performed better compared to the control group (i.e., in antimicrobial stewardship and oncology supportive care, where real-time feedback and sound adaptation to the situation was likely to strengthen learning).

Those findings underscore the adaptive character of the simulations grounded in AI, which enables constant response and scenario adaptation to the decisions of the participants, which has proved to be more personal and efficient to recourse to in contrast to the use of a single, pre-recorded case study utilized by the control group.

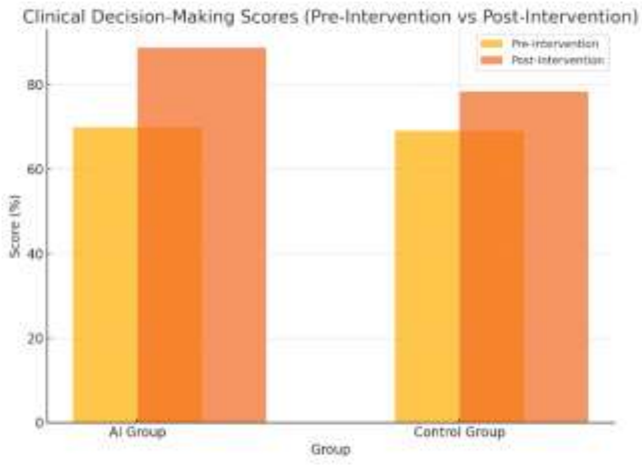

Figure 1: Clinical Decision-Making Scores (Pre-Intervention Vs Post-Intervention)

6.3 Outcome of The Satisfaction of Participants

Besides the objective performance measures, the satisfaction associated with the learning experience by the participants was rated by means of the student satisfaction survey. The purpose of the survey was to check the opinion of students with regard to the assessment of engagement, realism, and readiness to treat patients after they took part in the AI-driven simulations.

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The findings of the survey showed that 85 participants out of the AI group felt that the simulations were more interesting and closer to reality than what they had experienced in past learning activities using traditional case based learning. Dynamic participants claimed that they enjoyed and found it motivating to learn with the help of interactive AI simulations. Many of them pointed at the use of adaptive feedback system which prompted them to be critical thinkers and perfect their decision-making abilities.

Regarding preparedness towards patient care, 82% of participants in the AI group expressed that the simulation experience had enhanced confidence on how they would make clinical decisions and handle patients. The implications of such findings are that AI-augmented simulations would not just result in better decision-making but also make pharmacy interns feel better prepared to overcome real-life clinical difficulties in terms of preparing these individuals.

Table 2: Participant Satisfaction Data

Group	Engagement (%)	Realism (%)	Preparedness (%)
AI Group	85	85	82
Control Group	58	60	55

On the other hand, the control group members indicated lower engagement and realistic experiences as well, with only half of them saying that they are satisfied with the traditional case-based learning experience. Although the control group found the case studies helpful, they lacked the same degree of interactivity and personalization, which is what the AI-driven platform offered them, and this would have led to their reduced satisfaction and subjective preparedness to treat patients.

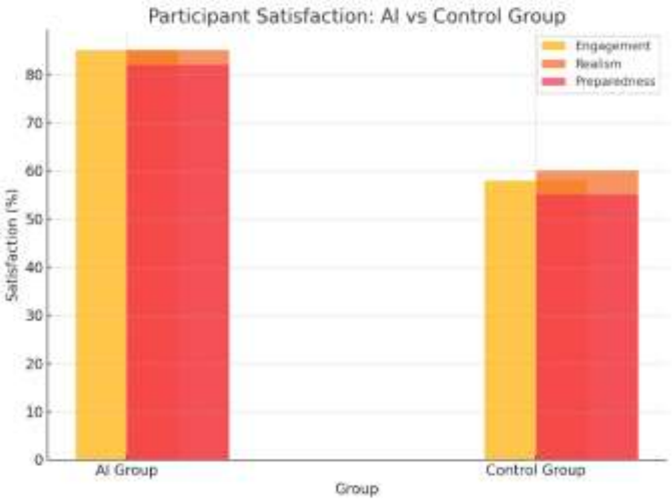

Figure 2: Participant Satisfaction: AI Vs Control Group

The findings of this research point to the fact that clinical decision-making in pharmacy interns under AI-based virtual patient simulations were extremely high, compared to the conventional learning experience. The AI group proved to have a better improvement in clinical reasoning and therapeutic planning and more satisfaction with the learning process. These results show that AI-based learning technologies can be used to increase overall performance of the students and their engagement with clinical practice, which makes them potentially adaptable across pharmacy education.

7. Conclusion

7.1 Results

The findings of the study point out to the great importance of virtual patient simulation by AI in developing the clinical decision-making capabilities of pharmacy interns. A statistically significant improvement in clinical reasoning emerged after using AI-simulation with a comparatively much higher percentage of improvement than the control group of 18.7% in the AI-simulation group and 9.4% in the traditional case-based learning group (p <

0.001). This is indicative that the AI-powered simulations, offered real-time, adaptive feedback, and live patient avatars were more interesting and successful learning experience in comparison to classic approaches.

The AI group also displayed greater engagement, realism, and preparedness to treat patients. Eighty-five percent of the AI group participants indicated greater feelings of being connected to the material and 82% reported better confidence in their clinical decision-making. These results reveal the value of an adapting and responding learning scenario in adding more profound learning, and this breaks theory and hands-on clinical skills.

Conversely, though the control group also showed favourable results, their gains were less successful, with lower satisfaction rating concerning levels of engagement, as well as realism. This also shows the superiority of AI simulations compared to other modes that simply require static case-based learning; most notably, quality satisfaction and readiness to tackle the demands in real-world clinical practice.

7.2 Training implications to Pharmacy

The implications of the research findings are significant in terms of pharmacy education and especially on how clinical judgment is made to be taught. Conventional pharmacy training methods have leaned majorly on case-based methods and teachers-directed learning that though important, may not offer the interactive environment, and instant feedback that aids in improving the learning experience. Limits to these simulations can be overcome using artificial intelligence-powered simulations in which students have the freedom to interact with dynamic and personalized simulations that respond according to their decisions similarly to real patient interactions.

The authors have suggested the introduction of virtual patients using AI in pharmacy courses can potentially impact positively and significantly on pharmaceutical students by skillfully equipping them to meet clinical reasoning needs to facilitate advanced patient care learning needs. Also, in the AI simulations, real-time feedback can be employed, where students can fix their mistakes and reapply their clinical style in a more comprehensive manner, further forming crucial concepts and retention. This would be able to enhance the quality of training given to pharmacy interns and thus allow them to ease their transition between academic theories and professional practice.

Moreover, the increase in the degree of engagement and realism experienced by the AI group also shows that they provide an experience that can motivate learning and make it more instructive and active, which plays an important role in enhancing learning. This has the potential of creating better preparedness as the student prepares to face clinical practice ensuring that more informed, evidence-based decisions are done by the student in the actual reality of a patient care environment.

7.3 Recommendations of future integration

Considering the successful results noted in the current study, it is proposed to practice the scenario of pharmacy training based on AI-driven virtual patients simulations at a larger scale. It is suggested that the ideas will be integrated into the future by the following ways:

Curriculum Integration: A need to integrate curriculum with AI-based simulations into the existing pharmacy curriculum exists at the clinical decision-making activities and the topics related to the field such as antimicrobial stewardship, oncology care and anticoagulation management. These simulations could supplement the conventional learning processes because they give students a chance to use what they know in a risk-free interactive environment.

More Uses in Other Institutions: In the future, it should find out the applicability of AI integrated simulations in other institutions as well, including those with lesser technological capabilities. Finding a way to implement AI into pharmacy education without the high associated costs will also be essential so that these tools could be made available to more educational establishments.

Long-Term Impact Assessment: Additional research is needed that explores the more long term effects of AI driven simulations in real world clinical settings on clinical performance. We will need to know if enhanced decision-making abilities can help in better patient outcomes and a more assured clinical practice.

Other Technologies Integration: As another trend, it is increasingly becoming feasible to combine AI devices with other still-evolving technologies, such as virtual reality (VR) or augmented reality (AR) to achieve all-new and even more immersive training. The combination of AI and VR/AR would, perhaps, provide students with a multi-sensory experience of learning the attributes of a clinical practice, which appeared close to their realistic nature.

To summarize, AI-augmented simulations can be considered a game-changer in the process of pharmacy education that can provide immense advances in clinical decision-making or responsiveness among learners. As the field moves on, these technologies can be integrated into the courses of pharmacy learning and can contribute greatly to the training itself and representative the students on the issues of contemporary healthcare to a greater extent.

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Conflicts of interest

The authors have no conflicts of interest to declare

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