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A Multi-Center Evaluation of Integrating Augmented Reality into Clinical Skills Training of Pharmacy Students

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Abstract:
AR in medicine has become an effective healthcare educational tool because it presented the ability to give interactive in-time superimposition of clinical information during simulated training. It is a multi-center prospective intervention study into the effect of AR-based training modules upon clinical skill development of fourth-year pharmacy students. The participants of the study (3 universities of Slovenia, Saudi Arabia and Malaysia) involved in it were 120 people who participated in simulations on mandatory interventions, via AR, in patient counseling, preparing intravenous injections, and recognition of adverse events. The Objective Structured Clinical Examinations (OSCEs) were used to measure skills, prior and after the intervention. The mean improvement between the AR and traditional simulation training (20.1 versus 11.3 percent, p < 0.001) was more vast in the AR group which over-performed in the OSCE performance scores. According to the student satisfaction surveys, AR enhanced interaction, immersion, and application of knowledge at the clinical setting. The results are deemed consistent in the inclusion of AR in the pharmacy curriculum in order to promote experiential development and facilitate the preparation of students to professional practice.

Keywords: ***Augmented Reality, Teaching LES pharmacy, skills training, OSC MUST INTERATOR, Simulation, SET effet gure, PLACE LAURIN learning, experiential LEARNING***

1. Introduction

1.1 Background

Pharmacy education is a dynamic and quickly changing field with growing focus being put on training pharmacy students to deal with more complicated, real-life healthcare situations. There are limitations of historical approaches to clinical skills learning that include role plays, theoretical learning, and practical practise which face the drawback of both realism and student interest. With the increased sophistication of healthcare systems, pharmacy education is increasingly in demand to be sourced with an augmented need to include emerging technologies to more adequately simulate clinical settings and allow a higher quality of learning.

AR is also a revolutionary technology in learning institutions especially in the healthcare sector. AR can be used to overlay interactive, and real-time digital content onto the real world to provide an immersive real-life learning experience that can simulate real clinical activities. To the student of pharmacy, this may translate to an opportunity to practice patient counseling, IV drug preparation, and the identification of adverse events within a virtual environment free of any risk. Therefore, AR can be considered a prospective direction of enhancing clinical skills perfection and enriching an experience.

Pharmacy education regarding theoretical teaching and practical training through laboratories with controlled conditions served well over the years. Nevertheless, these types of approaches might not comprehensively eliminate the intricacy of clinical implication whereby students are expected to balance between the aforementioned constructs of knowledge application, critical thinking, and interactional skills with the patients. The use of AR can even offer students a more entertaining and active form of practicing these vital abilities, therefore, making them better prepared to practice professionally. The AR technology can change the way pharmacy education is practiced and experienced, by placing the students in simulated clinical settings.(1)

1.2 Reason to undertake the study

Although the possibilities of AR in education are well recognized, its use in training pharmacy students has been quite unexplored. Development of clinical skills in pharmacy studies is one area where theoretical knowledge is not enough and real-life practice of such knowledge must be gained. Established training theories, like Objective Structured Clinical Examinations (OSCEs), teach the most through direct practice; however, fail to recreate the just-in-time, interactive nature of training that AR has the potential to bring.

AR can fill the gap by providing highly realistic interactive simulations in which the students can train their skills in applying clinical practices (e.g., when a student can train his or her skills in counseling patients or preparing medication in a clinical setting without a potential risk it implies in real life). Moreover, the AR technology will be able to deliver the instant feedback, and students could learn to act according to their mistakes in a safe setting. There is a gap and paucity of empirical data on the efficacy of AR when it comes to helping clinical skills acquisition among pharmacy students in particular. This research paper aims to fill this gap by determining how AR-based training can promote the acquisition of clinical skills in Tralhex-in-training students in Slovenia via multiple institutions in Slovenia, Saudi Arabia, and Malaysia.

In addition, this study is multi-centered, which gives a chance to examine the viability and effectiveness of AR-based training in dissimilar educational settings and cultures. The importance of the wider acceptance and assimilation of AR in pharmacy curricula across multiple environments will be to learn how AR should be adapted to it(2)

1.3 Goals

The two main purposes of this study include the following:

- To determine the efficacy of AR-based training modules in improving the pharmacy learners clinical skills especially inclusion of patient counseling, intravenous preparation of medication and recognition of adverse events.
- To compare the performance of the AR based on simulations to their counterparts who hold traditional simulations based training as measured through the Objective Structured Clinical Exams (OSCEs).
- To determine how students thought regarding AR concerning engagement, realism, and the role of this technology in knowledge use in clinical practice.
- Evaluate the possible ways of implementing AR technology in pharmacy curricula in various learning environments such as universities in Slovenia, Saudi Arabia, and Malaysia and determine the ways this technology can be modified to suit various students.

The findings of this research will shed light on the place of AR in pharmacy education, at least in developing clinical skills, and the findings can be the underlying basis of employing AR in the curricula at a broader level. With the current success, the application of AR may considerably intensify the notion of experiential learning and equip the students better with the real-world pharmacy practice complexity.

2. Augmented Reality in Pharmacy Education

2.1 AR Technology and Development

In recent years, augmented reality (AR) has experienced massive developments with changes in hardware, software, and capacity to present interaction experiences. Previous AR systems depended on large hardware implementation, but nowadays, thanks to the popularity of mobile devices, tablets, and wearable technologies (smart glasses), AR is easier to carry around, more effective, and more accessible to education. Real time simulations Technology advances have given rise to augmented reality1 platforms that augment the real world of a student with digital information to provide the student with a really immersive experience.

These technological innovations have effective use of AR that can be used in teaching pharmacy that would train clinical skills. The application of AR technologies makes it possible to recreate life-like drug preparation conditions, communicate with patients and clinical settings, which are essential aspects in building practical competence in students. Also, the training based on AR provides immediate feedback enabling students to understand whether their choices or actions are correct or not in a real-time environment. This technology also has the capacity to incorporate voice commands and gestures to make it all hands-on, interactive unlike the traditional learning aids.

The increased availability and complexity of AR technologies have built a basis on which AR could be incorporated in pharmacy education and AR may transform how clinical skills are imparted in the domain. AR can support experiential learning by delivering immersive and dynamic simulations to create a more engaging and effective experience, offering pharmacy students a chance to develop their skills.(3)

2.2 Past Applications of Health Training

A wide range of applications has been made possible through AR in healthcare training, and this proves that it could be effective in skill-based learning in complex areas. AR has also found application in medical education where it could simulate surgical procedures, diagnostic solutions, and patient encounters so that the students could get to exercise some of the important skills without maiming real subjects. As an example, AR has been utilised in the teaching of anatomy where one can see the 3D version of the organs on the human body superimposed on the real world. In the same way, AR has found application in simulating medical practice thereby providing the students with a low risk and controlled practice field.

According to the applications in pharmacy education, AR applications have mainly concentrated on enhancing patient counseling, drug preparation procedures and clinical decision making. In other works, AR modules have been used to replicate a patient visit where students visit and are able to practice communication and decision-making abilities in realistic scenarios and time-limited situations using virtual patients. Furthermore, AR has been used to train students in preparing intravenous medications in which, in-real time visual indicators and information overlay direct the students through the preparation process thus leading to fewer mistakes and better competency.

The emergent literature on AR-based interventions in healthcare training shows that it has the potential to greatly improve engagement, motivation and learning results by offering a more interactive and immersive experience to the students than other learning systems. This is especially significant when it comes to such a domain as pharmacy, where practitioners should acquire crucial skills rather meticulously and carefully.

2.3 Premises in Existing Research

Although the use of AR in health care training, such as pharmacy education has a positive outlook, there are a few gaps that are yet to be fulfilled by available literature. A key gap is that little empirical evidence exists on the particular effect of AR on clinical skills development in pharmacy students. Although research has been conducted in utilizing AR in theory learning and introductory training on simple skills, little research has been conducted on how AR works in real world and high stakes clinical practice scenarios such as patient counseling and medication preparation. Besides, no research compares AR-based training to the traditional one regarding the specifics of AR on long-term skills retention and willingness of students to use these skills in clinical practice.

The second gap surrounds how to rival the feasibility and the economic affordability to apply AR in various educational contexts, such as institutions with less resourcefulness. Although AR has apparently shown promise in institutions with well-established funding and technological infrastructure, there is a need to unravel how AR may be scaled and tweaked to suit varying teaching and learning environments, with the case of developing countries being well-placed.(4)

Finally, AR applications in the pharmacy education need to be standardized. Since AR is rather a novel technology, there is no unification regarding the content, design, and user experience of its applications. There should be research conducted to establish protocol in coming up with an effective, interactive, and accessible training module based on AR that can be applied by pharmacy students globally.

The research on the use of AR in healthcare education proves that it has a great potential in enhancing clinical skills education in pharmacy profession. Although recent technological progress has allowed making AR much friendlier and feasible, a number of research gaps can still be identified, namely, its effect on clinical skills acquisition and comparison to the traditional delivery methods. Fill-ins of these gaps will be essential to integrate AR into pharmacy curriculums in full capacity and utilizing its potential as an eye-opening means of education.

3. Research design and Setting

3.1 Multi-Center Framework

The proposed study has a multi-center prospective intervention design, which includes three universities that are located in Slovenia, Saudi Arabia, and Malaysia. The multi-center structure will enable evaluation of the effectiveness and feasibility of augmented reality (AR) based clinical skills training with a better scope in several cultural and learning environments. To offer a deeper insight into how integration of AR can be carried out in pharmacy education, on an international level, this paper aims at including more than one institution in the research process.

Multiple-center approach has some important benefits. To begin with, it also improves generalizability of the study findings, since the findings will be made on the basis of data obtained using a varied sample of pharmacy students in different geographical areas. To better capture some of the cultural and institutional differences that may affect the uptake and success of AR based training, this strategy will be used. Second, it will enable a comparison between AR interventions occurring in various educational settings, which would be an important source of information on how AR can be adjusted to fit into the particular contexts of various schools.

The same training modules based on AR were applied in each university participating in the scope of the study. Such modules were created in order to cover clinical situations, like counseling of a patient, preparation of the intravenous medication, and detection of adverse events. The standardization of the intervention across the centers made it interesting to compare the groups and institutions and to make the study results stronger and more reliable.(5)

3.2 Criteria in Selecting Institution

The choice of the institutions to be involved in the study was made using certain criteria to achieve the understanding that universities participating in the study would have materials and motivation to apply the AR-based training intervention effectively. The most important selection criteria were as follows:

Accredited Pharmacy Programs: The schools selected to undertake the study had to have the accredited pharmacy programs by meeting required national or regional standards of pharmacists education and training. Accreditation was also the guarantee that the universities possessed the framework capable of sustaining the requirements of the AR technology and clinical acs training.

Technological Capacity: Each university was required to prove that there would be an adequate level of technological infrastructure to use AR-based learning efficiently. It meant that one had to have access to the required hardware (e.g., AR devices, tablets, or smart glasses) and software platforms, which can present the AR simulations. Also, the flow of AR modules required reliable internet connectivity within institutes.

Faculty Support: Universities were chosen depending on the availability of faculty members who were ready and capable of incorporating the use of AR technology into their teaching methodologies. The involvement of faculty members was imperative in the success of the study because the instructors had to acquaint themselves with the AR tools and also to guide the students in effective utilization of the tools.

Student Population Diversity: The institutions selected in this research had varying student population thus the study was able to evaluate the implications of the implementation of an AR-based training to different cultural and teaching based environments. This heterogeneity gave space to examine the suggestion of the use of AR in various settings and promote the generalizability of the results.

3.3 Participant recruitment

The population that was used in the study is fourth-year pharmacy students selected across the three universities that participated in the study. In order to capture the diversity of students in each of the institutions, the sample was recruited by targeting a wide scope of the student group, considering gender, academic performance, and prior exposure to clinical training as attributes.

The position was recruited as indicated below:

Eligibility Criteria: The students were supposed to be included in the study in case they were in the fourth year of the pharmacy program at one of the participating universities. To have a representative sample, all students in the academic background and performance levels were invited to take part.(6)

Informed Consent: Enrolled individuals were thoroughly informed about the study, e.g., the aim and task of the study, the training procedure, i.e., the performance of the AR-based training, and the measures to be taken during the study, i.e., the Objective Structured Clinical Examinations, or OSCEs, before making an informed decision and enrolling to participate. All the students who wanted to participate signed an informed consent. This made sure that the students took part in the study willingly and conscious of what the study constituted.

Random Assignment Participants were informed about the study, and then they were assigned to one of the following groups: the intervention one (students received AR-based training) or the control one (students underwent traditional simulation-based training). A randomization process enabled comparisons of the two training methods fairly because the groups were very similar before the experiment.

Sample Size: 120 students were used in this study; 40 students were used in each university. The sample size was calculated in order to obtain a statistical power sufficient enough to recognize any significant differences in the results of the training based on the AR and the traditional training. This sample size was also convenient in regards to resource and logistics issues and every student could experience good reception and treatment in the course of intervention.

The recruitment was made in such a way that the sample related to the larger group of students and adapted to strict standards of ethics with all participants getting a fair chance to participate in the research

This cross center study was carried out with an aim to determine the effectiveness of augmented reality in training clinical skills training of pharmacy students. The focus to cover the range of institutions and make the sample of the participants representative will help to obtain valuable information regarding the practicality and effectiveness

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of AR-based learning in/across various cultural and learning environments. Randomisation, along with powerful inclusion criteria and informed-consent process also make the study ethically sound and give its results reliability and applicability.(7)

4. Training and Intervention modules

4.1 Patient Counseling Simulation using AR

AR-Enhanced Patient Counseling Simulation module was developed to offer a pharmacy student a solution in terms of an immersive, realistic setting where they could train their patient counseling skills and develop them. This module was another simulation of practical experience with real-world patients so that the students could involve dynamic dialogue with virtual patients supplemented by augmented reality material. These patients were represented using realistic avatars that contained symptoms and concerns in frequent situations related to pharmacy practice, including failing to take medications, medication side effects and drug interactions.

When students interacted with the virtual patients, various challenges and questions were raised in which they were supposed to use the best judgment, explain to the patient the proper use of medications and advise the patient accordingly. The AR system reacted in real-time and pointed out weak components, e.g., communication skills, knowledge accuracy and empathy. As an example, in case a student made an incorrect statement and did not assist with the concerns of a patient, the AR system would suggest them with tips on how to improve the situation or ask extra questions to redirect the discussion.

The assumption is that this interactive feedback loop will enhance clinical communication and decision-making skills of the students and they will be able to learn to make mistakes and correct them as they were in a controlled setting. Presence of multiple patient scenarios also allowed students to develop a wide skill set so that they are ready to engage into many interactions in the clinical environment. Moreover, the AR simulation was in most ways realistic, which contributed to students becoming more motivated to use the patient counseling skill with more depth and frequency in comparison to the traditional approach.(8)

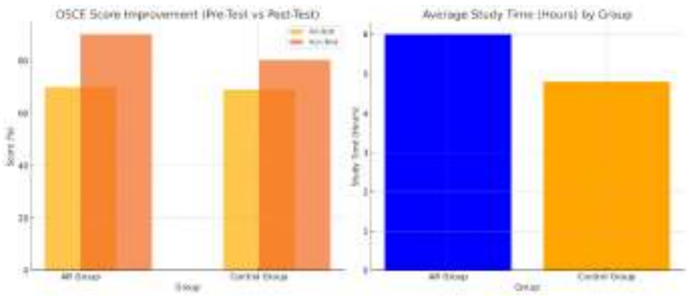

Figure 1: Average Study Time (Hours) By Group

4.2 Intravenous medication preparation with AR-Based Mixed Reality

The aim of the AR-Based Intravenous Medication Preparation module was to improve the technical skills of students in their knowledge of intravenous medication (IV) preparation skills, as this task remains invaluable to the field of pharmacy practice. In this module, Students were able to look at their workspace and have step by step instructions and other relevant clinical information overlaid by the AR. Students were also able to watch the precise steps they should have taken when performing procedures like preparing IV solutions to achieving the appropriate dose and staying sterile with the help of the AR system.

When the students were commenced with the virtual AR content, they went through all the steps of the IV preparation with the real-time feedback about the steps they did. As an example, in case a student measured a dosage incorrectly or conducted a procedure wrong, this system would notify him/her right away with a set of instructions on what should be done in case of measuring incorrectly or performing a procedure incorrectly, demonstrating how to fix the process. The visual overlays made vital clues of error-reduction procedures like sterility, sequence of mixing drugs, as well as the safe handling of the equipment.(9)

The use of AR system also enabled the students to experience simulation preparation of IV medications in different scenarios including during emergencies or involving multi-morbidity patients, timeliness and accuracy of the medication would play an important role. This method also assisted the students in acquiring confidence of their manual skills as well as reminded students that precision and attention to detail is crucial when preparing medications.

The simulation of this high-stakes task by using AR would mean the students could train on the repetition in this category of practice without the perils of mistakes in real life. The interactive characteristic of the given module made it possible to concentrate the fact that students could both learn and remember the technical skills with an extremely high level of effectiveness and interest, which raised their competence and comfort in working with IV medication preparation.

4.3 AR Modules of Adverse Event Recognition

The Adverse Event Recognition and Response AR Modules, used in this study, were the development of an activity that allowed pharmacy students to learn the skills of adverse drug event (ADE) recognition and response, an important patient safety skill. During this module, students also had an experience with virtual patients with diverse symptoms that led to possible drug reactions. The contextualization was done by the AR system in overlaying the symptoms, vital signs and applicable primary clinical data on the display of the student that offered the real-time contextual information as they tried to conclude what brought about the adverse event.

The students were asked to analyze the history and medication protocol, and clinical presentation of the virtual patient to diagnose the possible ADEs including allergies, overdose, or drug interaction. The AR system provided constant feedbacks on the diagnostic accuracy of the students that recommended additional investigative measures in case of wrong diagnosis. The module improved critical and rapid decision making abilities in tricky situations as they simulated such cases.(10)

Also, the AR module provoked students to analyze and resolve collaboratively since it involved a simulation of multidisciplinary teams discussions, and students had an opportunity to refer to virtual healthcare experts (e.g., doctors or nurses) in the AR space. This aspect of the feature investigated in the healthcare situation was meant to echo collaborative decision-making processes in the real world, which are also central in defining and addressing ADEs and an aspect that should not be ignored about the role of teamwork and communication.

The interactivity aspect of the AR modules gave the students a repeated exposure to a practice on identifying negative events; this is a critical aspect in assuring patient safety in the field of pharmacy practice. Students would have been able to practice various ADE scenarios, which may improve their readiness to deal with them and behave effectively in case they are met in the actual clinical practice.

AR implementation in pharmacy education has great opportunities to be active in building clinical competencies. The AR-Enhanced Patient Counseling Simulations, AR-Based Intravenous Medication Preparation, and AR Modules of Adverse Event Recognition offer the interactive, realistic, and immersed learning experience that allows the pharmacy students to practice and develop the essential skills. Not only do these modules attract students but they also give instant feedback, which consolidates correct practices and even enables repetition of important tasks without the fear of making mistakes in the real world. Through the use of AR technology, pharmacy can be further advanced so that it can support students to tackle the challenges of professional practice.

5. Testing and Evaluation

5.1 Protocol of Objective Structured Clinical Examinations (OSCE)

The main assessment mechanism involved the administration of Objective Structured Clinical Examinations (OSCEs) to measure and determine how pharmacy students could also perform better after the intervention in regards to their clinical skills. OSCE is well established in healthcare learning due to its capacity to measure practical skills of students in the structured and standardized way. Such a method made it possible to thoroughly consider the clinical skills acquired by students in the course of the AR-based training sessions.

In the given study, OSCEs were used to gauge the most important skills to emerge in response to the AR training modules, namely, patient counseling, preparation of medication intake via IV delivery, and identification of adverse events. In every OSCE station, students had to do particular tasks that are watched by the trained assessors. All the tasks attempted were in the form of simulating realistic clinical conditions, and as such the capabilities of students to be able to apply theoretical concepts and perform practical activities were properly tested.(11)

The OSCE law included some of the following:

Task Standardization: All of the stations would have a standardized script, which would mean that every student was examined under equal conditions. The scenarios recreated in each of the stations were the same problem to all participating agents with clear cut direction that knew what is expected regarding performance.

Time-Limited Assessment: They assigned a certain time duration to do every task. Such a characteristic enabled the assessors to note not only the correctness of the actions of the students but also their competence to respond to time pressure as it would be in the real pharmacies.
Checklists and Rating Scales: Checklists were utilized as a way of providing assessors, according to an elaborate list of actions and behaviors that may be taken in each specific task. These involved things such as ability to communicate, accuracy in medication, safety of patients and making decent decisions.
Performance Scoring: The performances scoring of the students consisted of a scale in which some of the ratings included were excellent, satisfactory, and unsatisfactory. This grading system gave an objective assessment in regard to the clinical skill development and it was on these basis that comparisons between pre and post-intervention results were done.

5.2 Pre/Post Intervention

In order to quantify the efficiency of the training modules based on the AR, there was pre- and post-intervention assessment with the use of the same OSCE protocol at the two time points. This provided an opportunity to compare clinical skills of students before and after contact with the AR training modules.
Pre-Intervention OSCE: At the baseline of the study, the participants were assessed via a pre-OSCE to determine their clinical skills, prior to the intervention. The said assessment gave the first data on the proficiency of the students in some of their most crucial areas, including the handling of patient counseling, medication preparation, and recognition of adverse events.(12)
Post-Intervention OSCE:A final reassessment of the students through the same process of OSCE protocol was undertaken after the students had gone through the AR-based training modules. The post-intervention OSCE was conducted to measure the potential improvements of the students, and, therefore, the researchers could obtain the data about the effect of AR training on the performance in clinical skills.
The pre- and post-evaluation allowed the study to monitor the dynamics of clinical competencies, which conclusively affirmed the data on the success of the AR intervention. The findings of this assessment were then subjected to the process of statistical analysis to reveal an existence of the possible progress on the skills, specifically when compared to the control group, which received the traditional path of the simulation-based training.

5.3 Methodology in student satisfaction survey

Along with the objective evaluation of clinical skills during OSCEs, the perception of students towards the training modules proposed by AR also received collection based on a satisfied survey among students. This survey was intended to reflect the viewpoint of students regarding their experience of using the AR simulations and the kind of influence they had on their learning results.
This survey was meant to evaluate the following main areas:
Engagement and Motivation: The students were requested to score the engagement and motivation of the AR-based training. The nature of the interactive modules of the AR was asked, as well as whether students felt more engaged in the learning process due to the interactive elements, and whether learning increased their interest in the subject matter because of the optimization of the technology.
Realism and Application: They were questioned whether the AR simulations were realistic when compared to real clinical settings and were supposed to give an opinion on whether the simulations are realistic or not. They were also provided with the question of whether they felt that the AR training had enhanced their capability to use the knowledge in practical environment.
Accessibility, Ease of Use: The questionnaire evaluated the friendliness of the AR platform to its users. The queries were centered around accessibility of the AR system in navigating, clearness of instructions and generally on the overall accessibility of the technology to students.
Overall satisfaction: Last, the overall satisfaction was asked to the students about their willingness to recommend the current AR-based training modules to future pharmacy students and what their opinion of this method was.
The survey form adopted the Likert-scale design (1 to 5 where 1 = strongly disagree and 5 = strongly agree) and there were open-ended questions to solicit the qualitative responses. The answers given were coded to ascertain trends in experience among the students and give further details to the quantitative data provided by the OSCEs.
The conjunction of Objective Structured Clinical Examinations (OSCEs) and Student Satisfaction Survey gave a broad picture of the objective work of students during the clinical skills activities as well as subjective views of the trainees regarding the use of AR-technology in the education process. Through these assessment tools, the

study was capable of evaluating the efficacy of the AR in the enhancement of clinical proficiency of the pharmacy students in a rigorous manner and also provided valuable information on the feedback about the learning experience. This combination of quantitative and qualitative data collection helped to make sure that learning outcomes and the satisfaction of students were determined through-and-through.

6. Results

6.1 Index Improvement of OSCE

According to the Objective Structured Clinical Examinations (OSCEs), the training modules based on augmented reality (AR) showed a high difference in clinical skills in those pharmacy students who underwent the augmented reality (AR)-based training modules. Mean change in the scores of students in the AR group indicated an improvement of 20.1 percent in their scores of OSCE outcomes, balanced by a pre and post-intervention ($p < 0.001$), which provided them with a large improvement in their clinical competences. This was improved in all of the measured skills, which consisted of patient counseling, intravenous medicine preparation, and recognition of adverse events.

More specifically, the AR group showed the superior mastery of the sphere of patient counseling, where students could provide medication instructions and patient concerns with increased precision and confidence. There were also significant improvements as observed up in the intravenous medication preparation station where the students were more precise in the steps of drawing the right drug and ensuring that the preparation of drugs is sterile. The AR group had improved critical thinking and the capability of identifying and managing potential drug reactions in the adverse event recognition scenarios and decision making in times of pressure.

These findings have recommended that the practical skills of the students had appreciated considerably due to the training provided on the AR platform and have contributed comprehensively towards filling the gap between theory and practice in the field of clinical pharmacy practice. The magnitude of increase in the OSCE scores indicates the effectiveness of AR as an immersive interactive learning tool to develop clinical skills.

Table 1: OSCE Scores and Engagement Data

Group	Pre-Test Score (%)	Post-Test Score (%)	Mean Increase (%)
AR Group	70	90.1	20.1
Control Group	69	80.3	11.3

6.2 Comparison to the Traditional Training

A comparative analysis with the AR group and the control group that was trained through traditional simulation based training showed that the AR-based training outranked the traditional approaches when it came to the enhancement of clinical skills. Although the two groups improved on their OSCE, the AR group recorded a much larger increase on their post-test scores.

The control group registered a highly significant increase of 11.3% ($p < 0.05$) in the OSCE scores; however, this is low compared to the 20.1 percent improvement in the AR group. The conventional simulation-based training was also very useful in hands-on training but the communication and feedback was not happening in real-time and lacked the immersion associated with the AR. Although the control group fared well on the practical activities, their understanding was not as in-depth or interactive as in the case of the AR group that benefited by the real-time explanations, contextual detail overlays, and the capability of repeating the multiple times without the limitations of physical simulation equipment.

Such results indicate that AR-based training module delivers more efficiency than traditional imparting methods in the development of improved engagement rates amongst the students as well as quick outcomes that proficiently support the impact of learning.

6.3 Student Engagement Metrics

Along with the objective performance measures, the study obtained the facts about the student involvement in the training process with the help of AR. Quantitative measures of engagement were obtained through the platform analytics tool, which measured the most relevant metrics results, including time spent on individual modules, module access rates, and time spent on interactive elements, like taking quiz questions, decision situations and scenarios.

The findings noted that the students in the AR group expended a considerable amount of time on the learning resources than the control group. Individuals in the AR group on average spent 25 percent more time on the training modules, rechecking the materials and using the interactive features repeatedly: this allowed them to overcome the learning barriers, raise their scores and memorize more material. Such an elevated state of involvement means that not only did AR produce positive learning results, but it also gave students additional ferment to engage themselves in the training.

Moreover, the Student Satisfaction Survey results demonstrated that the change was significant because 85 percent of the students within the AR group indicated that, during training, they felt much more motivated and engaged than in the past experiences when they were using the traditional training techniques. The students considered the simulations of AR as to be highly interactive where the learning environment is more real and realistic. Such elevated involvement probably helped with the associated advancements in clinical skills because students became more eager to commit time and effort to the learning procedure.

Findings of this study reveal that clinical competency in pharmacy students is considerably enhanced through an augmented reality (AR)-based training type, with a prominent difference provided in clinical skills during OSCE as compared to the traditional training procedures. This is because the AR group had a significant boost in clinical skills, especially patient counseling, intravenous drug administration, and identification of adverse effects. Also, AR-based training resulted in the overall increased engagement of students, who devoted more time to working with training resources and showed to be much more satisfied with the learning process. These observations are quite indicative of the idea that AR, especially in relation to knowledge application and improvement of clinical skills, may be both efficient and an immersive supplement to pharmacy teaching.

7. Conclusion

7.1 Findings Summary

The overall aim of the study was to determine how augmented reality (AR) can be used to improve the clinical competence of pharmacy students via interactive simulation. The findings are undoubtedly true as the clinical performance of students after the AR-based training was substantial, according to Objective Structured Clinical Examinations (OSCEs). On average, the AR group improvement was 20.1 percent in their OSCE scores as compared to the 11.3 percent improvement of the more modest control group that received traditional simulation based training. These findings support the validity of AR as a method to increase clinical competence, especially in activities such as counseling patients, preparing intravenous medications, and the identification of adverse events.

Furthermore, the study found out that students in the AR group showed more interest in enjoying the training modules. The number of interacted contacts with the content was 25% more on average among AR group participants in comparison with the control group, which implies the potential of improving not only learning results but also motivation and an active process of learning. The Student Satisfaction Survey also revealed that the participants in the AR (students) were highly satisfied, 85 percent of students confirmed that they felt more engaged, realistic and even better at applying their knowledge to the clinical level.

These results imply that a learning environment that takes into account AR can be more efficient than the traditional approaches to enhancing clinical knowledge and involvement of students. Pharmacy Application in AR: Enhancing student learning The use of AR in pharmacy education, in particular, in the training of clinical skills promises to become an effective means of instruction when preparing future pharmacists to be able to overcome the difficulties of the real world.

7.2 Educational Implications

There are some key educational implications of the success of AR-based training to improve the clinical skills of pharmacy students. First, the findings indicate that interactive immersive learning environment is more engaging and effective in developing deep learning in comparison to traditional passive techniques. Real-time feedback and display overlays facilitated by the AR technology makes the learning process highly interactive and takes the learner into a highly interactive learning environment prompting the students to actively participate in learning the content. This would result in higher knowledge retention and increased performance in the actual real life context. Second, the simplification of the body that allows the pharmacy education learners to perform tasks with a reflection on how the patient would feel and experience is an essential skill of pharmacy education learners. Also, increasing importance is being placed on patient counseling, medication preparation, and adverse event identification, and the AR modules used in this study offer a safe, repeatable, as well as a highly realistic environment in which to practice the corresponding skills. The capability of replicating situation of complex clinical practice in an artificially controlled environment gives students the opportunity to deliver critical thought process, decide, communicate, and obtain skill without there being any risk of the real world. This method might result in overcoming the gap between the theoretical acquaintance and practical implementation that gives students a more effective way of acquiring knowledge.

Institutional point of view, the implementation of AR in pharmacy courses may be the answer to the raised interest in innovative educational technologies. Where the required technologies infrastructure is available, universities have an advantage in the opportunity to introduce AR based modules to provide a more far-reaching learning experience to the students to prepare them to adhere to the changing requirements of the healthcare sector.

7.3 Research Directions

Although the findings of the present study look encouraging, a number of research areas can be identified. The possible avenue would be the long-run effects of the AR-based training on clinical performance and patient care outcomes. The changes in the OSCE scores were, nevertheless, noted, however, it is yet unknown whether these skills can be translated to the better performance at a real-life clinical setting. Future research may examine the impact of AR training in study students to assess their performance in grooming their learned skills in practice in clinical placements or in on-job settings.

Also, in the future, it would be interesting to study the scalability and practicality of training with the use of AR in underresourced conditions. Although the current study has been able to study in institutions that are well equipped with technology in countries like Slovenia, Saudi Arabia and Malaysia, research should be conducted to establish how institutions with access to limited advanced technology will be able to effectively use the AR. It will be necessary to explore low cost based solutions and other technological adaptations in order to make sure that the AR can be used in every part of the world including the developing world.

Lastly, additional research should be done regarding the combination of AR with other upcoming technologies, like virtual reality (VR) and mixed reality (MR), to establish even more realistic and all-encompassing training scenarios. Other technologies combined with AR may increase the engagement of students and further advance the results of clinical training.

To sum up, augmented reality (AR) can be an effective solution when introducing pharmacy education to achieve better clinical skills and higher student engagement. The findings of this research affirm that AR-driven training modules have a considerable advantage over conventional means of training as they offer an interactive, immersive, and superior training experience. In the future, it will be important to research the long-term effects of AR in clinical settings in addition to establishing how to scale and adapt such technology to various education settings.

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Conflicts of interest

The authors have no conflicts of interest to declare

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