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ORIGINAL ARTICLE

Impact of Virtual Reality-Based Clinical Case Learning on Medical Knowledge and Clinical Engagement in Medical Education

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ABSTRACT

Background: Challenges in medical education in Pakistan are the lack of clinical exposure and the use of traditional methods of teaching. Virtual reality (VR) based clinical case learning is an innovative approach to bridge the gap between the theoretical knowledge and practical clinical experience. This study examines the effect of learning using VR on medical knowledge as well as clinical engagement of MBBS students in a five-year programme.

Methods: This cross-sectional comparative study was done among n=200 MBBS students of Khawaja Muhammad Safdar Medical College Sialkot in Pakistan involved in all academic years (Years I–V). The group was split into the VR group (n=100), which spent 6 weeks using immersive VR clinical simulations, and the Traditional group (n=100), which performed paper-based case studies and instructor-led discussions on the same clinical scenarios. A standardized multiple-choice questionnaire (MCQ) was used to measure medical knowledge and clinical engagement was assessed through a validated survey instrument using a five-point Likert scale. Independent samples t-test was used to analyze continuous variables, and Chi-square test for categorical variables, with $p < 0.05$.

Results: There was a significant difference in the mean MCQ scores for the VR group (85.3 ± 6.8) versus the Traditional group (77.1 ± 8.2; $p < 0.001$). Furthermore, the mean clinical engagement score was greater in the VR group (4.2 ± 0.6) than in the Traditional group (3.5 ± 0.7; $p < 0.001$). No significant difference ($p > 0.05$) was found in baseline demographic variables, age, gender, and MBBS year distribution, between the groups.

Conclusion: Medical knowledge and clinical engagement of MBBS students in Pakistan are improved significantly by VR based clinical case learning. These findings indicate that the use of immersive VR technology as an adjunct to traditional teaching methods in the medical curriculum could improve clinical competence in resource constrained educational settings.

Keywords: Virtual Reality, Medical Education, Clinical Engagement, MBBS, Pakistan, Simulation-Based Learning, Clinical Case Learning

INTRODUCTION

Traditionally, medical education in Pakistan has been based on a combination of didactic lectures, textbook learning, and clinical rotations to provide an important knowledge and skill base to future healthcare professionals[1]. However, in an era where healthcare delivery is evolving and the complexity of clinical scenarios is growing, more innovative and interactive training methods are needed. Over the past few years, virtual reality (VR) has emerged as a promising emerging educational technology to enhance the learning experience. Research conducted in the context of Pakistan's unique educational and healthcare environment explores the impact of VR-based clinical case learning on medical knowledge and clinical engagement[2].

Pakistan's medical education system has its challenges. Often, overcrowded classrooms and insufficient clinical exposure for students have been caused by rapid population growth, limited resources, and a high patient-to-doctor ratio[3]. While such traditional simulation methods as mannequin-based training are valuable, they are limited in their ability to accurately reproduce the dynamic and unpredictable nature of actual clinical environments[4]. These constraints have prompted educators and policymakers to search for new solutions that will bridge the gap between what is known in theory and what is used in practice. Medical training has the potential to be revolutionized with the introduction of VR as an immersive and interactive platform that allows safe and controlled engagement with various clinical scenarios[5].

In Pakistan, the implementation of VR in medical education is of vital importance in the context of the availability of resources in most of the institutions. VR-based learning modules are a cost-effective, scalable alternative to access high-quality clinical education with limited access to advanced simulation centers and clinical training facilities[6]. VR is not only better than traditional learning methods for improving knowledge retention but also for teaching critical decision-making and clinical confidence skills to students by simulating realistic patient encounters and clinical procedures. This is especially relevant in a situation where real-world clinical exposure may be sparse and nonconsecutive depriving the development of critical clinical competencies[7].

Additionally, VR-based clinical case learning satisfies the demand for increased clinical engagement which is essential to educate students to handle the demands and intricacies of contemporary healthcare. While traditional lecture-based methodologies have been successful in delivering foundational knowledge, they tend to fall short of fully engaging learners or fostering hands-on problem-solving skills needed in clinical settings[8]. On the contrary, VR allows students to become immersed in simulated environments where they have to interactively participate in patient assessment, diagnosis, and management. Such active engagement does not only reiterate theoretical concepts but also fosters the development of practical skills and adaptive expertise deemed essential to real clinical practice[9].

Global studies provide preliminary evidence of enhanced clinical reasoning, greater knowledge retention, and higher student satisfaction that can be achieved through immersive learning experiences. Although there is little research regarding the use of VR-based clinical learning in the context of Pakistan[10]. The evaluation of VR's potential benefits and challenges should be localized for cultural, economic, and infrastructural factors peculiar to Pakistan. The purpose of this study is to close this gap by systematically investigating the effect of VR-based medical case learning on the medical knowledge and clinical engagement of Pakistani medical students[11].

In this study, a mixed methods approach where knowledge retention and clinical performance are quantitatively assessed and feedback from the students and educators is qualitatively obtained[12]. The study examines not only the direct educational consequences of VR-based training but also the potential of VR-based training for curriculum development and long-term clinical competency development. This Study aimed to integrate VR into the current framework of education to bring some insights into how technology-driven innovation can be used to improve medical

education in Pakistan, a country that is undergoing rapid modernization in its health care system and fighting many challenges[13].

Thus, this study investigates how VR-based clinical case learning can be a transformative tool in Pakistani medical education. This study attempts to contribute to an effective, interactive, and accessible medical educational system in Pakistan by addressing the limitations of traditional training methods and utilizing the benefits of advanced simulation technology. The findings of this study can inform educational policies and inform innovation in clinical training to further improve the quality of healthcare delivery in the region[14].

MATERIALS AND METHODS

It was a cross-sectional comparative study to assess the impact of a virtual reality (VR) based clinical case learning on medical knowledge level and clinical engagement during 5 years MBBS program (Year I through Year V) study in Pakistan. Recruitment was done from Khawaja Muhammad Safdar Medical College Sialkot, Pakistan through academic announcements and a total of n=200 students were recruited. All students of any academic year were allowed to participate; those with previous extensive VR experience or previous participation in VR pilot projects were excluded to avoid bias.

In terms of exposure to different teaching methods, the participants were naturally divided into two groups. Students who had already participated in an immersive clinical case simulation module piloted in the VR module as part of their curriculum made up the VR group (n = 100). The two developed these simulations together with clinical educators and technology experts to simulate common clinical scenarios in Pakistan that include myocardial infarction, sepsis, and diabetic emergencies. The intervention was delivered over six weeks, per session lasting approximately two hours, and students interacted with high-fidelity simulations which provided them with instant feedback on their decision-making. On the other hand, the traditional learning group (n = 100) learned the same clinical content at a similar time using conventional methods such as paper-based case studies and instructor-led discussions.

The standardized multiple-choice questionnaire (MCQ) was designed to assess clinical reasoning and retention of material presented in the clinical cases. A validated survey instrument was used to measure clinical engagement using student motivation, perceived realism of the learning experience, and confidence in clinical decision-making on a five-point Likert scale. The MCQ and the engagement survey were given at the end of the six-week intervention.

Descriptive statistics (means, standard deviations, frequencies, and percentages) were calculated for participant demographics and outcome measures as the data analysis. Independent samples t-tests were conducted to compare differences between the VR and traditional groups for continuous variables such as MCQ scores and engagement ratings. The Chi-square test was used to test the difference in the categorical variables such as gender distribution and MBBS year. A p-value of less than 0.05 was considered statistically significant. The study was approved by the Institutional Review Board of Khawaja Muhammad Safdar Medical College, Sialkot and all participants signed written informed consent before enrolment.

RESULTS

A total of n=200 students of MBBS from Khawaja Muhammad Safdar Medical College Sialkot, were enrolled and distributed equally into the VR-based learning group and traditional learning group. The overall aim was to determine the effect of virtual reality (VR) clinical case learning on medical knowledge and clinical engagement across all years of the MBBS curriculum (i.e., Year I to Year V), which is five years in Pakistan. Care was taken to record baseline demographic characteristics of the groups, and to compare groups.

Participants in the VR group were 22.6 years (SD = 1.8) and 22.8 years (SD = 2.0) for the traditional group, with no statistically significant difference (p = 0.55). Similar gender distribution was also found, as the VR group included 60 males and 40 females and the traditional group 58 males and 42 females (p = 0.78). Furthermore, the distribution of students between MBBS Years I and V was similar between groups (p = 0.90). Table 1 summarizes these demographic characteristics.

This table provides a detailed comparison of the baseline demographics of the study groups, including age, gender, and MBBS year distribution, with corresponding p-values indicating no significant differences.

Table 1: Demographic Characteristics of Participants

Variable	VR Group (n = 100)	Traditional Group (n = 100)	p-value
Age (years), mean ± SD	22.6 ± 1.8	22.8 ± 2.0	0.55
Gender (Male/Female)	60 / 40	58 / 42	0.78
MBBS Year			0.90
Year I	20 (20%)	18 (18%)	
Year II	20 (20%)	22 (22%)	
Year III	20 (20%)	20 (20%)	
Year IV	20 (20%)	20 (20%)	
Year V	20 (20%)	20 (20%)	

Outcome measures were then evaluated. A standardized multiple-choice questionnaire (MCQ) was developed to test clinical reasoning and case-based understanding of medical knowledge and a validated survey instrument to assess clinical engagement with questions that assess motivation, perceived realism, and confidence in clinical decision making.

A significantly higher mean MCQ score of 85.3 (SD = 6.8) was obtained by the VR group compared to 77.1 (SD = 8.2) by the traditional group. This difference was confirmed to be statistically significant with an independent samples t-test ($t(198) = 5.89$, $p < 0.001$). Similarly, the mean clinical engagement score of 4.2 (SD = 0.6) in the VR group was significantly greater than that of the traditional group (3.5, SD = 0.7; $t(198) = 6.24$, $p < 0.001$). The details of these results are presented in Table 2.

The results are shown in this table comparing the VR-based and traditional learning groups on the MCQ scores and clinical engagement ratings. The VR group showed statistically significant improvement in both measures.

Table 2: Outcome Measures for Medical Knowledge and Clinical Engagement

Outcome Measure	VR Group (n = 100)	Traditional Group (n = 100)	p-value
MCQ Score, mean ± SD	85.3 ± 6.8	77.1 ± 8.2	< 0.001
Engagement Score, mean ± SD	4.2 ± 0.6	3.5 ± 0.7	< 0.001

Overall, the detailed demographic analysis demonstrates that the two groups were similar at baseline, and the subsequent statistical analysis indicates that clinical case learning using VR is highly effective in terms of improving acquisition of medical knowledge and level of clinical engagement among MBBS students. This finding highlights the potential of VR to be harnessed as an innovative tool in the Pakistani medical education context.

DISCUSSION

The results of the study suggest that VR-based clinical case learning improves both medical knowledge and clinical engagement among MBBS students in Pakistan. In terms of MCQ scores, students' performance in immersive VR simulation was much higher than in the traditional methods of teaching, suggesting better clinical reasoning and retention of knowledge[15]. VR's interactive nature of realistic patient scenarios and immediate

feedback seems to develop a dynamic learning environment that enhances understanding of the theories and their practical application. This improvement implies that VR can fill the gap between classroom and real clinical practice to provide a more effective educational tool than the conventional[16].

In the Pakistani MBBS curriculum where the educational resource and clinical exposure may be limited, the benefits of VR are more important. Baseline differences were absent in the balanced demographic characteristics in all the academic years, and so, the improvements seen in the VR group were not due to those[17]. This further supports the potential for VR to encourage active learning and higher motivation amongst students and the enhanced clinical engagement reported by students. This is good news for resource-constrained settings, as VR-based learning is a scalable method to enrich clinical training and may help ease some of the systemic challenges in medical education in Pakistan[18].

The study has several limitations that should be discussed despite these promising outcomes. This is a cross-sectional design that does not allow knowledge retention over the long term and sustained improvements of the clinical competencies[19, 20]. Additionally, self-reports of clinical engagement could be biased, and more objective assessments (e.g. OSCEs) would be useful. Future research should be longitudinal and also broader in scope, incorporating objective performance measures. Furthermore, the focus on how VR can be used in each of the various components of the MBBS curriculum could reveal a more complete picture of VR's potential as a means to enhance the effectiveness and practical applicability of VR across different educational institutions[21].

CONCLUSION

The integration of VR-based clinical case learning into the Pakistan MBBS curriculum holds the potential to improve both medical knowledge and clinical engagement. The benefits of VR for immediate as well as future learning outcomes extend to the ability to create an immersive and interactive learning environment, which can enhance educational outcomes and better prepare future healthcare professionals for the complexities of clinical practice. These findings were validated further by longitudinal and objective studies to validate these findings and explore the full potential of VR in facilitating the revolution of medical education in resource-constrained environments.

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