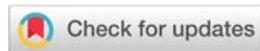


## ORIGINAL ARTICLE

# Data-Driven Evaluation of Metaverse Integration in Healthcare Education: User Adoption Readiness and Impact on Clinical Competency among Healthcare Professionals

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**ABSTRACT**

**Background:** One of the new methods of change in healthcare and higher education is the integration of metaverse technologies such as virtual reality, augmented reality and mixed reality. The traditional medical training has been found to have challenges of poor access to clinical practice, patient safety issues, ethical issues and health practitioners' shortage.

**Objective:** To assess the applicability of metaverse technologies in medical education assessing both the willingness of medical workers to implement immersive learning devices and the effects of training with the help of metaverse on clinical performance results.

**Methodology:** This quantitative study was carried out at Healthcare Institution in Sind, Pakistan from 1<sup>st</sup> January 2024 to 30<sup>th</sup> June 2025. Adoption element entailed 383 recruited healthcare professionals and students who were recruited through stratified sampling. The perceptions, behavioral intention, and determinants of adoption were measured using a structured questionnaire which was prepared according to Unified Theory of Acceptance and Use of Technology 2 (UTAUT2). The quasi-experimental design with clinical effectiveness assessment was performed with regard to an experimental group (metaverse based training, n= 26) and a control group (traditional training, n= 30).

**Results:** The respondents showed favorable attitudes toward the adoption of the metaverse, and the following were found to be the major influencing attitude factors, namely, performance expectancy (M=3.86), hedonic motivation (M = 3.83), and personal innovativeness (M=3.77). Compared influence was seen in social influence as well as in perceived privacy. Overall, OSCE scores in the experimental and control groups were significantly higher in all the stations namely; spinal injury transport, treatment of composite injuries, CPR and tracheal intubation, and bronchoscopic lung segment recognition (80.31±11.15 vs. 70.50±10.76; p = 0.002), treatment of composite injuries, CPR and tracheal intubation (87.17±5.74 vs. 77.30±11.45)

**Conclusion:** Immersive learning through metaverse proved to be very acceptable and clearly enhanced clinical competency, compared to conventional approaches to training. These results substantiate the idea of the inclusion in the academic toolset of immersive technologies to optimize clinical skills training and overcome the shortcomings of the traditional health care training systems.

**Keywords:** Virtual reality, Metaverse, Medical education, Healthcare training, Technology adoption, Clinical competency, Immersive learning.

## INTRODUCTION

The fast-development of immersive technologies and especially the metaverse is changing the paradigms in the direction of education in various fields, such as medical and higher education. The metaverse combines virtual reality (VR), augmented reality (AR), and mixed reality (MR) spaces to form the interaction and multi-sensory learning experiences that will allow the user to experience the complex situations in a secure and controlled environment. They serve as innovative ways out of the long running challenges in healthcare education, including lack of clinical exposure, safety issue at the work place, ethical barriers, and shortage of qualified healthcare professionals<sup>1-3</sup>.

The conventional methods of teaching in the medical field tend to be based more on classroom learning, simulation, and clinical placements. But growing number of students, limited hospital resources and patient safety requirements have left loopholes between the understanding of theory and acquisition of clinical skills. Repeat practice, real-time feedback and experience Learning through immersive metaverse based simulations offer an opportunity to influence patient safety without jeopardizing it. Collaborative learning as well as remote participation and individualized learning journeys are also facilitated by these technologies, which is specifically useful in resource-restrained healthcare systems<sup>4-6</sup>.

Although the metaverse has great potential in teaching round care, user acceptance, technological preparedness, institutional backing, and quantifiable educational results are the key success factors of implementing the metaverse in healthcare. The Information culture frameworks and the Unified Theory of Acceptance and Use of Technology are a significant theoretical foundation to analyze psychological and behavioral, as well as technological, elements of adoption. At the same time, objective performance measurements, including Objective Structured Clinical Examination (OSCE) scores, provide some physical results of the didactic efficiency of the immersive training in opposition to the traditional procedures<sup>7-9</sup>.

## MATERIAL AND METHOD

This quantitative study with a cross-sectional survey to determine user adoption, perceptions and readiness toward metaverse technologies in healthcare education, Combining the data on behavioral and performance provided the opportunity to conduct a thorough analysis of both the acceptance and educational performances of the metaverse technologies. The study was done in

healthcare teaching facilities and clinical training center in Sindh, Pakistan. The selection of these institutions was done to create diversity in the educational settings, exposure to technology, and diversity in the demographics of the participants. The tests on clinical skills were conducted in institutional simulation laboratories that had standard OSCE stations. The data collection will take place between 18 months January 2024 - June 2025 which will cover both participants recruitment, survey administration, immersive training intervention and OSCE assessment. The research population targeted the healthcare professionals and the students of healthcare, which included medical students, nursing students, nurse practitioners and first-year health practitioners and faculty members that are involved in training (clinical). They had to be familiar with digital learning platforms at the basic level to make a significant assessment of the adoption of immersive technology. The survey component involved the 383 respondents with a stratified random sampling method to have representation in terms of gender, age groups and education levels. Adequacy of the sample was established according to the recommendations of structural and behavioural modeling studies that indicate that there should be at least 300 participants with statistical analysis is reliable. The criteria that participants had to meet were had attended or become members of a healthcare training program, or clinical institution, gave an informed consent to participate, possessed the basic computer literacy and ability to interact with the digital platforms and ready to carry out intensive training and OSCE examination were included. The participants who were excluded due to the following reasons, experienced much before with high-level immersive simulation technology, lack of time to attend training because of time constraints, refused to participate or changed her mind in the study, suffers medical or physical incapacity to take part in simulation exercises and study instruments were excluded. Statistical Package of Social Sciences version 26 was used to analyze the data. Comparison of the OSCE scores of the groups by the use of independent sample t - tests. Significance level set at  $p < 0.05$

## RESULTS

Table 1 shows the demographic composition of the 383 respondents that made up the study. Gender distribution of the sample was relatively equal, where 52.5 percent of the participants were males, and 47.5 percent females. Most of the respondents (54.8) belonged to the younger age range (18-29 years) with the remainder of 31.6% via the 40- 49 years range, which showed that the greatest number of respondents were early-career healthcare

practitioners or students. The percentage of respondents who were of older age (40-65 year) was very low (30-39 year: 9.4%; 50-59 year: 4.2). In terms of education, the most significant percentage had bachelor's degree (79.4%), Master degree (12.0) and doctoral degree (7.0) or a degree diploma (1.6). This distribution indicates that the study sample mainly comprised of learners at the undergraduate level or new-level professionals, which is valid when determining the willingness to use technology in education since younger and more actively involved people are usually more open to innovative methods of learning through metaverse technologies.

The table 2 shows descriptive statistics of important constructs, which impact the adoption of metaverse technology. The mean performance expectancy had the highest score ( $M = 3.86$ ,  $SD = 0.657$ ), which implied that the respondents were strongly convinced that the metaverse could improve their learning performances and clinical competencies. One of these was hedonic motivation ( $M = 3.83$ ) with personal innovativeness ( $M = 3.77$ ) also scoring high which implies that fun and ready to explore new technologies are likely to be important motivational factors in adoption. Attitudes towards change in the culture, user satisfaction, the expectation of effort, and the behavioral intention to use proved to have good perceived importance possessing mean values exceeding 3.6 indicating generally positive attitudes towards immersive learning technologies. Social influence ( $M = 3.034$ ,  $SD = 1.042$ ) and perceived privacy related issues ( $M = 3.216$ ,  $SD = 0.687$ ) on the other hand were rated relatively lower reflecting moderate worry of peer influence and data security matters. On the whole, the results indicate that intrinsic motivation and perceived usefulness have a greater influence on the use of a system than the imposed external social forces.

The results presented in Table 3 demonstrate the differences in the clinical performance outcomes of the participating groups in the study, namely, the experimental group being trained using the metaverse-based immersive approach and the control group being

trained under the traditional teaching. In all the four evaluation stations, the experimental group showed better mean scores as compared to the control group and this is seen as a sign that immersive training is related with better clinical skills acquisition. The most significant performance disparity came in Station 4 (bronchoscopic lung segment recognition) at which the mean of the results of the experimental condition was 75.00 as compared to 52.33 in the control condition. Such an improvement is significant to indicate that the immersive technologies of visualization work exceptionally in relation to complex anatomical recognition tasks. Likewise, there has been a considerable positive change concerning life-saving procedures such as CPR and tracheal intubation (87.17 vs. 77.30), composite injury treatment (86.83 vs. 75.60), and transport of spinal injuries (80.31 vs. 70.50). Such results suggest that metaverse-driven learning settings have the potential to increase cognitive knowledge, as well as psychomotor skill development (Table 3).

The statistical comparison between groups is also offered in Table 4, which discloses the relevance of the extent of improvement of metaverse-based training. The average differences were between 9.81 and 22.67 points at the four assessment stations, with all the p-values of less than 0.05 implying that there is statistically significant difference in the experimental and control groups. Bronchoscopic lung segment recognition improvement was the most significant (mean difference = 22.67,  $p < 0.001$ ), which proves the efficiency of immersive simulation in training complex procedures. The results of CPR and tracheal intubation were also found to be highly significant ( $p < 0.001$ ), which could indicate that immersive learning has the potential to make a considerable positive impact on life-saving skills. These results are statistically significant and formidable arguments that training in the virtual reality of a metaverse is superior to traditional pedagogical techniques in improving clinical competence in medical students (Table 4).

**Table 1:** Demographic Characteristics of Study Respondents (N = 383)

Variable	Category	No.	%
Gender	Male	201	52.50
	Female	182	47.50
Age (years)	18–29	210	54.80
	30–39	36	9.40
	40–49	121	31.60
	50–59	16	4.20
Education Level	Bachelor's	304	79.40
	Master's	46	12.00
	Doctorate	27	7.00
	Diploma	6	1.60

**Table 2:** Descriptive statistics of perceived importance of adoption factors

Construct	Mean	Standard Deviation
Performance Expectancy	3.86	0.657
Hedonic Motivation	3.83	0.816
Personal Innovativeness	3.77	0.736
Cultural Attitudes Towards Change	3.697	0.652
User Satisfaction	3.666	0.741
Effort Expectancy	3.624	0.68
Behavioral Intention to Use	3.611	0.762
Social Influence	3.034	1.042
Perceived Privacy	3.216	0.687

**Table 3:** OSCE Skill Assessment Scores (Experimental vs. Control Groups)

Assessment Station	Test Group (N = 26)	Control group (N = 30)
Station 1: Spinal injury transport	80.31±11.15	70.50±10.76
Station 2: Treatment of composite injuries	86.83±13.61	75.60±13.55
Station 3: CPR and Tracheal intubation	87.17±5.74	77.30±11.45
Station 4: Bronchoscopic lung segment recognition	75.00±13.04	52.33±14.07

**Table 4:** Statistical Comparison and Mean Differences Between Groups

Assessment Station	Mean Difference (Test – Control)	P-Value
Station 1: Spinal injury transport	9.81	0.002
Station 2: Treatment of composite injuries	11.23	0.003
Station 3: CPR and Tracheal intubation	9.87	< 0.001
Station 4: Bronchoscopic lung segment recognition	22.67	< 0.001

## DISCUSSION

The current research paper incorporates a multidimensional assessment of metaverse integration into healthcare education because it incorporates user adoption views with objective performance clinical results. The two-facet solution empowers the evidence base and covers both behavior preparedness and quantifiable educational effects that are to play a key role in determining the successfulness of technological application in the field of medical training<sup>7,10</sup>.

The demographic characteristics of the participants showed that the professionals or students on that group were mostly young in age with some having undergraduate education. The latter observation is especially applicable since younger students are those who usually exhibit greater levels of digital literacy, technological eagerness, and are able to adjust to new learning models. Nevertheless, the fact that the participants also belong to the older age groups suggests that the acceptance of immersive technologies is not limited to the early-career professionals and the reason is that the acceptance can be widely accepted at different professional levels. This fact concurs with current studies that depict that perceived usefulness and training advantages can be utilized to hit age-related strain on technology acceptance, given that the support systems are satisfactory<sup>11,12</sup>.

The results of the adoption point to performance expectancy as the most influential factor of metaverse acceptance in accordance with the Unified Theory of Acceptance and Use of Technology (UTAUT2). The perceived improvement of the learning efficiency, clinical competence, and mastery of skills seems to be the driving power within the hands of healthcare professionals. This is especially so in the clinical training where practical performance change is a major outcome measure. The influences of hedonic motivation and personal innovativeness were also strong indicating that the factors of immersive engagement and curiosity regarding new technologies have significant effects on the process of adoption. The motivation of immersion and interaction promoted by metaverse environments is likely to provoke intrinsic motivation, which causes aesthetic processing and experiential learning<sup>12-13</sup>.

Surprisingly, the social influence was observed to have a rather loose impact on the intention to adopt. This implies that medical workers are less vulnerable to peer or institutional pressure in explaining the usefulness of education by depending on the personal judgments. This result might be the result of professional autonomy that is usually observed in healthcare where developed personal competency and evidence-based decision-making are a priority. Moderate concerns with perceived privacy, in the meantime, put focus on institutional regulative frameworks, safe data management models, and moral

integrity to generate user guarantees of immersive environments<sup>14-15</sup>.

The strongest evidence of value of educational metaverse technology can be seen on the result of the OSCE performance. The students who had been trained using the immersive virtual environments had much higher scores in all the clinical stations in comparison to those who had been trained in conventional ways. Improvements were especially observed in bronchoscopic lung segment recognition that involves the enhanced spatial perception, anatomy visualization, and procedural knowledge. The immersive technologies fare best in these situations since it offers three-dimensional visualization, the ability to manipulate in an interactive way and even giving opportunities of repetitive practice in the traditional methods of teaching is hard to seize alone<sup>14-15</sup>.

Equally, positive changes witnessed in life-saving procedural skills such as CPR and tracheal intubation show that immersive simulations are effective in enhancing psychomotor coordination, procedure sequencing, and clinical decision making. Repetitive training in a risk-free environment lowers anxiety, builds self-confidence in the learner, and enables adults to learn in a way that is demanding in terms of skill-related competencies in the real clinical setting. The results confirm the theory of experiential learning, which proves the importance of active engagement, reflection and practical interaction as the important elements of skill development<sup>17</sup>. The role of metaverse technology in the healthcare education systemic issues also presents another crucial factor. A paucity of clinical exposure, rising number of student enrolment, patient safety standards and the quality of training has been an open issue throughout the world and especially where the number of healthcare systems is constrained by resources and funding. Immersive simulation offers standardized training experience capable of minimizing the differences in clinical training and guaranteeing the safety of patients<sup>19</sup>. Moreover, metaverse platforms can be accessed remotely, which is an option of distributed learning, which is especially applicable to geographically spread or underserved areas. Pedagogically, learning in the metaverse helps facilitate models of competency-based education because it allows the objective evaluation and assessment, real-time, and direct feedback and customizable learning processes. Immersive platforms also enable the integration of analytics into education and enable educators to monitor the progress of learners, developing skills, and intervening. These data-driven education techniques are an important improvement in comparison to the traditional data selection method of education, which is usually subjective and has little opportunity in terms of observation<sup>18,20</sup>.

In addition, although the research report shows notable changes in simulated clinical performance, the transfer of these competencies into the practical and real-world clinical setting is an issue that needs more research. The fidelity of the simulation, the immersion of the learner, and the transfer of the skills to the long-term effectiveness are also considered factors when representing the evaluation of the simulation effectiveness. An exploration of longitudinal outcomes, clinical performance retention and patient-related outcomes related to immersive training is thus potential future research. There is also significant consideration on the findings in terms of equity and accessibility. The presence of advanced immersive technologies could result in increased education inequalities in case these technologies are only available in well-resourced institutions. Thus, scalable and affordable solutions are needed to make sure that unfair treatment is applied to the implementation process in various healthcare systems, especially in the developing world.

## CONCLUSION

The results of this research give solid grounds to the fact that immersive learning through metaverse can be considered as appropriate by medical staff and effective in enhancing clinical competency. The participants expressed a positive attitude toward usefulness, enjoyment, and novelty regarding metaverse technology without objective performance measures which proved that the skills of clinics were improved significantly when trained with the help of the metaverse technology compared to the use of traditional training methods.

The main aim of immersive technology application in healthcare education has been seen as a promising remedy to the issues of restricted clinical exposure, suitability of patient safety, and staffing shortages. Altogether, the metaverse is a valuable educational resource that can be used to improve theoretical knowledge, as well as practical skills in a healthcare training field.

### Recommendations

According to the research findings, it can be proposed the following recommendations:

- The metaverse-based simulations are meant to be embedded in medical and nursing programs of healthcare institutions to complement the traditional teaching experience.
- Teachers need to be taken through special training to learn how to properly use immersive technologies in teaching and evaluation.
- To enhance an immersive learning process, institutions are encouraged to invest in technological architecture, such as the use of VR gadgets and software platforms.
- Crystal clear policies concerning patient privacy, ethical use, and safety should be laid down.

- Immersion simulations could be used with conventional clinical exposure to create the best learning results.
- Analysis of performance and satisfaction of learners should be done regularly so as to achieve effectiveness and sustainability.

## IMPLICATIONS

**Educational Implications:** This study proves that immersive metaverse-based technologies may significantly improve experiential learning, knowledge retention, and clinical competency. This helps with the shift towards competence models of medical education.

**Clinical Implications:** The enhancement of the procedural skills and decision-making capabilities of healthcare professionals can lead to improved patient outcomes and a minimal number of medical errors in the real clinical environment.

**Institutional Implications:** The medical facilities might find it advantageous to implement scalable solutions on immersive training to meet the workforce shortages and training constraints to a greater scale especially in developing nations.

**Technological Implications:** According to the results, the user-centered design, accessibility, and usability are essential to creating metaverse platforms in healthcare education.

This study throws out several avenues of research into the future:

- The retention of the skills obtained in the process of metaverse training should be investigated in the future.
- Research done across different healthcare facilities and institutions would be more generalizable.
- Large-scale implementation requires economic analyses to ascertain the financial viability of the implementation.
- Studies should also be conducted in the future to determine whether the training improvements can be studied to result in measurable patient care outcomes.
- It would be more insightful to compare studies of various professional fields in healthcare (medicine, nursing, allied health).

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