

The effectiveness of a Metaverse Based Emergency Training Platform for undergraduate medical students

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Abstract

Following the successful implementation of a VR anatomy module, this study evaluates the effectiveness of a metaverse-based emergency training platform. The research explores the feasibility of using immersive, multiplayer environments to enhance emergency medical competencies among students in resource-constrained educational settings.

A cohort of second-year medical students at the Ibn Al-Jazzar Faculty of Medicine participated in three progressively challenging simulation scenarios: cardiopulmonary resuscitation (CPR), management of moderate asthma exacerbation, and mass-casualty triage using the START method. The platform was developed in Unity 3D, featuring interactive multiplayer avatar collaboration. Students completed pre- and post-simulation questionnaires to assess seven key dimensions: realism, navigation, engagement, memorization, anxiety reduction, confidence, and perceived decision-making under pressure.

The platform received high ratings for accuracy and realism, with 90% of participants scoring it as "good" or "excellent." Usability was rated positively by 73% of students. Significant improvements were observed in anxiety reduction and confidence (mean score increased from 2.68 to 4.28) and perceived preparedness (mean 4.41 to 4.76). While students strongly supported the integration of VR as a supplementary tool (mean 4.39 to 4.56), they remained cautious regarding the total replacement of physical labs (mean 3.23 to 3.43).

Metaverse-based emergency simulations represent a feasible, scalable, and cost-effective approach to strengthening both technical and non-technical competencies. The findings support a blended learning model where immersive

technology supplements traditional clinical training, particularly in environments where physical simulation resources may be limited.

Keywords— Anxiety reduction, Confidence, Emergency Simulation-based training, Interprofessional education (IPE), Metaverse, Medical education, Virtual Reality, Undergraduate medical students,

I. INTRODUCTION¹

As part of our ongoing innovation in integrating a flexible metaverse platform and following the success of our VR human anatomy simulation program where students expressed high satisfaction with its interactivity, support for memorization, and reduction of exam-related anxiety we observed strong enthusiasm among students to experience even more dynamic, VR-based clinical scenarios. Many students reported being "extremely excited" to apply their skills in more active and urgent situations after their positive exposure to VR-based anatomy learning [1]. Building on this momentum, we introduced a VR emergency simulation training program for the same cohort of undergraduate medical students. Emergency simulations were chosen because they replicate critical, high-pressure clinical conditions that require rapid decision-making, teamwork, and technical precision skills that are essential for future physicians [2,3]. Three key scenarios were selected to progressively build complexity and emotional resilience: Cardiopulmonary Resuscitation (CPR) allowing students to practice fundamental life-saving techniques

under time constraints, Moderate Asthma Attack (Level 2) helping students recognize respiratory distress and apply immediate management strategies and Victim Triage exposing students to mass casualty situations requiring fast, ethical decision-making and prioritization under stress. These scenarios align with recent trends emphasizing simulation-based learning to improve both technical and non-technical skills in undergraduate medical education [4,5]. The value of VR emergency training is increasingly supported by international research. A study by Makransky et al. showed that VR emergency simulations significantly enhance medical students' clinical decision-making skills and stress management compared to traditional methods [6]. Similarly, Padilha et al. demonstrated that VR training improves emotional coping mechanisms during critical situations, thereby reducing cognitive overload during real emergencies [7]. Our VR platform was designed to be open-access, interactive, and scalable, ensuring its adaptability across different educational contexts. This approach addresses existing barriers in traditional simulation training, such as limited access to mannequins, high costs, and the need for specialized physical facilities issues particularly relevant in resource-limited settings [8,9]. Additionally, the open-access nature of the platform aligns with global educational initiatives advocating for equitable access to innovative learning tools, especially in low- and middle-income countries. By providing flexible, repeatable, and ethically sound emergency simulations, this platform complements the anatomy VR system while preparing students for real-world clinical responsibilities. In line with recent findings, immersive VR fosters a greater sense of presence and urgency during simulations, which translates into better skill transfer to clinical practice [10]. The progressive difficulty of our selected scenarios from basic CPR to complex triage decisions ensures that students gradually build both technical proficiency and psychological readiness. In conclusion, by integrating emergency simulation modules into the VR platform, we extend the benefits observed during the anatomy VR training, offering students holistic and highly interactive preparation for their future medical practice. This project not only enriches the current educational landscape in Tunisia but also offers a scalable model for other institutions globally, particularly those seeking innovative, cost-effective training solutions.

II. RELATED WORKS

To better understand how virtual reality (VR) can support emergency training for medical students, we conducted a detailed review of recent research. A systematic search was conducted in PubMed, Web of Science, Scopus, and the Cochrane Central Register of Controlled Trials (CENTRAL). Key words like “virtual reality,” “emergency simulation,” “medical students,” “clinical training,” and “decision-making skills” guided our search. We followed the PRISMA guidelines to ensure a systematic and thorough review. Several recent reviews and empirical studies highlight the growing impact of VR-based

emergency simulations in medical education. For example, recent systematic reviews report that immersive VR emergency simulations significantly enhance situational awareness, clinical decision-making, and teamwork, which are critical competencies in real-life emergency settings [11, 12].

Meta-analytic evidence further supports these findings. Large-scale analyses have demonstrated that medical students trained using immersive VR perform faster and more accurately in emergency decision-making tasks and show improved clinical performance compared with those trained using conventional methods [13,14].

Beyond cognitive and technical skills, VR-based emergency simulations have been shown to positively influence confidence, preparedness, and emotional regulation. Reviews focusing on acute and emergency care education report that immersive VR training improves learners' self-confidence and readiness for managing scenarios such as CPR, trauma, and respiratory emergencies [15], [16].

Recent experimental studies also indicate that immersive VR environments help reduce anxiety and cognitive overload during high-pressure simulations. By exposing learners to realistic stressors in a safe and controlled environment, VR training supports emotional resilience and improves performance under pressure [17], [18].

Finally, comparative studies evaluating VR against traditional emergency training methods show that students trained with VR exhibit higher engagement, greater satisfaction, and faster skill acquisition, particularly in tasks such as CPR and mass-casualty triage [19], [20]. These findings align with broader educational trends emphasizing simulation-based and technology-enhanced learning to address limited real-world emergency exposure in undergraduate medical curricula.

Building on these insights, our upcoming case study at the Faculty of Medicine represents a natural progression from research to educational innovation. By integrating a scalable metaverse-based VR platform, we aim to deliver an immersive, evidence-based, and student-centered training environment that enhances clinical reasoning, emotional resilience, and preparedness for high-pressure emergency situations, positioning our university at the forefront of regional medical education innovation.

III. METHODOLOGY

This study builds upon previous research that evaluated the effectiveness of a virtual reality (VR) human anatomy simulation training program for undergraduate medical students at Ibn Al-Jazzar University. Maintaining continuity with the same cohort of 179 second-year students from the Faculty of Medicine, we extended our investigation to assess the impact of VR-based emergency simulation training. This approach ensures consistency in

participants' backgrounds and learning exposure, enabling a robust comparative analysis at the conclusion of the study.

The emergency training component was introduced as a subsequent phase, allowing students to engage with immersive, progressively challenging scenario-based simulations. These scenarios were designed to reflect real-world emergencies, beginning with basic cardiopulmonary resuscitation (CPR) during cardiac arrest, followed by managing a level 2 asthma crisis, and culminating in complex decision-making involving the prioritization of multiple victims in a mass casualty situation.

Pre- and post-training questionnaires and assessments were used to measure not only perceived realism, ease of use, and engagement but also key competencies such as rapid reaction under stress, confidence in handling dangerous situations, and the ability to make critical decisions under pressure. These cognitive and emotional dimensions are crucial for emergency preparedness and professional readiness in medical students.

As with the anatomy module, the VR emergency training platform remains open-source, cost-effective, and scalable for deployment in a variety of educational contexts. By continuing with the same student group, this methodology supports longitudinal insight into the effectiveness of VR integration in medical education and allows for meaningful comparisons across different clinical training domains.

A. Study Design and Sample Selection

To ensure continuity in evaluating progressive VR training from foundational anatomy to complex emergency scenarios, the same cohort of 179 second-year medical students who previously completed the VR anatomy simulation was invited to participate in this emergency training study. This longitudinal design enabled a seamless assessment of skill progression, as participants were already familiar with the VR platform's navigation and interaction mechanics.

The final sample comprised 152 students, as some participants could not be reached or withdrew due to personal reasons. Despite this reduction, the sample size originally calculated using Cochran's equation (95% confidence level, $P = 0.5$, $d = 0.05$) remained statistically adequate for this phase of the study.

By retaining the same participants, we minimized inter-group variability and isolated the effect of VR training on advanced emergency competencies, including rapid decision-making during CPR, triage prioritization, and performance under high-stress conditions. Building on the methodology of the prior anatomy study, a crossover design was implemented, whereby each group experienced both VR-based and traditional training modules in alternating sequences. This design ensured methodological comparability while reducing confounding factors such as platform learning curves and baseline familiarity.

1. Eligibility Criteria:

The study retained the same cohort of second-year medical students from the VR anatomy training to ensure continuity in skill development from basic anatomical understanding to advanced emergency care. Participant selection was guided by two core principles:

- Curriculum coherence: Emergency scenarios were designed to build directly on previously acquired anatomical knowledge and early clinical exposure.
- Controlled progression: Using the same participants eliminated variability related to VR platform familiarity.

Eligibility criteria included:

- Current enrollment in the second year of medical school
- Prior completion of the VR anatomy training module
- No external VR emergency training outside the study
- No medical conditions contraindicating VR use (e.g.: epilepsy, severe motion sickness, uncorrected visual impairment)
- Reconfirmed informed consent for participation in this phase

New consideration:

Successful completion of the VR anatomy module served as confirmation of participants' readiness for advanced emergency simulations. This approach:

- Controlled for individual learning curves
- Maintained ethical continuity without re-screening for prior conditions
- Preserved a structured progression from simple (anatomy) to complex (emergency) tasks

2. Setting and Recruitment

The study was conducted at the Ibn Al-Jazzar Faculty of Medicine, utilizing university facilities to maintain consistency with the prior VR anatomy study. Recruitment targeted the same student cohort, with communication maintained through email, WhatsApp, and phone calls to coordinate participation and scheduling.

Written informed consent was reconfirmed for this phase, with specific emphasis on:

- The advanced and high-stress nature of emergency scenarios

- The right to withdraw at any time without penalty

Participants were explicitly informed that simulations such as CPR and time-pressured triage could be more psychologically demanding than the earlier anatomy training.

3. Demographics and Gender Distribution

Participants' ages ranged from 18 to 23 years (mean = 20.3, SD = 1.4). The gender distribution remained consistent with the anatomy phase (85 females, 67 males), closely reflecting the medical school's enrollment demographics. This demographic stability enabled direct comparison between anatomy and emergency training outcomes without demographic confounding.

4. Normality Testing and Effect Size Reporting

Data normality was assessed using the Shapiro–Wilk test for all primary outcomes, including

- Emergency scenario completion time
- Accuracy of triage prioritization
- Stress-response indicators

For between-group comparisons (VR vs. traditional training), Cohen's *d* was reported to quantify effect sizes, with particular focus on:

- Decision-making speed under time pressure
- Clinical accuracy in high-stakes scenarios
- Pre- and post-training anxiety levels

5. Handling of Missing Data

Consistent with the anatomy study, listwise deletion was applied, including only participants with complete datasets in the final analysis. This ensured methodological consistency and strengthened the validity of comparisons across both study phases, particularly for stress perception and confidence measures.

6. Confounding Variables

Building on the prior anatomy study, multivariate regression analysis was employed to isolate the effects of VR training while controlling for potential confounders. Emergency-specific variables included:

- Prior clinical exposure (e.g., CPR certification, emergency rotations)
- Stress resilience
- Scenario difficulty progression

Modified control from anatomy phase: Baseline anatomy knowledge was excluded as a covariate, as all participants completed standardized VR anatomy training. This allowed the analysis to:

- Focus solely on emergency skill acquisition
- Avoid over-adjustment in a uniformly trained cohort
- Isolate VR's impact on time-sensitive clinical decision-making.

B. Questionnaire Development and Validation

The questionnaire used in this study was specifically developed for this research to assess students' perceptions of the VR emergency simulation. It builds upon a validated instrument previously used by the authors to evaluate VR anatomy training [1]. The original eight items, which focused on engagement, memorization, and anxiety reduction, were supplemented with two new items specifically designed for the emergency context: panic reduction in critical situations and the speed of clinical decision-making. To ensure content validity and reliability, the expanded questionnaire was reviewed and refined by a professional team with expertise in medical education and emergency medicine. An English language version of the questionnaire has been uploaded as a supplementary file [22].

The questionnaire was divided into two sections:

The first section comprised Likert scale questions (from 1 to 5) to quantitatively assess the effectiveness of the VR training. Each question targeted specific factors, including:

Engagement: How engaging did you find VR training?

(1 = Not engaging, 5 = Highly engaging)

Effectiveness: How effective was VR training in helping you understand and manage medical emergency situations?

(1 = Not effective, 5 = Extremely effective)

Anxiety Reduction & Memorization: Do you think the VR training reduced your anxiety and enhanced your ability to recall emergency protocols?

(1 = Not helpful, 5 = Very helpful)

Panic Reduction: Do you believe that VR simulation reduces panic in real-life critical situations?

(1 = Not at all, 5 = Very significantly)

Decision-Making Speed: Do you believe that VR simulation improves the speed of decision-making in emergency situations?

(1 = Not at all, 5 = Very significantly)

The second section consisted of open-ended questions, allowing students to express their perspectives, highlight

the strengths of the VR platform, and offer constructive feedback for future improvements.

Pre- and post-simulation responses were analyzed to identify shifts in perception and assess the impact of VR emergency simulation training on students' learning experiences and confidence in critical care scenarios.

C. Scenarios design

1. Cardiopulmonary Resuscitation CPR

While waiting to be seen in the hospital's outpatient clinic, a 56-year-old male collapses in front of the student team. The students are expected to initiate immediate assessment and Basic Life Support (BLS), activate emergency response, and prepare for Advanced Cardiovascular Life Support (ACLS) until the resuscitation team arrives (Fig 1).



Figure 1 CPR scene

By the end of the simulation, students will be able to rapidly identify cardiac arrest, initiate and perform high-quality Basic Life Support, and safely operate an Automated External Defibrillator in accordance with clinical guidelines. They will demonstrate effective teamwork by activating emergency responses, assigning roles, and communicating clearly under pressure using closed-loop communication and SBAR handover. Students will also accurately document all interventions and reflect on both individual and team performance. In addition, the simulation develops awareness of the psychological impact of emergency events, fostering empathy, reassurance, and emotional self-regulation when managing patients, bystanders, and healthcare teams during and after high-stress scenarios.

2. Patient with asthma level 2

Sami is a 37-year-old male who presents to the clinic for a follow-up appointment related to worsening of his asthma. He is in stable condition but in the “yellow zone” according to her Asthma Action Plan. Students should perform a focused subjective and objective respiratory assessment, analyze her respiratory status

according to her Asthma Action Plan and Asthma Severity protocol, report abnormal findings to the provider, perform patient education, and accurately document findings (Fig 2).

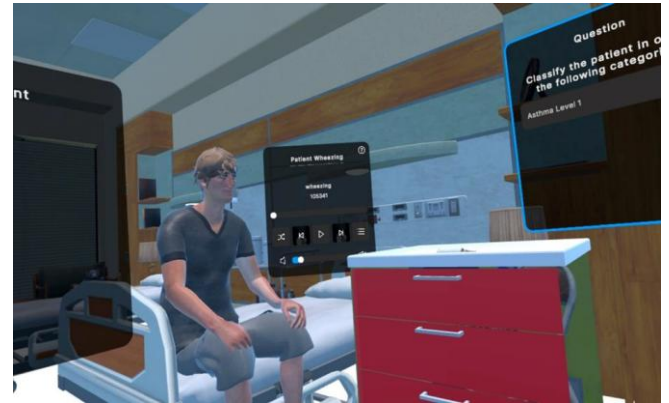


Figure 2 Moderate Asthma case simulation in a clinic room setting

The learning objectives of this scenario are to enable students to accurately perform a focused respiratory assessment, recognize and appropriately respond to deviations from normal respiratory findings, and provide clear patient education on the correct administration of respiratory medications. In addition, students will develop therapeutic communication skills and learn to report complete, accurate, and relevant clinical information effectively to the healthcare team.

3. Prioritize Victims scenario

In a chaotic late-afternoon emergency in downtown Sousse, near the busy intersection of Rue de la République and Boulevard Mohamed V, a violent multi-vehicle collision involving a police car, a delivery van, and a civilian SUV has brought traffic to a standstill. Three heavily damaged vehicles block the street, one of them engulfed in flames, sending thick black smoke into the sky as firefighters remain on route. Sirens from approaching emergency vehicles, shouting bystanders, and the persistent buzz of a drone intensify the sense of urgency, while the smell of burning rubber and gasoline fills the air. Police have secured the area with yellow tape, struggling to manage a panicked crowd as an ambulance arrives abruptly on scene. Amid this high-stress environment, your team of medical students arrives on foot as part of an emergency response drill, equipped with triage kits and protective gear. Your task is to rapidly assess and prioritize all victims using the START (Simple Triage and Rapid Treatment) system, focusing on identifying life-threatening injuries, making swift and objective triage decisions, and demonstrating effective teamwork and situational awareness under pressure.

D. Study Procedure

1. Pre-Simulation Phase

Students first participated in a 15-minute orientation session introducing the VR-based emergency training application. The briefing covered the fundamentals of navigating the virtual environment, recognizing critical patient information, and applying the START triage system in mass casualty scenarios. Students were shown how to interact with virtual victims, interpret vital signs, and use the interface to assess injury severity and urgency.

Following the orientation, participants completed a pre-simulation survey to evaluate their baseline perceptions regarding VR-based emergency learning. The survey assessed factors such as:

- Confidence in managing multi-casualty incidents
 - Perceived usefulness of VR for enhancing memorization of triage procedures
 - Levels of pre-simulation anxiety related to decision-making under pressure
 - Familiarity with prioritization frameworks like START
- This phase aims to establish students' initial preparedness and expectations before engaging in the immersive emergency response simulation.

2. VR Simulation and Assessment

2.1. VR Simulation procedure

Building on their previous experience with the VR-based anatomy simulation, students entered the emergency response training phase. This phase was intentionally designed to progress from simple to complex scenarios, allowing students to adapt gradually to clinical stressors, enhance their decision-making skills, and build situational awareness in high-pressure environments. To accommodate individual preferences and ensure a comfortable learning experience, users could choose to join a public room for collaborative learning or a private room if they preferred more privacy (Fig3,4). This flexible setup allowed participants to engage at their own pace and comfort level, fostering both teamwork and personal reflection during the interactive training sessions.

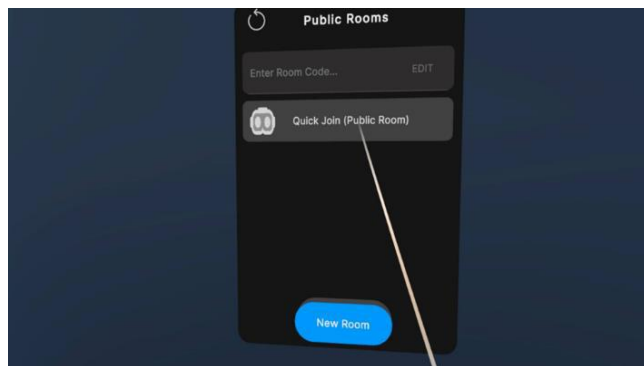


Figure 3 Public room joining

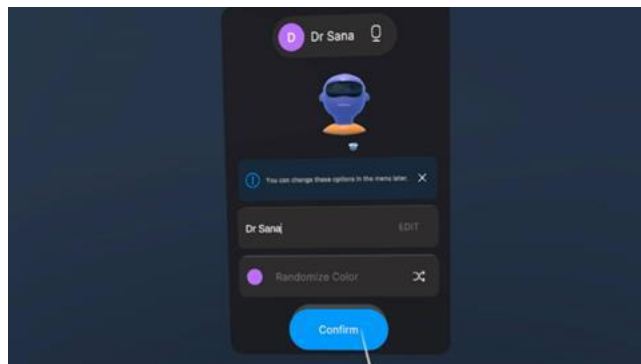


Figure 4 Private room joining

Before launching the simulation phase, a pilot test was conducted to determine the ideal session length. Based on feedback, a duration of 45 minutes per session was selected to allow sufficient time for exploration, clinical action, and post-scenario assessment—while avoiding cognitive overload or fatigue.

Scenario 1: CPR Resuscitation – Foundational Emergency Response

Focused on basic life support for an unresponsive patient in cardiac arrest, allowing students to practice algorithmic response and manual skills in a low-pressure setting.

Scenario 2: Asthma Exacerbation – Managing a Time-Sensitive Crisis

In the second scenario, students responded to a middle-aged patient experiencing severe asthma exacerbation. The patient was sitting upright, struggling to breathe, and had an audible wheeze. Panic, crowd noise, and the patient's rising anxiety added realism to the environment.

This scenario focused on clinical reasoning, rapid symptom recognition, and correct intervention under pressure.

Scenario 3: Mass Casualty Triage – Advanced Decision-Making

The final scenario placed students at the scene of a large-scale traffic accident in downtown Sousse, involving multiple victims with varying injuries.

The virtual system displayed vital information upon approaching each victim (Fig5). Multiplayer functionality allows students to coordinate decisions with peers and instructors, promoting collaborative problem-solving. Instructors joined as avatars to provide real-time guidance and observe performance.



Figure 5 Patient status

2.2. Simulation Features and Assessment

After each scenario, students were prompted to complete an integrated quiz within the VR system. The questions focused on:

- Critical actions performed
- Recognition of clinical signs
- Justification of triage decisions or treatments

Each question allowed only one attempt, encouraging thoughtful responses. Immediate feedback helped students identify strengths and areas for improvement.

The session ended when the student selected the “Go Home” button, returning to the main VR menu.

Instructors monitored each simulation via shared displays or control dashboards, enabling them to observe clinical decision-making, identify learning gaps, and deliver real-time support. The multiplayer functionality enriched this process by allowing instructors to engage directly with students inside the virtual environment using interactive avatars, fostering a truly immersive and adaptive teaching experience.

This progressive simulation model ensured a scaffolded learning experience, gradually increasing in complexity and realism. It helped students transition smoothly from practicing isolated skills to managing complex, multi-patient scenarios with confidence and clinical competence (Fig 6).

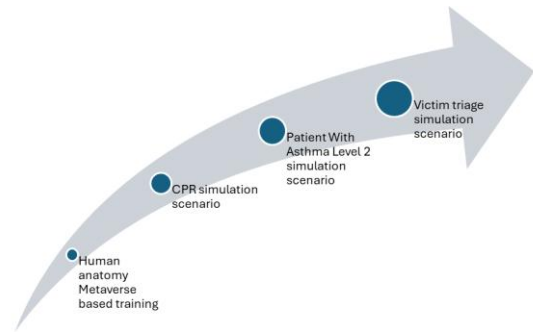


Figure 6 Metaverse Simulation: From Anatomy to Emergencies

3. Post-Simulation Phase

After completing the three emergency simulation scenarios, students were asked to fill out a post-simulation survey, which included the same eight questions from the pre-survey. The aim was to reassess their perceptions of VR-based training with a specific focus on emergency preparedness.

Key dimensions evaluated included:

- Perceived realism and clinical accuracy of the emergency scenarios
- Ease of navigation within high-pressure environments
- Level of engagement and immersion during triage and decision-making
- Impact on clinical confidence, especially in CPR and asthma management
- Effectiveness of VR in memorizing emergency protocols
- Reduction in stress and anxiety related to practical emergency exams

In addition, an open-ended section invited students to reflect on their experience with the VR emergency platform, including suggestions for improvements and feedback on how the progressive structure from CPR to triage affected their learning curve and adaptability.

Most students reported increased motivation to continue using the platform across other emergency topics. Many appreciated the stepwise structure of scenarios, stating that it helped them transition from simple tasks to complex decision-making in a manageable and confidence-building way.

To evaluate the long-term impact of the training, all participants were contacted again through the academic year after their initial simulation.

This follow-up assessed:

- Knowledge retention of emergency procedures
- Continued confidence in real-world triage or CPR settings
- Willingness to use VR for future clinical training modules

These insights were crucial in determining the effectiveness of VR-based emergency training as a

sustainable and scalable method for developing clinical competence in undergraduate medical students.

E. Data Analysis

Survey responses were collected electronically throughout the continuous VR-based emergency training program. The data was analyzed using Microsoft Excel, focusing on frequencies and percentages to assess the perceived benefits and learning outcomes of the three emergency scenarios: CPR resuscitation, asthma management, and mass casualty triage.

A comparative analysis was performed between the pre- and post-simulation surveys to assess changes in student perceptions regarding:

- The realism and clinical utility of the VR scenarios
- Ease of use and immersion in emergency environments
- Impact on confidence, memorization of protocols, and exam-related anxiety
- Effectiveness of VR training compared to traditional emergency drills

This analysis helped us better understand how students' attitudes evolved through the step-by-step simulation experience and whether the increasing complexity of scenarios enhanced their learning outcomes.

To ensure the accuracy and reliability of our results, an independent biostatistics expert reviewed and validated the statistical methods used.

Before starting the study, all students provided updated written informed consent after receiving a clear explanation of the study's objectives, procedures, potential benefits, and any associated risks. An information session was conducted to make sure participants understood that their participation was voluntary and that they could withdraw at any time without any academic consequences.

The study strictly followed all relevant ethical guidelines, including the standards of the university's research ethics committee. Ethical approval was granted under DECISION N°256 [Ref: CEFMS 256/2024].

To protect participant privacy, all data remained confidential and anonymous. While we collected contact details such as email addresses and phone numbers for follow-up purposes, each student was assigned a unique identification number instead of using their name. This allowed us to accurately track individual progress and perform comparative analysis while safeguarding their identity. All data was securely stored and used exclusively for research and educational development.

By following these procedures, the study ensured that participants' rights, safety, and privacy were fully respected throughout the emergency training program. the research process.

IV. SOFTWARE DEVELOPMENT

The metaverse platform was developed using Unity 3D, a powerful and widely used real-time development engine that supports the creation of interactive, immersive, and high-fidelity simulations [21].

Unity 3D is known for its cross-platform capabilities, allowing the simulation to run seamlessly on various devices such as VR headsets, desktops, and even mobile systems making it accessible for both classroom and remote learning.

Unity 3D provided flexibility to design lifelike environments for emergency scenarios such as CPR resuscitation, asthma management, and mass casualty triage. Using Unity's built-in physics and lighting systems, we were able to simulate realistic conditions such as collapsing patients, loud ambulance sirens, smoke effects, auditory cues like sirens (Fig 7) and wheezing sounds that replicate the urgency of real-life emergencies (Fig 8). These sensory elements help students develop situational awareness and remain calm under pressure.



Figure 7 Public accident scene

The platform was built in modular Unity scenes, with each scene representing a specific emergency setting. Within each scene, students could interact with dynamic 3D patients and medical tools through intuitive controls. Unity's collision detection, animation systems, and AI-based scripting allowed for realistic patient behavior, such as labored breathing, convulsions, or loss of consciousness offering students real-time clinical clues to inform their decisions.



Figure 8 patient with Asthma in a clinic room

Most importantly, Unity enabled the integration of a robust multiplayer system. Students enter the simulation as avatars either named or anonymous and collaborate with peers and instructors in real-time. Unity's networking and synchronization features ensure smooth communication and coordinated actions among all users, even if they're joining remotely from different devices. For instance, during a CPR simulation, one student can perform compressions while another manages the airway, and a third monitors vital signals while an instructor guides or observes the session.

The instructor avatar feature allows teachers to actively participate inside the virtual scenario, making it possible to provide live support, demonstrate techniques, or simulate patient changes in response to student actions. This transforms the platform into a truly interactive and adaptive learning environment, reinforcing team-based emergency response training.

In summary, Unity 3D was critical in creating a flexible, realistic, and collaborative VR experience tailored to the needs of emergency medical education. Its rich toolset, performance optimization, and strong community support made it the ideal foundation for building our next-generation training solution.

The home screen of the VR application is designed as a virtual central hall, serving as the main hub where students can access different emergency training scenarios. Around the hall are several doors, each clearly labeled to represent a specific module such as CPR resuscitation, asthma management, or mass casualty triage (Fig 9).

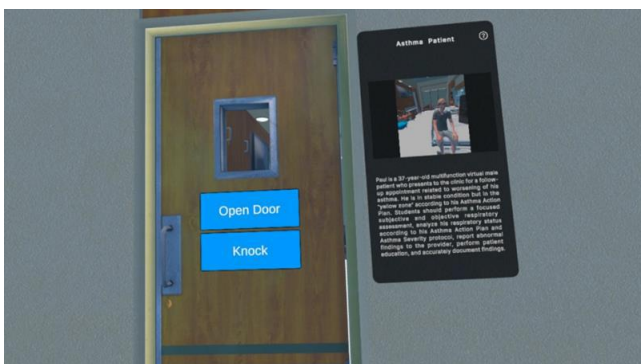


Figure 9 Asthma Scenario door

Students move through the space using their VR pointing devices (joysticks or hand controllers). By simply pointing and selecting a door, they are instantly transported into the corresponding training scenario.

For example, choosing the door labeled "Triage Scenario" takes the student directly into a realistic public road accident scene. Once the simulation is complete, the student can click the "Go Home" button to return to the central hall. From there, they can approach and open another door to begin a new emergency scenario (Fig 10).



Figure 10 Application home screen

This user-friendly structure allows students to move smoothly between simulations, gradually building their confidence and clinical decision-making skills as they progress through increasingly complex emergency situations.

As part of the emergency VR training, students are evaluated through various assessments designed to test their understanding of each scenario whether it's CPR, asthma management, or mass casualty triage. Each question can be answered only once, and after submission, it becomes locked.

In the CPR scenario, students receive real-time alerts if their technique is incorrect such as improper rhythm or hand placement helping them adjust their actions on the spot.

In the asthma management scenario, students are asked to assess the severity of the attack based on wheezing sounds and patient-reported symptoms (Fig 11).



Figure 11 Asthma scenario assessment

In the mass casualty triage scenario, students must prioritize four victims by assigning them triage numbers from 1 to 4 (Fig 12). This task requires navigating between each victim, gathering clinical clues, and then completing the triage activity located near the “Exit” button. After submitting their decisions, students are transported to a virtual hospital lobby, where they can either exit the metaverse platform or choose to replay another scenario for additional practice.



Figure 12 the mass casualty triage scenario

This instant visual feedback highlighting correct and incorrect responses reinforces learning by helping students clearly see where they made the right choices and where they need improvement.

Additionally, students have access to short instructional videos within the VR application. These cover essential emergency procedures, such as airway management and chest compressions, and serve as valuable revision tools. These clear, repeatable visual demonstrations help strengthen students’ understanding and improve their performance in the assessments.

The technical performance of the emergency VR training platform was carefully reviewed and continuously improved in collaboration with a Unity 3D expert, ensuring a smoother and more user-friendly experience. If students encounter any unexpected issues such as freezing or glitches simply exiting and restarting the application usually resolves the problem and restores full functionality. To make training more interactive, multiplayer functionality was introduced within the metaverse

environment, allowing students to collaborate in real time with classmates and instructors. This feature significantly enhances team-based learning, especially during scenarios like mass casualty triage, where decision-making and communication are critical.

However, one ongoing challenge is the platform’s reliance on a stable internet connection, which can occasionally affect performance, especially in multiplayer scenarios where real-time collaboration is essential. Since teamwork is a critical component of emergency training, switching to single-player mode isn’t an ideal solution.

A more effective approach would be to enable local network connections (such as through a shared Wi-Fi network), allowing students in the same room to remain connected and continue training together even if the internet connection drops.

Additionally, the platform could incorporate an auto-reconnect feature that silently works in the background to restore lost connections, minimizing disruption and maintaining training continuity.

These improvements would enhance the platform’s reliability while preserving the collaborative, hands-on learning experience that is crucial for effective emergency training.

V. DISCUSSION AND RESULTS

The results showed that students were very positive about using VR for emergency training. They felt the realistic scenarios like CPR, asthma attacks, and accident triage helped them better understand what to do in real emergencies.

Many said VR made learning more engaging and that working with others in the multiplayer mode improved their teamwork skills. Overall, students felt more confident and prepared after the training, showing that VR can be a helpful tool alongside traditional medical education.

5.1. Perceived Accuracy and Realism:

The chart below illustrates students’ perceptions of the accuracy of VR-based emergency training. A significant majority 47% rated the simulation as good (4/5), while 43% rated it as excellent (5/5), indicating strong confidence in the platform’s realism and reliability. Only 9% gave it an average score (3/5), and just 1% rated it poor (2/5), with no responses in the lowest category. Overall, 90% of participants felt that the simulation accurately represented real-life emergency scenarios, confirming the effectiveness of the VR tool in delivering realistic and high-quality training experiences (Fig 13).

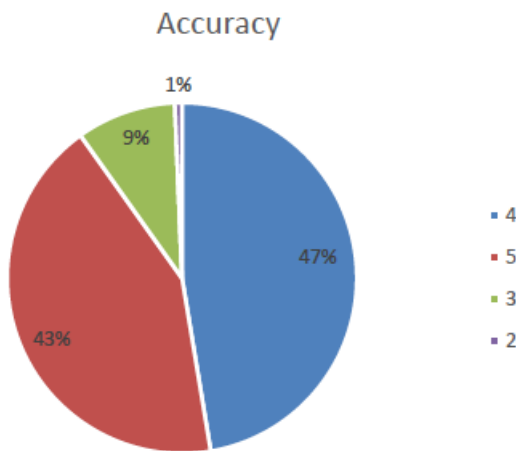


Figure 13 Accuracy perception chart

The chart below shows students' ratings of the realism of the VR-based emergency training. Most students gave positive feedback, with 40% rating realism as good (4/5) and 33% as excellent (5/5). This suggests that over 70% of students found the VR scenarios to be realistic and believable. Additionally, 22% gave an average rating (3/5), indicating that some students felt the experience could be improved but was still acceptable. Only 5% gave a low rating (2/5), showing minimal dissatisfaction. Overall, the results reflect a generally favorable perception of how well the VR simulations mirrored real-life emergency situations (Fig 14).

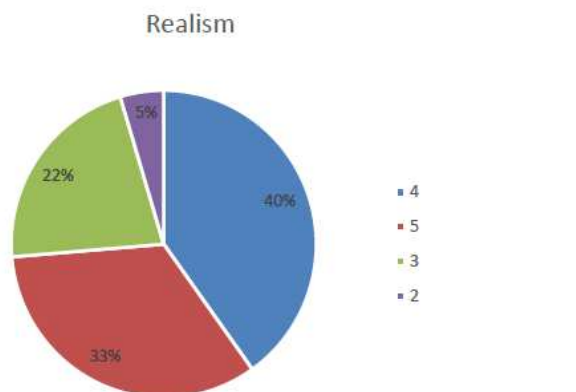


Figure 14 realism perception chart

5.2. Ease of Navigation:

The pie chart presents students' feedback on the ease of navigation within the VR-based emergency training platform. The results show that 41% of students rated navigation as good (4/5) and 32% as excellent (5/5), indicating that nearly three-quarters of participants found the system user-friendly and easy to move through.

Another 24% gave an average rating (3/5), suggesting that while functional, some found it could be more intuitive. A small percentage of students reported difficulties: 2% rated it as poor (2/5), and 1% as very poor (1/5).

The overall user feedback is highly positive, demonstrating that most participants navigated the virtual environment with ease. However, the data also suggests that certain students could benefit from enhanced onboarding processes or further interface refinements to optimize their experience (Fig. 15). These observations align with broader research into immersive 3D learning materials, which emphasizes the importance of balancing innovative interactive tools with traditional training methods to ensure maximum effectiveness across all user groups. Importantly, our VR platform was designed to be easy to use and accessible for all types of schools. Unlike other VR systems that need expensive subscriptions or special equipment, our platform is light, flexible, and works well even with basic computers and low-cost VR headsets. This makes it suitable for both well-funded and low-resource institutions.

It also includes a multiplayer mode, allowing students to train together with classmates or teachers in real time. This teamwork feature helps students learn from each other, get support when needed, and feel more confident using the platform.

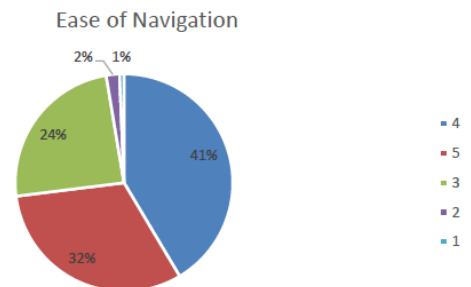


Figure 15 Ease of use chart

5.3. Engagement and memorization improvement

The pie chart titled "Memorization" illustrates participants' perceptions of how effectively the learning intervention supported their ability to memorize course content. The results reveal a strong positive response, with 80% of respondents rating the experience at the highest level (5), indicating that the intervention likely involving immersive or interactive learning methods was highly effective in enhancing memory retention. An additional 18% rated it as 4, suggesting that while they found it beneficial, there may have been minor limitations or areas for improvement. Only 2% of participants gave a neutral score of 3, indicating a minimal level of dissatisfaction. These individuals may have faced technical difficulties, lacked familiarity with the tool, or preferred more traditional learning methods. Overall, the chart demonstrates that 98%

of students responded positively to the intervention, underscoring its strong potential to support memorization through engaging and interactive educational experiences (Fig 16).

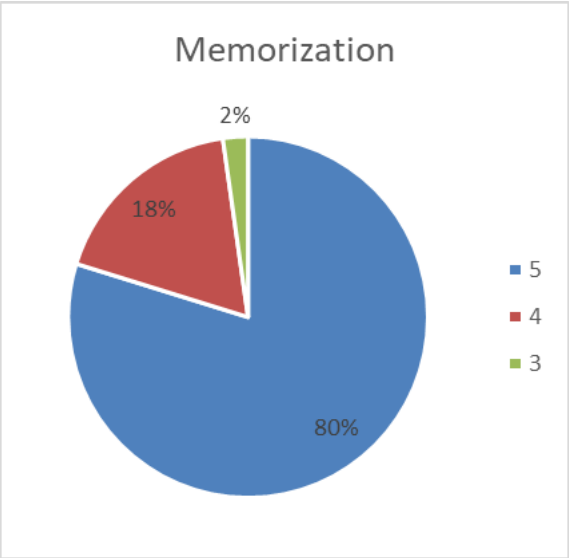


Figure 16 Memorization improvement chart

The pie chart titled "Engagement within the virtual scenario" reflects participants' evaluations of their level of engagement while interacting with the virtual learning environment. The data shows that 58% of respondents gave the highest rating (5), suggesting that the majority found the virtual scenario highly engaging and immersive. This implies that the scenario successfully captured learners' attention and encouraged active participation, likely due to its interactive design and realism. Additionally, 29% rated their engagement at level 4, indicating a generally positive experience with minor reservations. 12% of respondents rated it at level 3, showing a moderate level of engagement, possibly due to individual differences in learning preferences or challenges navigating the virtual environment. A very small minority 1% rated their engagement at level 2, suggesting that for a few participants, the scenario may not have met their expectations or needs. Overall, with 87% rating their engagement as 4 or 5, the chart highlights a strong endorsement of the virtual scenario's ability to effectively involve learners and create an interactive educational experience (Fig17).

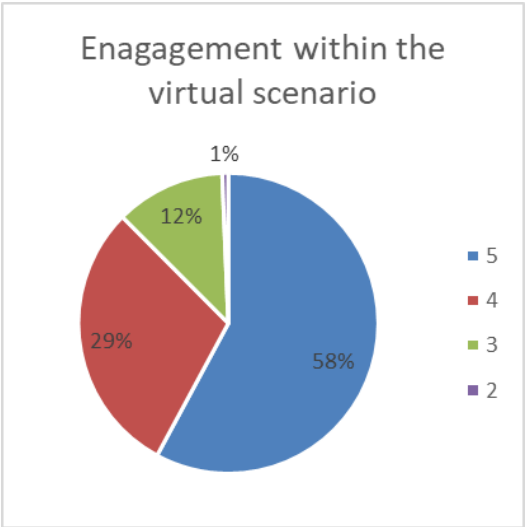


Figure 17 Engagement within the virtual scenario chart

5.4. Reduce of anxiety

The pie chart titled "Reduce Anxiety and Increase Confidence" presents participants' perceptions of how effectively the intervention, likely a metaverse-based or virtual simulation platform, helped reduce their anxiety and boost their confidence. The data reveals that 47% of respondents rated the experience as 4, and 41% gave the highest rating of 5, indicating that nearly 88% of students experienced a strong positive impact on their emotional readiness. Only 11% rated it at 3, reflecting a moderate benefit, while just 1% gave a lower rating of 2 (Fig 18). This overwhelmingly positive feedback can be attributed to the unlimited and flexible practice opportunities provided by the Metaverse platform. Students are allowed to repeatedly immerse themselves in realistic emergency scenarios at their own pace and without the pressure of real-world consequences.

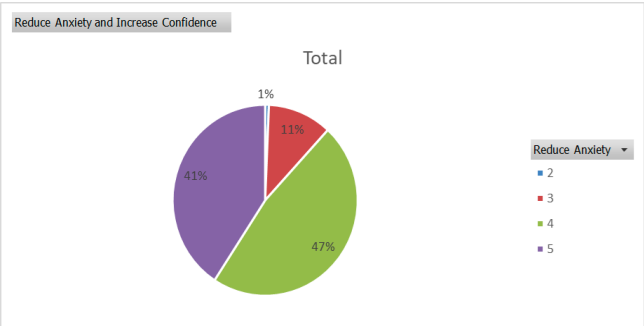


Figure 18 Reduce of anxiety and confidence-built chart

Over time, this repeated exposure builds familiarity and automaticity, helping students develop a sense of control and preparedness. As a result, their anxiety is significantly reduced, and their self-confidence increases, not only during exams but also in real-life emergency situations. The safe, engaging, and adaptive environment of the metaverse allows students to make mistakes, learn from them, and gradually master complex decision-making under pressure

key factors in shaping calm, confident future healthcare professionals.

5.5. Comparison of students' perception

The table 1 presents the results of a comparative analysis conducted to evaluate the impact of a Virtual Reality (VR) intervention on students' learning experiences. It highlights the mean scores and standard deviations for three key factors: Anxiety Reduction and Confidence Built, Memorization and Apprehension Improvement, and Engagement and Learning Efficiency measured both before and after the VR-based activity. The purpose of this analysis is to assess the effectiveness of VR in enhancing emotional, cognitive, and behavioral aspects of student learning.

Table 1: Comparison of students' perception

Factor	Pre-VR Mean (M) ± SD	Post-VR Mean (M) ± SD
Anxiety reduction and confidence built	2.68 ± 1.09	4.28 ± 0.69
Memorization and apprehension	4.41 ± 1.02	4.76 ± 0.47

The results from the pre- and post-training surveys show that the VR experience had a strong, positive impact on students' learning. One of the biggest changes was in how students felt emotionally after the VR training, they reported feeling much less anxious and more confident, with the average score rising from 2.68 to 4.28. This suggests that the safe, hands-on virtual environment helped reduce stress and allowed students to practice without fear of making mistakes.

Students also showed improvement in memorization and felt more prepared, with scores going up from 4.41 to 4.76. On top of that, the difference in responses between students became much smaller, meaning most of them shared a similar, positive experience. The interactive and visual nature of VR likely made it easier for them to understand and remember complex concepts.

When it came to engagement and learning efficiency, the average score also went up slightly from 4.39 to 4.45. Even though the improvement wasn't large, it shows that students continued to feel involved and motivated. The wider range in responses here may reflect personal differences in how students adapt to new technology, but overall, engagement remained high.

What really stands out is that after using VR, students not only rated the experience more positively they also became more consistent in how they felt about it. Before the training, opinions were more mixed, especially around anxiety and learning comfort. But afterward, most students agreed: the VR training helped them feel calmer, more focused, and better prepared.

In short, VR training didn't just help students learn better, it also helped them feel better. It created a shared, supportive environment where most students felt confident, engaged, and ready to learn. This shows that VR can be a great addition to traditional teaching methods, offering both emotional support and a powerful way to practice skills in a safe, interactive way.

5.6. Interest in the Integration of Metaverse-Based Learning

The pie chart illustrates students' perceptions regarding the integration of Virtual Reality (VR) as a learning tool, measured on a Likert scale from 1 to 5, where 5 represents the highest level of agreement or satisfaction. Most respondents, 58% rated the integration as a 5, indicating strong approval and recognition of VR's effectiveness in enhancing their learning experience. An additional 41% rated it as a 4, further reinforcing a positive reception. Only 1% gave a rating of 3, while ratings of 1 or 2 were entirely absent (0%), suggesting that no participants expressed significant dissatisfaction or disapproval (Fig 19).

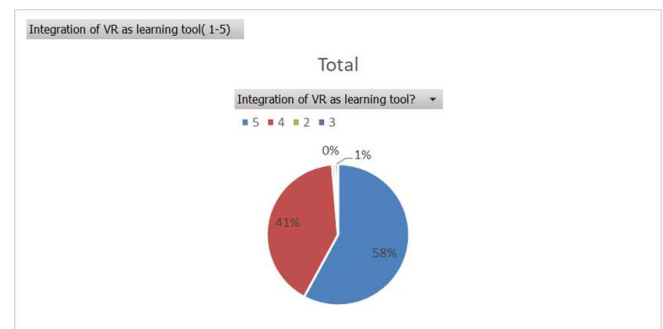


Figure 19 Integration of VR as learning tool

This overwhelmingly positive response (a combined 99% rating of 4 or 5) suggests that students not only accepted the use of VR but also found it highly valuable in their educational context. The absence of low ratings further supports the conclusion that the integration was well-executed and met learners' expectations in terms of engagement, understanding, and overall impact. This finding aligns with the earlier table's results, where VR was shown to significantly reduce anxiety and improve memorization. Overall, the data highlights the strong potential of VR to be an effective and well-received educational tool when thoughtfully implemented.

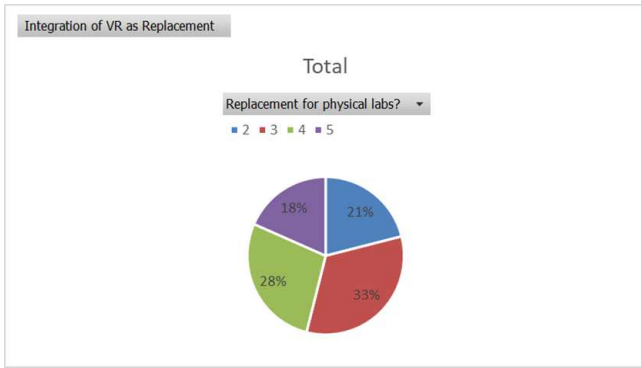


Figure 20 Integration of VR as replacement

The pie chart provides insights into students' perceptions of Virtual Reality (VR) as a replacement for physical labs, using a Likert scale ranging from 2 to 5. The responses show a more diverse distribution of opinions compared to the previous chart focused on VR as a general learning tool. The largest group, 33%, rated the replacement potential of VR as a 3, suggesting a neutral or moderately skeptical stance. Following that, 28% gave it a 4, showing moderate support, while 21% rated it a 2, reflecting noticeable concern or disagreement about VR's ability to fully replace physical lab experiences. Only 18% rated the replacement potential as a 5, indicating strong approval (Fig 20)

This distribution suggests that while many students acknowledge VR's educational value, there is greater hesitation about its use as a complete substitute for physical labs. Most responses fall in the mid-range (2–4), reflecting a mixed sentiment: students may appreciate the benefits of VR such as safety, accessibility, and visualization but still value the hands-on, tangible learning experiences that physical labs uniquely provide. In summary, while VR is seen as a valuable supplementary tool, its role as a full replacement for traditional lab environments remains contested, indicating the importance of a blended approach that combines virtual and physical learning experiences (Fig 20).

To evaluate the impact of Virtual Reality (VR) exposure on students' attitudes toward its integration as a supplementary learning tool, we opted to compare their perceptions before and after the VR-based educational experience.

Table 2: Students interest in VR scenarios usage

Factor	Pre-VR Mean (M) ± SD	Post-VR Mean (M) ± SD
Integration of VR as an additional learning tool	4.39 ± 1.01	4.56 ± 0.55
Integration of VR as a replacement for physical labs	3.23 ± 0.8	3.43 ± 1.02

The table 2 highlights how students felt about using Virtual Reality (VR) in their medical education both as an extra

tool to support learning and as a possible replacement for traditional lab sessions.

First, when it comes to using VR as an additional learning tool, students already showed a strong level of interest even before trying it, with an average score of 4.39 out of 5. After using the VR system, their opinions became even more positive, with the score rising to 4.56. What's even more telling is the drop in variation among responses from 1.01 to 0.55 which means students not only liked the idea more after trying it but also started to agree more with each other. Even those who may have been unsure at first seemed to come around once they had experienced technology in action. This shows that the hands-on use of VR helped validate its usefulness, making students more confident that it truly supports their learning in a meaningful way.

On the other hand, when asked whether VR could replace physical lab work, students were noticeably more cautious. The average score started at 3.23 and only increased slightly to 3.43 after the VR experience. The larger standard deviation after the training (1.02) tells us that opinions were still quite mixed. While some students may have warmed up to the idea, others remained hesitant likely because real-life labs provide essential hands-on practice that VR can't fully replicate yet. For many, the physical experience of working with real materials and patients remains a core part of becoming a competent doctor.

In summary, students clearly see VR as a valuable and exciting addition to their education, especially after trying it for themselves. It helps them feel more engaged, confident, and supported in their learning. But at the same time, they don't believe it should replace traditional methods entirely. Instead, they prefer a balanced approach one that blends the strengths of new technologies like VR with the irreplaceable value of real-life, hands-on training. This reinforces the idea that in modern medical education, VR works best as a powerful partner, not a stand-in.

VI. CONCLUSION

Overall, user feedback has been highly positive, demonstrating that most participants navigated the virtual environment with ease. However, the data also suggests that certain students could benefit from enhanced onboarding processes or further interface refinements to optimize their experience. These observations align with broader research into immersive 3D learning materials, which emphasizes the importance of balancing innovative interactive tools with traditional training methods to ensure maximum effectiveness across all user groups.

Furthermore, the implications of this study extend beyond a single institution. Our findings underscore the growing importance of establishing "Metaverse Academies" within diverse university ecosystems. By developing scalable, cloud-based repositories of shared training modules,

academic institutions can collaborate to modernize curricula and provide inclusive, high-fidelity learning experiences. Future work will focus on expanding scenario diversity and fostering global academic partnerships to ensure these technological advances benefit a wide range of educational settings.

VII. DECLARATIONS

1. Abbreviations:

VR: Virtual Reality.

3D: Three dimensional.

SRS: simple random sampling.

2. Ethics approval and consent to participate:

This study received written ethical approval from the Ethics Committee of the Faculty of Medicine in Tunisia (DECISION N°256 [Ref: CEFMS 256/2024]). The research was conducted in strict compliance with the ethical standards of the institutional research committee and the Declaration of Helsinki. Informed consent was obtained from all the participants prior to their involvement in the study..

3. Consent for publication:

The "Consent for Publication" section is not applicable to this manuscript. Informed consent for participation was obtained from all participants, and their privacy is guaranteed as all students are anonymized.

4. Availability of data and materials:

The questionnaire developed and used during the current study is included in the published article as Supplementary File 1.

5. Competing Interests:

The authors declare that they have no competing interests.

6. Funding:

No specific funding was received for this research.

7. Authors' contributions:

Dr. Majed Bouchahma Developed the application. All authors contributed to the design, implementation, analysis, and writing of this study. Each author reviewed and approved the final manuscript.

8. Acknowledgments:

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- [22] Supplementary file 1

Supplementary Files

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