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# Virtual Conversational Agent: AI-Mediated Personalized and Autonomous Immersive Learning in Healthcare

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**Abstract.** This experimental mixed-methods study investigates the efficacy of an immersive virtual laboratory applied to the continuing education of nurses (aged 40–65). The goal of this work in progress is to validate a gamified biosafety environment, guided by a conversational agent (NPC) equipped with adaptive AI. The sample (n=66) was distributed into Control (Desktop) and Experimental (VR) groups. The methodology integrates subjective data collection with real-time neurophysiological monitoring via multi-channel portable EEG, measuring six specific cognitive metrics: engagement, excitement, interest, stress, relaxation, and focus. Data analysis adopts a robust approach: quantitatively, using SPSS v27 software for parametric (Student's t-test) and non-parametric (Mann-Whitney) tests with a 5% significance level; qualitatively, methodological triangulation is applied to interpret user perception. The results aim to correlate technological immersion with neurocognitive efficiency, proposing a scalable andragogical solution for patient safety and the upskilling of the senior healthcare workforce.

**Keywords:** Neuroeducation; Immersive Learning; EEG; Nursing; AI Agents.

## 1 Introduction

The advancement of digital technology in recent decades has marked the beginning of a new era in education, introducing innovative tools and methods with the potential to radically transform how teaching and learning are conceived and delivered. In this landscape of digital transformation, Immersive Virtual Worlds (IVWs) emerge as disruptive tools.

An IVW can be defined as a three-dimensional space, a persistent graphic environment that simulates characteristics of the physical world—such as gravity, time, topography, and its own economy—allowing the user not only to explore but to actively modify this world [1]. The fundamental characteristic of these spaces lies in their social and connective nature: users share a network that possesses persistence (the world continues to exist even when the user logs off) and synchronicity. Access to and population of IVWs are facilitated by networked computers, where individuals are digitally represented by avatars.

This digital representation constitutes the user's identity within the environment, enabling access, navigation, and, crucially, complex interaction with other avatars and system objects [2, 3]. In these environments, the freedom of identity construction is vast. Avatars can be customized to reflect real or idealized physical characteristics, allowing users to choose how they wish to be socially perceived. Beyond identity, user agency extends to the virtual physical space: it is possible to construct buildings, modify the landscape, and create interactive objects. The IVW can, therefore, represent a "digital twin" of an existing physical location (such as a hospital or laboratory) or create imaginary spaces and hypothetical situations that can be virtually experienced with safety. The great pedagogical advantage lies in the possibility of repeating situations and experiences infinitely, allowing for error without catastrophic consequences, which is vital for training in high-risk areas such as healthcare [2, 4].

The popularization and technical evolution of IVWs culminate in the contemporary concept of the Metaverse. According to Boll [3], the Metaverse is defined as a "massively scaled and interoperable network of real-time rendered 3D virtual worlds." This network can be experienced synchronously by an effectively unlimited number of users, providing an individual sense of presence and continuity of data (identity, history, entitlements, objects, and payments). This emerging technology paves the way for new educational approaches, offering experiences that transcend the physical boundaries of traditional classrooms and physical simulation centers, impacting diverse sectors such as entertainment, advertising, and fundamentally, health education.

### 1.1 Virtual Worlds in Education: Potential, Challenges, and Personalized Learning

The integration of virtual worlds into the health curriculum reveals itself as a revolutionary opportunity. Virtual environments, known for their high immersion and interactivity, represent a stimulating alternative to conventional expository methods. By aligning teaching methods with the technological proficiency of contemporary students and the need for lifelong learning among professionals, IVWs—acting as collaborative platforms and simulation laboratories—demonstrate considerable potential to improve engagement, intrinsic motivation, and learning retention results [4, 5].

In the training and continuing education of health professionals, such as nurses and physicians, virtual worlds allow for innovative ways of presenting complex content and procedural practices. The simulation of clinical situations and the use of virtual laboratories anchor the development of decision-making in realistic contexts, preparing professionals who are more skilled for safe care. International associations, such as the International Nursing Association for Clinical Simulation and Learning (INACSL), consistently point to the need to bridge the gap between academic theory and real care practice. Traditional methods often prove insufficient for this bridge, while simulated environments provide the opportunity for the development of the reflective process and contextualized critical analysis [6].

From the perspective of the neuroscience of learning, the use of virtual simulation is intrinsically linked to brain mechanisms of reward and anticipation. According to Cardoza [7], simulated experiences activate neurochemical connections involving the increase of neurotransmitters such as dopamine and adrenaline. This type of neurobiological response amplifies responsiveness in risk situations and decision-making; the more the brain is exposed to a stimulus that brings a reward (success in the virtual procedure), the greater the reinforcement of cognitive learning pathways. Recent studies, such as that by Cardoso et al. [8], corroborate this view by demonstrating that personalized learning routes in immersive laboratories mobilize brain areas responsible for long-term memory and attention, verified through electroencephalography (EEG) metrics. The perception of "loss of temporal awareness" (Flow state) reported by users reinforces the efficacy of immersion.

However, for immersion to be truly effective, it must be adaptive. It is at this point that Artificial Intelligence (AI) merges with IVWs through NPCs (Non-Player Characters). NPCs are entities that integrate the immersive environment, representing humans, animals, or objects, whose behavior is governed by scripts or AI algorithms. Unlike static objects, these agents are capable of interacting, monitoring, and collecting data on student actions, allowing for the personalization of learning routes [9, 10]. The typology of NPCs is vast and functional.

In health education, the evolution of NPCs into Conversational Agents (chatbots with Natural Language Processing) allows for high-fidelity simulations. These agents can simulate patients with complex clinical histories, allowing students to practice anamnesis, breaking bad news, and clinical decision-making in a safe environment. The capacity of AI to offer immediate and personalized feedback transforms the NPC from a mere background extra into an adaptive tutor, essential for the scalability of personalized teaching [9, 10].

### 1.2 Learning in Virtual Worlds and the Senior Workforce

While technology is often associated with young "digital natives," its impact on the senior workforce (professionals over 40) is profound and promising. Training in virtual worlds has demonstrated positive neuroplastic effects on the brains of mature adults. Studies indicate significant improvements in executive functions, memory, and attention, even in individuals with mild cognitive impairment. The immersion in VR requires the brain to process new spatial and procedural stimuli, acting as a "cognitive gym" that combats the natural decline associated with aging [12, 13].

For nursing professionals in this age group, who often face the challenge of technological and procedural updating, VR offers an environment of "psychological safety." Simulation allows for error without judgment and without risk to the real patient. This factor is crucial for andragogy (adult education), where performance anxiety can be a barrier to learning. In a virtual environment, errors generate reflection (debriefing), not punishment, which increases self-confidence and satisfaction with the learning process [14].

Beyond technical competence, immersive learning fosters socio-emotional competencies (soft skills). VR allows, for example, a nurse to experience the world from the perspective of an elderly patient with visual or auditory limitations ("virtual embodiment"). This perspective-taking is a powerful tool for developing empathy, improving the human quality of care provided [12].

Flexibility is another determining factor. Through remote access, immersive learning allows professionals with dense schedules or geographic limitations to participate in cutting-edge continuing education programs. Once initial digital literacy barriers are overcome—requiring intuitive interfaces and adequate onboarding—VR positions itself as an inclusive and effective strategy to keep the senior workforce active, updated, and cognitively stimulated [15].

### 1.3 Adherence to Biosafety Norms and Patient Safety

The practical application of these technologies finds a field of extreme relevance and urgency in hospital biosafety. The National Health Surveillance Agency (ANVISA) defines biosafety as the "condition of safety achieved by a set of actions designed to prevent, control, reduce or eliminate risk factors inherent to activities that may compromise human health" [16]. In the hospital environment, rigor in these norms is the only barrier between the patient and potentially lethal infections.

The International Patient Safety Goals establish clear guidelines: correct identification, effective communication, medication safety, safe surgery, reduction of infection risk, and fall prevention. Although theoretical awareness of these goals is high—with studies indicating knowledge rates above 78% among professionals—translating this into daily practice (adherence) faces obstacles. Fatigue, workload overload, and the repetitive nature of traditional training contribute to the "normalization of deviance," where small deviations from safety norms become acceptable over time [17, 18].

Fundamental strategies such as hand hygiene, correct use of Personal Protective Equipment (PPE), rigorous environmental cleaning, and isolation of infected patients depend not only on material resources but on consistent human behavior. Continuing education is pointed to as the solution, but passive lecture models have failed to generate the necessary and lasting behavioral change. The prevention of occupational diseases and cross-infection requires that knowledge gaps be filled in a dynamic and impactful way [20].

### 1.4 Implications for Infection Prevention in the Elderly

The scenario becomes critical when analyzing the demographic profile of patients. The prevention of Healthcare-Associated Infections (HAIs) in the elderly is a high-complexity challenge due to immunosenescence (aging of the immune system) and the presence of multiple comorbidities. Elderly patients are disproportionately vulnerable to HAIs, and the frequent use of invasive devices (catheters, tubes) exponentially increases this risk [19]. Antimicrobial resistance exacerbates this picture, turning infections that were once treatable into life-threatening conditions.

In this context, nursing plays a strategic leadership role. Nurses are the managers of care and the guardians of biosafety practices at the bedside. Educational interventions led by nurses have proven effective in reducing infection rates but require tools that support this leadership [20]. The development of virtual tools for teaching Biosafety, universal precautions, and patient safety, alongside the expected and necessary behavioral change, is justified by the continued effort of health establishments to ensure nursing and other health professionals adhere to universal precautions and Biosafety norms.

### 1.5 Objectives and Research Questions

Considering the gap identified in the literature regarding the efficacy of immersive interventions for continuing education, the general objective of this study is to evaluate the learning process of nursing professionals over 40 years old in a virtual laboratory for hospital biosafety and patient safety.

To operationalize this goal, the following specific objectives are defined:

**Instructional Development**: To structure the modules comprising the immersive learning route, focused on biosafety protocols; AI Integration: To implement a Non-Player Character (NPC) activated by Artificial Intelligence to act as an educational agent, enhancing experience personalization; Prototyping: To develop the pilot version of the laboratory compatible with Virtual Reality Head-Mounted Displays (HMDs) and

**Neurocognitive Validation**: To comparatively measure cognitive performance metrics (focus, stress, and engagement) via portable EEG, contrasting the immersive experience (VR) with conventional access (desktop).

This investigation is guided by the following Research Questions (RQs):

RQ1: Does the combination of Virtual Reality and Conversational Agents promote superior engagement and technical knowledge retention rates compared to traditional training?

RQ2: Are there distinct neurophysiological patterns measurable via EEG directly associated with the level of technological immersion?

RQ3: How does the interaction with an adaptive tutor agent influence the perception of self-efficacy and confidence in clinical safety among senior professionals?

## 2 Methodology (Work in Progress)

The study adopts a mixed-methods approach (quantitative and qualitative) with an exploratory and quasi-experimental design, divided into two main stages, the first of which is currently underway [4]:

### 2.1 Phase 1: Technological Development

The first phase, currently in progress, involves the development of the IVL, a 3D gamified environment focused on biosafety procedures (e.g., hand washing, donning and doffing protective equipment). The main focus is programming the Conversational Agent (NPC), which will utilize Natural Language Processing (NLP) and Machine Learning (ML) to understand user interactions and guide the experience adaptively. The IVL will be accessible via desktop (Control Group) and Virtual Reality Head-Mounted Displays (HMD) (Experimental Group). Figures 1 and 2 demonstrate the avatar's entry into the 3D environment and one of the phases of the learning path under development, respectively:


**Fig. 1.** Panoramic view of the entrance to the 3D environment.


**Fig. 2.** The figure shows a gamified moment of the project's educational proposal.

### 2.2 Phase 2: Application and Experimental Evaluation

The second phase, scheduled for the first semester of 2026, will be a quasi-experimental trial involving 66 nursing professionals. The main methodological differentiator is the neurophysiological assessment of cognitive performance. Participants in the Experimental Group (VR) will have cognitive performance metrics (engagement, focus, interest, and stress) monitored in real-time during interaction with the VL, using a portable Electroencephalography (EEG) device [5].

In addition to EEG, the following will be used: (a) pre- and post-intervention questionnaires (knowledge, self-efficacy); and (b) performance analysis (platform log data) to compare learning efficacy. Figures 3 and 4 show detailed diagrams of the 2 phases of the work in progress.

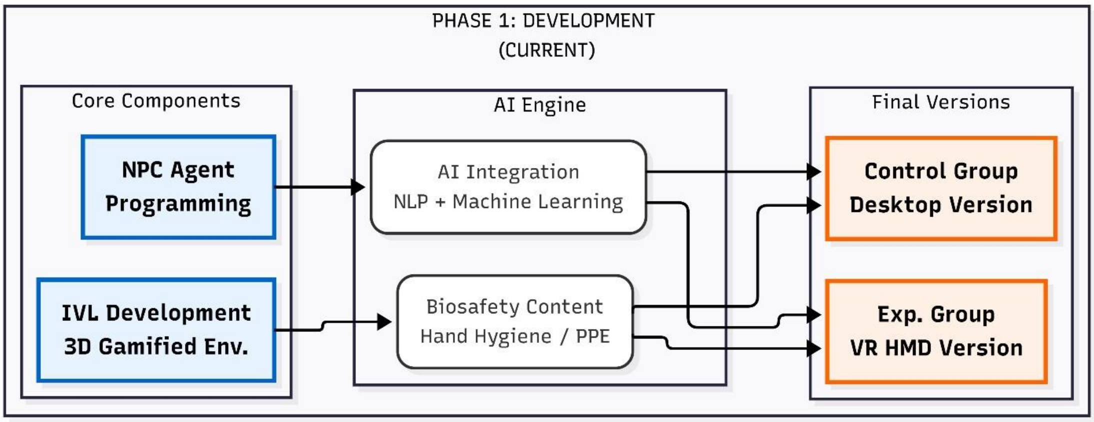


**Fig. 3.** The figure shows the diagram of Phase 1 of the project.

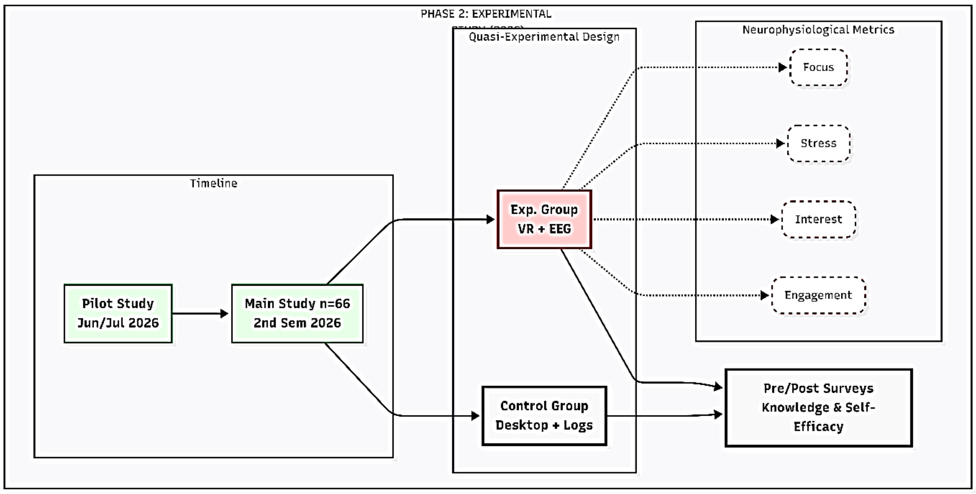


**Fig. 4.** The figure demonstrates the diagram of planned actions for Phase 2.

## 3 Related Works

The foundation of this project stems from a critical analysis of three research axes: the efficacy of immersion in health, the intelligence of virtual agents, and neuroeducation for mature adults. Below, we detail how the current proposal advances regarding existing works in these areas.

### 3.1 Immersive Technologies: From Initial Training to Continuing Education

Current literature offers robust evidence on the efficacy of Virtual Reality (VR). Systematic reviews, such as Marougkas et al. [4], and INACSL guidelines [6], consolidate simulation as superior to passive methods for engagement and retention. However, a detailed analysis reveals that the vast majority of these studies concentrate on initial academic training (undergraduate) or isolated technical training for young professionals.

The Gap: There is a critical scarcity of validated tools specifically aimed at the continuing education of active teams, especially in the post-pandemic context of biosafety, where fatigue from traditional training generates low adherence [20]. Our Contribution: Unlike the cited works, this proposal focuses exclusively on the upskilling of the active workforce, addressing behavioral change in complex biosafety protocols rather than just initial technique acquisition.

### 3.2 Virtual Agents: From Static Actors to Intelligent Tutors

In the field of Artificial Intelligence, Sardesai et al. [9] and Pretty [10] demonstrate significant advances in the use of conversational agents for soft skills training (communication). Although Warpefelt and Verhagen's taxonomy [11] classifies NPC functions well, most solutions available on the market still operate with pre-scripted dialogue trees or focus purely on social skills.

The Gap: There is a deficit of systems that can integrate Natural Language Processing (NLP) with the technical rigor of procedural protocols (such as the exact sequence of PPE usage), while maintaining dialogue naturalness. Our Contribution: This project overcomes the limitations of static scripts by implementing a Machine Learning Tutor Agent capable of contextualizing rigid biosafety norms into adaptive guidance, offering precise technical feedback in real-time.

### 3.3 Neuroeducation: From Subjectivity to Objective Metrics

The demographic scope is the main differentiator of this study. Bauer and Andringa [12] and Thapa et al. [13] establish that VR acts as a "cognitive gym" for the senior workforce, combating the natural decline of attention. Kim and Kim [14] corroborate usability for middle-aged professionals. However, efficacy validation in these studies relies predominantly on self-reporting (satisfaction questionnaires), which are susceptible to perception biases.

The Gap: There is a lack of objectivity in measuring cognitive load and stress during the learning process in advanced ages. Our Contribution: We advance beyond subjective perception by incorporating neurophysiological monitoring (EEG) [7, 8]. By triangulating objective biometric data with psychometric scales, we propose a more robust validation model regarding how the mature brain processes immersive learning.

### 3.4 Conditions and Limitations of the Study

It is important to highlight the boundary conditions of this research (Work in Progress). The planned sample (n=66), although robust for neuroscience studies with EEG, imposes limits on statistical generalization for global nursing populations. Additionally, implementation depends on overcoming digital literacy barriers in the experimental group (40-65 years), a factor that will be mitigated, but not eliminated, through familiarization sessions (onboarding) prior to data collection.

## 4 Expected Results and Contributions

Based on the proposed experimental design and theoretical framework, this "Work in Progress" study projects results that impact both neuroeducation theory and clinical hospital practice. The central hypothesis is that the intervention mediated by Virtual Reality (VR) and Intelligent Agents will promote superior retention and engagement metrics compared to the traditional desktop model.

The expected contributions are detailed in three dimensions:

**Neurophysiological Validation of Senior Learning**: Through EEG data, we expect to demonstrate a statistically significant positive correlation between the immersive environment and increased Beta waves (associated with focus and active attention) and engagement levels in the Experimental Group (40-65 years). These data will provide empirical evidence on neuroplasticity in the senior workforce, countering stereotypes about the digital ineptitude of this demographic and validating VR as an effective andragogical tool.

**Efficacy of the Intelligent Tutor in Behavioral Change**: We aim to validate the Conversational Agent (NPC) architecture as a tutor capable of offering precise technical feedback in real-time. It is expected that adaptive interaction will reduce the forgetting curve of biosafety protocols (such as hand hygiene and PPE usage), resulting in higher self-efficacy and theoretical knowledge in post-tests compared to the control group using non-adaptive methods.

**Systemic Impact and Scalability**: From a practical standpoint, the project aims to deliver a validated high-fidelity prototype, serving as a scalable and economically viable solution for continuing education in hospitals. By improving adherence to patient safety norms through motivating and risk-free training, the tool has the potential to contribute in the long term to the reduction of Healthcare-Associated Infections (HAIs), generating positive social and economic impact on healthcare institutions.

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