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The Evaluation of the Virtual Immersive Learning Laboratory in Health and Nursing (LIASE): A Study in Neuroeducation

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Abstract. The objective of this study was to assess the Immersive Learning Laboratory in Health and Nursing (LIASE), with a focus on the key themes of biosafety in health and the learning process of undergraduate nursing students at a federal public university. This was achieved through the use of a portable electroencephalogram (EEG), in conjunction with the Emotiv Insight 2.0, observation, and Intrinsic Motivation Inventory. This study employed a mixed-methods approach, combining qualitative and quantitative techniques, to gain insights into the effectiveness of a pilot virtual laboratory developed in Second Life (SL). The sample consisted of 17 students who met the study's inclusion criteria. Nine of these students exhibited stable EEG signals. The students were observed while their brain activity was monitored by EEG, and at the conclusion of the proposed learning path, they completed the Intrinsic Motivation Inventory. The results were obtained by triangulating the different collection instruments and the variables—stress, enthusiasm/excitement, engagement, focus/attention, and relaxation—measured and verified by analyzing brain waves using the Emotiv algorithm, whose algorithm and which correspond to brain performance metrics.

Keywords: Biological Risk Containment, Nursing Education, Virtual Labs, Neuroeducation, Computer Simulation.

1 Introduction

The objective of this study is to assess the effectiveness of the Virtual Immersive Learning Laboratory in Health and Nursing (LIASE) by observing and monitoring the learning process through the use of electroencephalography (EEG), identifying cognitive performance metrics, and assessing the intrinsic motivation (IMI) of the study participants at the conclusion of the learning route.

In the training of health students, the possibility of practical learning is constrained by the difficulties of unrestricted access to on-site laboratories and the limited space of the facilities provided. The expansion of essential skills in traditional nursing practice laboratories, which are necessary for professional training and safe patient care, is facilitated by the possibility of tools that provide a safe learning space, where simulation is partly mediated by technology and allows for monitored repetition, recording, and individualized teaching [1].

The use of equipment and protocols similar to those used in the real world, combined with the creation of virtual laboratories, allows students to repeat the experience autonomously, moving away from the traditional learning model in which students merely repeat the guidance provided by their professors.

In this context, the simulation of clinical situations, the use of virtual laboratories, and other technology-based possibilities represent tools for curricular changes that can provide personalized nursing education, geared towards the technology-using generation.

It is evident that the training of human resources in health is a strategic imperative for the health system and its users. However, merely incorporating technology into the learning process is insufficient; rather, it must be employed to enhance the processes of cognition, learning, and retention. Furthermore, it is crucial to identify mechanisms for monitoring the learning process based on neuroeducation and the brain activities stimulated by the technological resources developed, as well as their effectiveness.

Simulated situations and practices can elicit a response and mobilize brain areas, neurotransmitters, and the manner in which knowledge is stored, thereby contributing to the learning process.

Monitoring students' brain activity using the electroencephalogram (EEG) during simulated virtual learning processes can help us gain insight into the processes occurring within the brain. Studies of this nature are essential for the advancement of knowledge regarding the use of these virtual tools.

The monitoring of cognitive mental states in volunteers engaged in various activities has revealed the oscillation between focus/attention, engagement, stress, and relaxation, which indicates the reaction to varying levels of difficulty in carrying out a task or test [2].

Cognitive mental states, such as engagement, relaxation, focus/attention, stress, and arousal/excitement, can be measured by capturing brain electrical activity via EEG, which provides a performance metric of cognitive mental/emotional states in real time during the performance of an activity. This allows for the observation of the brain's potential to understand a concept, contextualize it, and solve a problem. The identification of attention and emotional states associated with brain waves and verified by EEG can facilitate the implementation of more effective teaching-learning processes, resulting in improved outcomes for individuals [3].

In studies of brain-computer interfaces, EEG was employed as a psychophysiological measure to obtain emotional/mental cognitive metrics. The electrode sensors were positioned in the frontal lobe of the brain and in other areas of the head, according to the area of interest. The analysis of brain waves is a well-established field in the area of health, but there has been comparatively little exploration of the potential of this approach in educational environments and classrooms. This highlights the importance of further studies in education [2-4].

The Immersive Virtual World (IMW) is a three-dimensional space, a graphic environment that represents a physical space. It simulates gravity, time, seasons, and even its own economy, allowing the user to modify this world. In these virtual spaces, users share a network that has the persistence and synchronicity of other people. These people access and populate the MVI, and their connection is facilitated by networked computers. Users are represented digitally, constituting their avatar, which allows them to access and interact in the MVI [5-7].

The evolution of IVWs has been growing, indicating the potential of these technologies not only for leisure, but also for the development of educational activities. One of the most notable examples is Second Life (SL), which offers the greatest flexibility and customization of the environment. Its numerous resources are privately owned and paid for, which has facilitated the development of other open-source IVWs, such as OpenSim and Open Wonderland. These IVWs share similarities with SL but maintain the open-source multiplatform. Like SL, OpenSim and Open Wonderland have multi-user access and sharing, customization of the environment, graphical modelling of 3D objects and interaction with the environment, but they allow objects and scripts to be created and shared freely [8].

The use of virtual simulators provides a safe environment for practicing the skills needed by students and professionals, in contrast to theoretical teaching and practice in traditional laboratories. Traditional laboratories limit students' access to real work situations and the possibility of developing clinical diagnostic skills and dealing with problems without restrictions of space, time, and place.

Biosafety actions in healthcare have a direct impact on the safety of patients and their environment, and are therefore essential learning for all students and healthcare professionals. Virtual laboratories can be utilized to simulate real-world occupational protection scenarios, such as handwashing, apron use, and the application of protective masks and gloves. Additionally, they can be employed to simulate the unique circumstances in which blood and body fluids can splash onto the operator's clothing, skin, mucous membranes, or wounds during the course of diagnosis, treatment, and nursing operations, including infusion, blood collection, and puncture. This approach has been shown to enhance students' learning outcomes [9-11].

Another aspect to be considered is the feeling of presence, without the pressure to get things right or wrong, which has the potential to be a positive influence on students' mental health. This is contingent on the values and ethical aspects being present in the communication and relationships between avatars [10-13].

The search for a connection between learning and the activities of brain areas has been the subject of several studies. In this context, the changes in brain waves that occur during the learning process can be monitored by means of a portable electroencephalogram, which provides evidence that the Immersive Virtual World (IVW) can be used as a tool for learning the decision-making process and mobilizing students' attention [11,12].

This study focuses on the development of the LIASE-Immersive Learning Laboratory for Health and Nursing, the monitoring of the learning process using EEG, and the application of the Intrinsic Motivation Inventory to study participants after they have completed the learning route.

2 Study Description

This study employed a qualitative-quantitative, exploratory, and experimental approach to evaluate the learning process of undergraduate nursing students who volunteered to participate in the research. The students' brain waves and performance metrics (engagement, excitement, enthusiasm, focus, interest, relaxation, and stress) were monitored by electroencephalography (EEG) during the use of the LIASE IVW. With regard to the technical procedures, the study employed triangulation of diverse instruments to collect data on the participants' learning process (observation, monitoring of brain activity, questionnaire), thereby facilitating a more comprehensive understanding of the phenomenon under investigation.

In the context of research, triangulation is defined as a method of examining a given topic from at least two distinct perspectives, under equivalent conditions, with the objective of expanding the knowledge that a single approach might provide [14].

The research subjects were undergraduate nursing students from a public university in Federal University of Rio Grande do Sul, officially enrolled in the course. The random sample for this study consisted of 17 voluntary participants. The research subjects were chosen because the proposed theme of LIASE is part of the undergraduate curriculum, which is fundamental in the training of nurses throughout the course. The exclusion criteria were previous neurological illness, use of psychoactive medication on a continuous basis or prior to data collection, use of alcohol or drugs on a regular basis and prior to collection, which were verified during the interview before collection. The procedures employed in this research are in accordance with the ethical standards set forth in Resolution No. 466/2012 and Resolution No. 510/2016, as well as the recommendations of the ethics and research committee of the UFRGS - CAAE - 57500622.3.0000.5347.

The equipment utilized to monitor the participants' brain activity was the EMOTIV PRO Insight 2.0 - 5 Channels Mobile Brainwear. The selection of this equipment was based on several criteria, including its portability, Bluetooth communication capabilities, and compatibility with the computer. Additionally, the equipment features five channels: The following channels were selected for compatibility with Windows and Android systems: AF3, AF4, T7, T8, and Pz. The sensors utilized semi-dry hydrophilic gummy polymer technology, which facilitates better penetration into the hair and contact with the scalp.

The equipment model employed real-time data and an algorithm for analyzing performance metrics, including excitement, engagement, relaxation, interest, stress, and focus.

It is possible to analyze the workload in memory access from wireless EEG devices with Emotiv, thus demonstrating the possibility of analyzing data using real-time recognition techniques to monitor and identify mental load levels in a wide variety of cognitive activities [15].

The pre-processing stage is based on the Emotiv library and the algorithm for analyzing the data obtained. Emotiv employs the Brain Computer Interfaces (BCI) software, a desktop application for Mac and Windows that enables visualization and training of EMOTIV's data streams while monitoring brain activity. The data streams encompass mental commands and performance metrics, facilitating passive and continuous control based on the participant's real-time cognitive state.

The Performance Metrics data is displayed in the application on an axis scaled from 0 to 100. The graph depicts historical data, namely the temporal measurement of the metric during the activity. The number on the left of the graph represents the current value of each metric, as illustrated in Fig. 1.

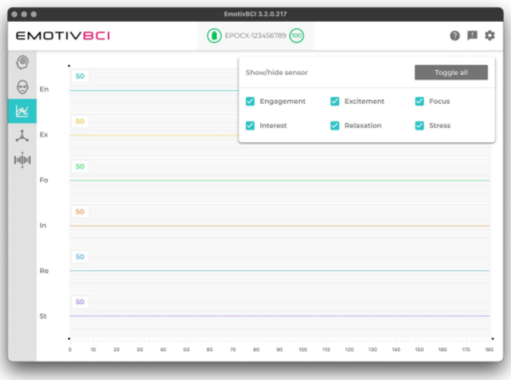

Fig. 1. Illustrating chart of the six-performance metrics. Source: Gitbook-Manual Emotiv. Available at: https://emotiv.gitbook.io/insight-manual/

The calibration method is configured in Emotiv and activated at the commencement of each EEG recording and monitoring session. This is in accordance with the participant's eye opening and closing movements, which are coordinated by the system.

The psychometric evaluation was conducted using the Intrinsic Motivation Inventory (IMI) [16]. The instrument is comprised of a device that measures the subjective experience of the participants in relation to a target activity. It assesses the participants' interest/pleasure, interest, satisfaction, effort, pressure and tension, and usefulness.

The present study employed a reduced version of the IMI proposed by Preuss [17], which was adapted for use with the LIASE. The responses were based on a Likert scale with five options, ranging from "strongly disagree" (1) to "strongly agree" (5). The questions proposed in the IMI were grouped according to the following aspects: perceived competence, interest and satisfaction, effort, pressure and tension, and usefulness. Additionally, optional open-ended questions have been included (23, 24, 25, 26, and 27).

23. Doing activities can be useful for:, 24. What was most difficult for me in developing the activity was:, 25. What was easiest for me in carrying out the activity was:, 26. What I missed during the activity was:, and finally 27. Comments (optional).

3 Study Results

The study yielded several findings, including the development of LIASE, an immersive learning route that places a strong emphasis on biosafety care, the process of learning hand hygiene, the use of alcohol gel, the rules for cleaning and disinfecting the environment, and the personal protective equipment (PPE) used to avoid the maximum risk of contamination in healthcare.

The study resulted in the development of two LIASE prototypes. The first prototype, created using the OpenSim platform, was developed prior to the onset of the COVID-19 pandemic. The pilot learning path did not incorporate the necessary adjustments required for the safety of health professionals during the pandemic. Consequently, the scope of the content and the learning route needed to be revised, leading to the development of the second prototype in Second Life, which was evaluated with the target audience [18].

The learning route and the description of the activities can be found in Figure 2.

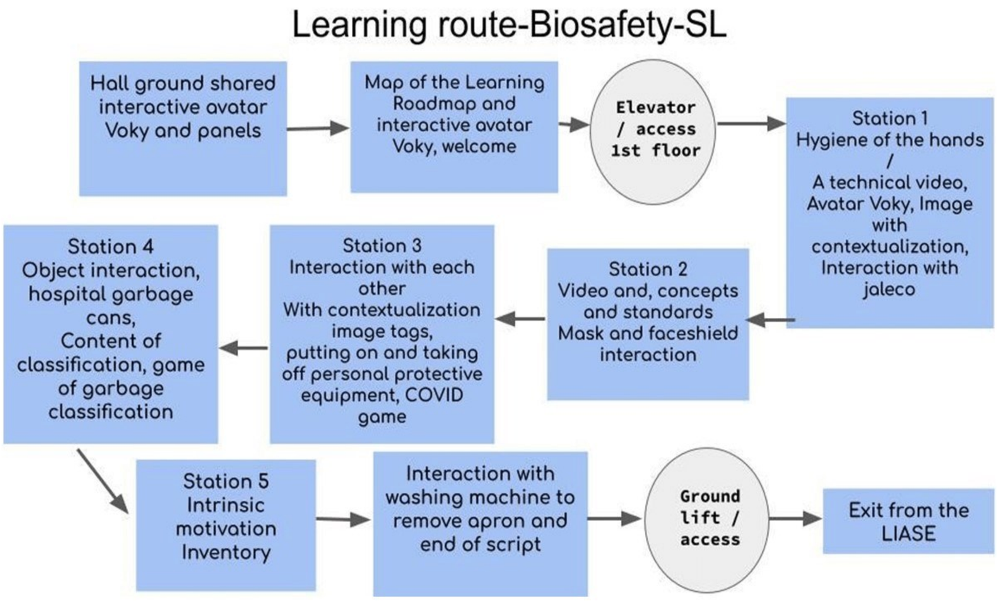

Fig. 2. Learning route-Biosafety in Second Life. Source: The author.

The LIASE system was developed using a learning script that incorporates several intuitive moments of student-machine interaction. During the learning process, the participant has complete control and can interrupt at any time if they have any doubts, move forward or backward in the script at their discretion.

In addition to monitoring the participant's brain waves and performance metrics via EEG during the use of LIASE, the researcher observed the interactions of the participant's avatar in the MVI and completed the process evaluation instrument virtually in LIASE before leaving the learning script.

The performance metrics of the participants were recorded individually and cross-referenced with the moments of interaction in LIASE and the evaluation of the learning process by the participant in the instrument available in MVI. The results of this study are the analysis of individual performance metrics, observation of the learning process by the researcher, and evaluation of the learning process by the participant.

The virtual building of LIASE is a tribute to the architect Oscar Niemeyer, with its design inspired by the Oscar Niemeyer Museum in the city of Curitiba, known as the "museum of the eye." This comparison is particularly apt when considering the future-oriented nature of LIASE. Figures 3 and 4 illustrate the exterior of the laboratory and one of the learning stations, respectively [19].

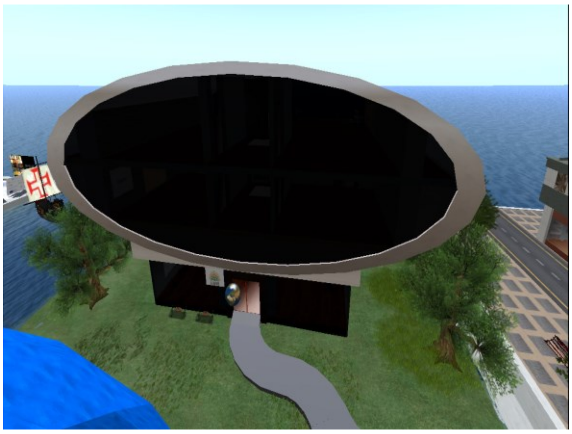

Fig. 3. View of LIASE’s virtual building. Source: the author.

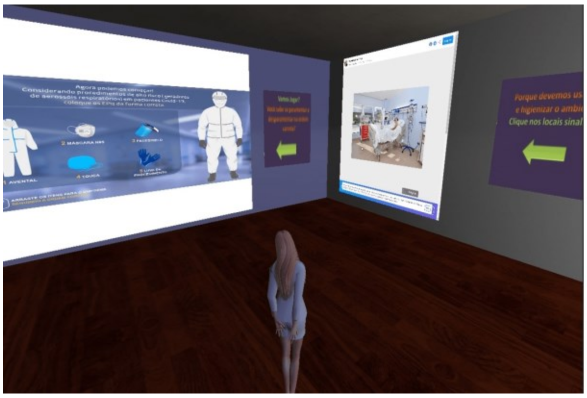

Fig. 4. Detail of station 4 with the theme of COVID personal protective equipment COVID-19. Source: the author.

Following the completion of the proposed learning script, which was monitored by electroencephalography (EEG), 17 participants responded to the Intrinsic Motivation Inventory (IMI), which is available on the Motivational Vulnerability Inventory (MVI).

The sample was predominantly female, which is characteristic of nursing courses, a profession that still has a higher female representation. Only one male participant was included in the study.

Following the interview, which included queries pertaining to the utilization of psychoactive medication and neurological pathologies, 17 participants were deemed eligible for inclusion and were granted access to the LIASE, responding to the IMI following the completion of the learning pathway.

The outcomes align with the triangulation between the observations of the participants during the learning journey and their access to the content and activities proposed in the virtual laboratory, the peak performance metrics verified in the EEG monitoring, and the participants' reports when they answered the IMI at the conclusion of the activity.

Table 1. IMI results of the 17 study participants. Source: the author.

Main questions	Results
I enjoyed the activity	64%
I was not nervous	47%
I was not paying attention	5.9%
It was interesting	82.4%
I was tense	5.9%
It was fun	58.8%
I felt in control	52.9%
I thought of other things	11.2%
I was immersed in the activity	41.2%
Aroused curiosity	70.6%
I lost track of time	47.1%
It was useful for my training	70.6%
I spent a lot of effort	17.6%

The performance metrics correspond to the moments observed when the participants clicked on and carried out one of the activities proposed at the learning route stations. The results reflect the peaks of activity related to brain performance with the highest scores verified by the Emotiv algorithm. The results of P2 correspond to the following activities: 1. Calibration, 2. "Video of hand hygiene with soap and water", 3. "Put on the lab coat", "Avatar" guidance moments hand hygiene", 4. Panels "Universal precautions", "Droplet precautions" "Respiratory precautions", 5. "PPE video", 6. Put on mask and face shield, 7. Interactive tags, 8.PPE game, 9. Hospital waste game, 10. End of the activity and completion of the IMI.

It can be seen that participant 2 maintained high levels of engagement, focus and interest in activities 3, 4, 5, 6, 7, 8 and 9, corroborating his report on the immersive activity in IMI. P2's results can be seen in Table 2.

Table 2. Metrics of mental performance during learning activities – participant 2. Source: the researcher.

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	53	47	65	32	49	24	64	31	65	31
Excitement	72	72	59	18	41	33	57	73	40	73
Focus	36	40	49	24	42	20	49	19	38	19
Interest	58	32	61	76	61	57	34	71	55	71
Relaxation	21	21	26	42	26	36	25	26	57	26
Stress	33	37	42	36	42	36	35	23	42	23

The results of P8 correspond to the following activities: 1. Calibration, 2."Video of hand hygiene with soap and water", 3. Dressing up in a lab coat, "Avatar" guiding moments of hand hygiene", 4. Panels "Universal precautions", "Droplet precautions", "Respiratory precautions", 5."PPE video", 6. Putting on a mask and face shield, 7. Interactive tags, 8. PPE game, 9. Hospital waste game, 10. End of activity and completion of IMI. It can be seen that participant 8 maintained high levels of engagement, focus and interest in activities 2, 4, 6, 7 and 9. P8's account of the immersive IMI activity describes anxiety and excitability due to the novelty of the activity. Participant 8 chose not to access activity 5. When checking levels of engagement, these remained stable for most of the time the activities were carried out. This means that P8 was in a state of alertness and consciously using attention for stimuli relevant to the task. P8's engagement score also measures the level of immersion during the activity and, in some **activities, greater attention, focus and** workload were detected. Engagement is characterized by increased physiological arousal and beta waves, along with attenuated alpha waves. The greater the attention, focus and workload, the higher the output score reported by Emotiv detection. P8's results can be seen in Table 3.

Table 3. Metrics of mental performance during learning activities – participant 8. Source: the researcher.

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	45	50	36	43	-	33	24	41	48	48
Excitement	72	53	28	72	-	33	37	70	56	24
Focus	37	39	29	30	-	33	26	36	43	36
Interest	35	33	35	37	-	40	38	37	46	47
Relaxation	11	12	21	22	-	27	26	20	34	29
Stress	19	21	29	28	-	30	32	26	31	30

The results of P16 correspond to the following activities: 1. Calibration, 2. "Hand hygiene with soap and water video", 3. Dressing up in a lab coat, "Avatar" guidance moments hand hygiene", 4. Panels "Universal precautions", "Droplet precautions" "Respiratory precautions", 5."PPE video", 6. Put on mask and face shield, 7. Interactive tags, 8. PPE game, 9. Hospital waste game, 10. End of the activity and completion of the IMI. It can be seen that participant 16 maintained the highest levels of engagement, focus and interest in activities 2, 3, 4, 6, 7 and 8. Checking P16's performance of the learning script showed levels of engagement, excitement and focus that fluctuated depending on the activity performed. The technical issues of signal quality were generally due to the volume and density of hair, especially afro hair, and the fluctuations in the university's Internet, leading to the collection process being restarted. In the evaluation of P16's activity at LIASE, we were able to observe peaks of engagement and interest, especially in the play activities. We also saw significant increases in excitement, indicating how much the activity involved the participant. P16's results can be seen in Table 4.

Table 4. Metrics of mental performance during learning activities – participant 16. Source: the researcher.

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	-	39	41	43	43	36	48	55	49	59
Excitement	-	59	67	66	66	71	53	36	43	59
Focus	-	32	31	25	25	18	36	29	45	40
Interest	-	62	55	59	59	70	46	41	67	60
Relaxation	-	18	24	30	30	40	28	35	35	35
Stress	-	28	29	34	34	35	32	37	35	38

The results of P20 correspond to the following activities: 1. Calibration, 2. "Hand hygiene with soap and water video", 3. Dressing up in a lab coat, "Avatar" guidance moments hand hygiene", 4. Panels "Universal precautions", "Droplet precautions" "Respiratory precautions", 5."PPE video", 6. Put on mask and face shield, 7. Interactive tags, 8. PPE game, 9. Hospital waste game, 10. End of the activity and completion of the IMI. Checking P20's performance of the learning script showed levels of engagement, excitement and focus which fluctuated according to the activity performed. During the monitoring of P20's brain activity, the Internet signal fluctuated and it was not possible to record the performance metrics for two activities. When comparing P20's brain activity, it is possible to see high levels of engagement, focus and interest when accessing games and interactive tags. It can be seen that participant 16 maintained the highest levels of engagement, focus and interest in activities 5, 7, 8 and 9. P20's results can be seen in Table 5.

Table 5. Mental performance metrics during learning activities - participant 20. Source: the researcher.

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	42	-	-	25	58	46	72	70	52	59
Excitement	31	-	-	26	39	28	40	29	48	13
Focus	17	-	-	20	25	24	54	45	40	62
Interest	54	-	-	52	71	50	43	53	93	56
Relaxation	53	-	-	48	50	35	25	25	55	33
Stress	40	-	-	39	40	31	30	41	48	40

The results of P23 correspond to the following activities: 1. Calibration, 2. "Video of hand hygiene with soap and water", 3. Dressing up in a lab coat, "Avatar" guiding moments of hand hygiene", 4. Panels "Universal precautions", "Droplet precautions", "Respiratory precautions", 5. "PPE video", 6. Putting on a mask and face shield, 7. Interactive tags, 8. PPE game, 9. Hospital waste game, 10. End of the activity and completion of the IMI. It can be seen that participant 23 maintained the highest levels of engagement, focus and interest in activities 6, 7, 8 and 9. There was significant fluctuation in the Internet signal, especially at the beginning and end of the recording. The P23 results can be seen in Table 6.

Table 6. Metrics of mental performance during learning activities - participant 23. Source: the researcher.

Performance metrics	1	2	3	4	5	6	7	8	9	10
Engagement	-	30	31	37	40	40	41	40	40	44
Excitement	-	49	11	11	11	15	56	52	58	64
Focus	-	25	25	26	28	27	30	27	22	34
Interest	-	39	31	45	45	46	42	46	36	48
Relaxation	-	39	46	37	30	41	43	37	35	35
Stress	-	48	34	42	38	45	47	43	42	42

Observation of the participants while they accessed LIASE and monitored their brain activity in real time revealed aspects of the effort made by individuals to learn in a virtual tool. There was a convergence between the participants' responses in the IMI and the monitoring of mental performance metrics observed when accessing the proposed learning script. In this sense, the performance metrics recorded represent what each participant expressed when reporting the effort spent on the process, the attention mobilized, and the interest that LIASE motivated.

The mental state of engagement and interest was found to be associated with the participants' reports of enjoyment and immersion during access to LIASE. These elements are fundamental to the significance of learning and the activation of the areas responsible for emotion and significance, as well as the selection of the events and respective memories that consolidate learning. The mention of the fun activity is consistent with the values presented for the "interest" performance metric. The results of the performance metrics indicate that the limbic system, especially the amygdala, was activated. The amygdala is responsible for receiving and interpreting external stimuli, which are then given emotional meaning, mobilizing attention and long-term memory. Most of the participants reported feeling relaxed when carrying out the proposed activity, which corroborates the results observed in the performance metrics and the responses obtained from the IMI.

Conversely, some participants exhibited notable excitability, likely due to significant physiological changes (pupil dilation, tachycardia, sweating) triggered by the nervous system, which were not monitored. These observations highlight the necessity for further studies that incorporate the collection of physiological and biometric data to gain a deeper understanding of individual reactions. These reactions, which have a positive background, signify the participants' enthusiasm when accessing something new and different, which positively influences motivation and predisposes to learning.

When comparing the data, it was evident that, both from the IMI report and the performance metrics monitored by the EEG, the participants had their attention mobilized in sufficient quality and depth to carry out the proposed activities and experience the sensation of immersion, with the feeling of losing the perception of time. This suggests that the learning process may have occurred during the participants' access to the virtual laboratory.

The impact of studies such as this on future research is twofold. Firstly, it will facilitate an understanding of the areas of the brain that are mobilized and activated during the learning process. Secondly, it will enable the development of learning tools that are increasingly focused on the needs of individuals and that are capable of inducing the mental states that are necessary and conducive to learning. The study also demonstrated a relationship between the mental state perceived by the participant and brain activity, a finding that is particularly noteworthy in the context of studies in the field of education.

The study's perceived limitations were primarily due to the influence of electrical activity in the vicinity of the collection room, fluctuations in the Internet, which reduced the signal captured by the Bluetooth equipment, and the size of the team and number of pieces of equipment, which affected the sample size and collection time. There is still much to be learned about the functioning of the brain and its capacity for plasticity. New studies are needed to further our understanding of brain activity in immersive environments and to explore ways of enhancing the learning process through them.

Neuroeducation has made significant contributions to the present day, including the understanding that each brain is unique and organized individually; that brains specialize and are not "good" at everything, generically; that they have plasticity and are constantly changing due to contact with new daily experiences and the need to adapt; that learning occurs due to the brain's need to analyze data, reflect and self-correct, looking for meanings and patterns with a human form of understanding; that the brain processes information in parts and simultaneously; and finally, that the brain is affected by emotions and its level of attention is more fluctuating than constant, involving conscious and unconscious processes and the ability to grow and learn in social interaction. To analyze data, reflect, and self-correct, looking for meanings and patterns with a human form of understanding; that the brain processes information in parts and simultaneously; and finally, that the brain is affected by emotions and its level of attention is more fluctuating than constant, involving conscious and unconscious processes and the ability to grow and learn in social interaction.

4 Related Studies, Future Studies and Conclusions

No studies were found that correlated the development of virtual health biosafety laboratories with the evaluation of the learning process by EEG in a specific nursing target group. It should be noted that studies in neuroeducation applied to health teaching are unprecedented, and no studies have been found evaluating the learning process using EEG. This highlights the novelty and innovative proposal of this study. The studies found on the ScienceDirect platform covered the period 2013-2022. The following terms were used for the searches: The search terms included "virtual worlds," "virtual labs," "nurse," "nursing education," "neuroeducation," and "electroencephalogram." These terms were refined as they involved a large number of publications. The vast majority of studies specifically involved virtual reality simulations and did not include an IVW or studies related to nursing or EEG monitoring. It is evident that studies with this focus have expanded considerably since 2020, in response to the constraints imposed by face-to-face instruction during the pandemic.

The use of immersive virtual worlds as an educational resource for nursing has been documented in several articles on SL as the platform utilized and the necessity for an educational theoretical basis in the development of educational proposals.

The trend towards IVW as a learning and simulation tool is more extensively discussed in the studies by SOTO [6] and GRIOL [7], which relate the engagement and retention of content in university students who used IVW in the learning process and the importance of planning educational activities.

A number of studies have indicated that aspects of the learning process are linked to neuroeducation, with particular emphasis on attention, engagement, and a mental/emotional state conducive to learning. These studies have focused on the university environment, as noted by CARDOZA [1], NG [4], YANG [9], TSAI [10], SPORTSMAN [12] and ANDERSEN. The studies referenced provide evidence of the relationship between the mobilization of cerebral areas of attention, the emotional state that the educational experience provides, and the activation of long-term memory in the learning process. The studies demonstrate the concern of researchers to point out new trends in nursing education, incorporating immersive virtual worlds as a valid tool for learning and simulation. In exploring new frontiers, the researchers also propose theoretical frameworks for understanding how the brain is engaged by immersive educational tools and the importance of aligning these tools with established educational theories.

Prior to 2020, the topic of biosafety was not included in the development of virtual activities. However, with the advent of the COVID-19 pandemic and the necessity to train undergraduate students and update professionals in the field, some studies have proposed the use of gamification strategies, as proposed by MURAD [11], and virtual reality.

The use and evaluation of the effectiveness of the learning process in nursing is also the concern of studies using environments such as YANG [9] and TSAI [10]. The studies presented so far show different aspects of the learning process, from a technological, educational, and neuroscience perspective, and evidence of the effectiveness of the process and its limitations when evaluating with different methodologies. However, there were no studies that included EEG monitoring, observation, and psychometric evaluation of the participant in the correlated studies found.

In light of the findings, it is postulated that this research could pave the way for further studies in the domain of neuroeducation and the investigation of the influence of immersive virtual environments on the brain. The continuation of these studies is crucial to enhance the impact of virtual laboratories in domains beyond health.

The study's objectives were met through the development and testing of a virtual laboratory covering the main biosafety topics: hand hygiene, use of personal protective equipment (PPE), types of isolation, COVID regulations, and classification of hospital waste. The results demonstrate that it is feasible to monitor and quantify attention through EEG during the learning process. This was achieved by monitoring performance metrics and utilizing the Intrinsic Motivation Inventory (IMI), which enabled the participants to provide feedback on their experience, thereby demonstrating that it was possible to achieve significant results in terms of attention and other brain performance metrics of the participants during the learning process through the proposed methodology.

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