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Original Article

Development and Implementation of a Space in the VRChat Metaverse to Explore a Scientific Research Environment

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Abstract - *In this study, the issue presented was that, although technology has advanced, access to scientific research laboratories is limited to institutions with adequate resources that prevent rapid and widespread public access to these research venues. The article's purpose was to build a fully functional scientific research laboratory in the VRChat metaverse. The purpose of this article was to develop a fully functional scientific research laboratory within the VRChat metaverse. The approach taken utilized Unity and the VRChat SDK to design the virtual and collaborative space, including the interactive 3D models and scientific animation, in addition to testing the virtual lab via a Likert scale survey under five critical dimensions, which were satisfaction, accessibility, interactivity, user experience, and content. The data gathered indicates that the virtual laboratory provides access to education and scientific research, as indicated by an average score of 4.58, showing the extent to which this is the case. This same tool allowed users to interact effectively with the different virtual elements, indicating that these laboratories can be considered valid educational resources in academic and scientific research contexts. In summary, we could argue that this research is evidence that the metaverse, as a medium for virtual laboratories, offers a viable and effective way of achieving some of these experiences that have a long tradition of being difficult or impossible to replicate due to physical limitations.*

Keywords - *Educational accessibility, Metaverse, Scientific research, Unity, Virtual education, VRChat.*

1. Introduction

Even with the rapid evolution of technology, access to research science laboratories continues to be constrained to sites capable of funding research. Consequently, the option for the average citizen and college students to have genuine research experiences is limited. This implies not only the promotion of new findings, but also leads to the improvement of existing ones, incorporating its philosophy into the various stages of research, from design, data collection, and review to publication [1]. In this situation, open science represents a potentially great initiative to promote collaborative research and open access. Latin America has shown growing interest in using science diplomacy as a means to address global challenges; however, obstacles remain that limit the full implementation of open science principles [2].

In contrast to that, the metaverse might place an even greater emphasis on this openness. The term "metaverse" was originally used in science fiction by Neal Stephenson in his novel Snow Crash, published in 1992, which depicted virtual reality [3]. This futuristic vision profoundly influenced the current understanding of the concept. Decades later, Mark Zuckerberg's announcement on 28 October 2021 about changing Facebook's name to Meta and his proposal to develop the metaverse within five to ten years [4].

Since then, global interest in this technology has skyrocketed. This increase has sparked a heated debate about how we can use it in everyday life, particularly in technology and at university, and has generated discussions at trade fairs and technological innovation venues around the world [5].

Furthermore, the metaverse has proven to be a digital environment where interactions and experiences are highly immersive and tailor-made. This feature consolidates it as a fertile ground for innovation and creativity. The convergence of technologies linked to the metaverse is changing education [6]. This integration of technology, combined with collaboration through metaverse platforms, improves the quality of education and demonstrates the need for further innovation and development of these systems [7]. This illustrates the transformative nature of technology that enables new learning environments. Additionally, immersive learning is designed in three-dimensional settings, which closely resemble the real world, and supports knowledge acquisition via first-hand experiences and interaction with others in these virtual worlds [8].

In recent years, metaverse technology in educational contexts has grown dramatically, but the literature in this area is limited to four countries and subtopics that remain underdeveloped, suggesting that there are opportunities for further exploration and deeper research on this topic [9]. While there has been progress in the use of the metaverse for educational purposes, it is still a technology under investigation. This requires research in Latin America on the application of the metaverse to discover spaces for scientific inquiry. Therefore, the objective of this work was to develop a virtual representation of the INTI-Lab scientific research laboratory, part of the University of Sciences and Humanities in Peru, in order to showcase and explore its research environment. As a result, a replica of the laboratory will be developed using the VRChat SDK and Unity.

The structure of this paper is as follows: Section 2 reviews the literature, Section 3 covers the methodology used, Section 4 discusses the tools used to model the environment, Section 5 describes the methodology employed, Section 6 presents the results obtained, and finally, Section 7 presents the discussions and conclusions.

2. Literature Review

In [10], the problem of limited access to physical pneumatics laboratory practices was addressed, a situation that has been exacerbated by the COVID-19 pandemic at the Universidad Nacional Autónoma de México (UNAM). The purpose of this research was to develop an educational resource to support the practice and teaching of pneumatics in an immersive virtual setting. The research methodology was to create a virtual environment to simulate the physical space of a real-world laboratory in the VRChat platform.

The findings indicated a good level of acceptability and were significantly helpful for teaching and learning, allowing students to simulate the use of pneumatic components virtually. The conclusions indicate that LaVNeuM successfully implements the Metaverse to enhance practical engineering education while providing a useful and interesting resource for teaching and learning modes, online and onsite.

Similarly, the authors in [11] decided to address the problem of the shortage of adequate physical academic spaces at the Traversari Institute in order to respond to existing technological challenges in education. The institute is based in Quito, Ecuador. The goal was to build a metaverse, creating educational situations that would make it possible to have new methodologies for teaching.

The methodology was cascading and launched through phases of analysis, design, development, application of the resources, and testing with the purpose of constructing a metaverse that reproduced the space of the Institute itself and allowed students to develop from immersion learning back to traditional face-to-face learning. The findings of the study demonstrated that interaction with 3D objects, as well as the reproduction of spaces that were familiar to student participants, increased their engagement and learning. The conclusions of the study suggest that the metaverse provides an appropriate educational context that supports controlled learning and effective educational experiences.

In contrast, the authors in [12] presented the use of virtual laboratories as a possible solution for advancing scientific experimentation without physical and economic limitations at the Isabel Moscoso Dávila Educational Unit. Their objective was to evaluate how virtual laboratories affect chemistry learning in these students. The study utilized a design that was quasi-experimental, quantitative, and exploratory, with a sample of 60 students who were placed into experimental and control groups, with an experimental group utilizing virtual laboratories and a control group utilizing customary Face-to-Face instruction. In evaluating whether virtual laboratories lead to a positive learning experience due to satisfaction/value, the study utilized questionnaires and statistical analysis. The researchers indicated that there was a significantly positive difference in chemistry learning with virtual laboratories and that the experimental group reported more satisfaction and understanding than the control group.

The authors in [13] highlighted the issue of a lack of genuine access to interactive virtual learning environments at universities, particularly at King Mongkut's University of Technology in northern Bangkok, Thailand. The main objective was to create a virtual laboratory learning environment using the metaverse to offer interactive learning experiences by virtually utilizing touch technologies. The utilised method is based on the ADDIE method of analyze, design, develop, implement, and evaluate, using either a virtual media development program such as Blender, or VRChat to simulate real-life scenarios.

The study shows participants had high levels of satisfaction with the learning environment design and ease of use, indicated by the high level of acceptance of VLLE in the metaverse as a means for self-directed learning and public interaction. VLLE, a metaverse environment, is effective in the use of the metaverse to promote interactive learning, making it a model for future implementations for virtual learning environments in different higher education institutions.

In addition, researchers in [14] found that the problem of how to incorporate the metaverse into the cardiac catheterisation laboratories of the Department of Cardiology at Fudan University Zhongshan Hospital and the Institute of Cardiovascular Diseases in Shanghai, China. A major aim of the study was to look at how the metaverse could enhance cardiac catheterisation procedures via technologies to offer more personalised and patient-centred procedures in a more efficient way. The authors examined and evaluated current and emerging technologies in the content of interventional cardiology with consideration of clinical decision support systems, augmented reality, vascular robotic systems, and voice-assisted catheterization laboratories in the assessment. The results suggested that the metaverse has the potential to be a game changer in terms of cardiac procedures, with improved precision and efficiency in interventions and improved diagnostics and treatment through machine learning systems, possibly providing a more efficient interface and a patient-specific experience in health care.

Subsequently, the authors in [15] emphasized that the real drawback lay in the limited availability of hands-on laboratories for students of different specialties, which is crucial for forging applicable skills in fields such as engineering and medicine. The main aim of the study was to develop a virtual geometry lab in the OpenSim metaverse to help create a learning environment that might assist in academic tasks and, in turn, promote student autonomy and interactivity. This involved a theoretical overview of metaverses, the analysis and testing of 3-dimensional object importation and creation, and coding for the use of interactive functions in the virtual space. The results showed that OpenSim was able to create a collaborative environment that was immersive in nature, offering the capability to import objects and utilize coded scripts to enhance user interactivity with the environment. It was concluded that metaverses, such as OpenSim, brought a level of realism to immersion and aided in the integration of various technologies into the procedure, although some complications were noted due to variations in different viewers.

On the other hand, the authors in [16] pointed out that their study identified the need to integrate advanced technologies such as virtual reality into neurosurgery education, highlighting the challenges of traditional training and opportunities for remote collaboration. The intentions were to provide an immersive virtual environment for the meaningful interaction of instructors and students based on realistic three-dimensional models of cadaver specimens developed from photogrammetry. Specifically, these images were developed into a Virtual Reality (VR) space and could be accessed through virtual reality headsets to provide an interactive learning experience. After utilizing the system, participants indicated a high level of acceptance regarding the performance of the function and a strong level of agreement that the VR system could improve neurosurgical training, supporting its use as a complement or replacement for existing methods of anatomical teaching.

Finally, in Brazil, the authors [17] addressed the difficulty of teaching practical activities in microbiology, particularly in distance learning. The main goal was to create a virtual laboratory that would enable learning and gain hands-on experience in a practical and cost-effective manner. The laboratory was implemented and assessed via student feedback in the form of students' perspectives on the laboratory experience. The student feedback indicated that, while the tool was viewed as useful, there were challenges in relation to familiarization and concerns for improvement with the interface. In conclusion, the laboratory was positively received, and we achieved the educational goals of creating the experience, which was successful, when we considered the results of the feedback and experiences with the tool; however, the tool needed improvements to maximize the potential of the laboratory experience.

3. Materials and Methods

The scientific research laboratory was developed within the VRChat metaverse through the application of a structured methodology addressing the design, modelling, implementation, and validation of the environment. The critical stages of this methodology are outlined below.

3.1. Design

The significant and representative laboratory components were identified, and the corresponding scales and distribution of the objects in space were determined. In order to function correctly, critical functionalities were established to create an immersive experience in the scientific research laboratory.

3.2. Modelling

At this stage, the environment was modelled based on the Intilab laboratory design. The various computer equipment, tools, and workspaces were modelled in order to accurately represent the laboratory.

3.3. Implementation

For this stage, the laboratory was implemented by integrating the different modelled elements, as well as integrating functionalities such as interacting with objects and locating oneself in workspaces.

3.4. Validation

In order to guarantee access to the virtual laboratory from various devices, at this point, the previous validation was done through testing using Android devices, Oculus Meta Quest 2 glasses, and PCs.

4. Tools

This section describes the tools used to develop the virtual laboratory.

4.1. Unity

Unity is a flexible game engine that allows for the creation and publishing of games and applications while integrating various tools for development and compatibility across multiple platforms [18, 19]. This enables developers to reach a wider audience and optimize their projects for multiple devices.

4.2. VRChat

In 2017, VRChat was launched, an online virtual reality game with multiplayer support. Although its name includes the word “VR”, it is not necessary to use virtual reality devices to enjoy some of its features [20]. This makes it accessible to a wider audience who do not own virtual reality equipment.

4.3. Steam

Steam is a video game digital distribution service from Valve Corporation, facilitating the purchase, download, and play of many games. Steam users access the service through a local Steam client, featuring support for Windows, Mac, and Linux operating systems [21].

4.4. Tinkercad

Tinkercad, by Autodesk, is a free and online program that can be easily accessed to help create 3D designs, electronic circuits and even some programming. It is made for educators and beginners who are trying to enter digital design and explore 3D printing. Tinkercad offers a simple interface that allows users to create a 3D model from scratch.

5. Development

For the development of a space in the VRChat metaverse for the exploration of a scientific research environment, the INTI-Lab environment was used, which is one of the research spaces at the University of Sciences and Humanities. In Figure 1, we can see the INTI-Lab, a research center at the University of Sciences and Humanities (UCH). This center is mainly dedicated to the development of projects related to signal and image processing, aerospace technology, rehabilitation engineering, smart cities, ICT, biotechnology, electronic systems development, computer systems, and artificial intelligence.

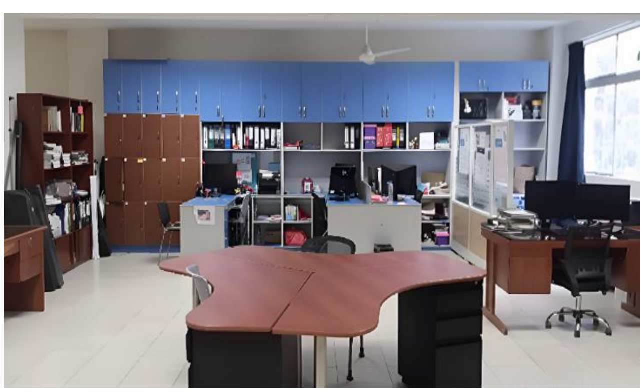

Fig. 1 INTI-Lab laboratory

The proposed features for the virtual laboratory include allowing avatars to sit in laboratory seats, pick up objects, and draw in the 3D environment. In addition, it will enable the viewing of videos and the visualization of an animated experiment.

In order to build the virtual laboratory environment, the SDK for VRChat was downloaded, which allows the environment created with Unity to be compatible, as shown in Figure 1 on page 5. To model the environment in the metaverse, Unity version 2019.4.31f1 was used. This version of Unity is compatible with virtual reality environments specific to VRChat's metaverse development, and this version of Unity was used to create and adapt the environment for use in the virtual laboratory space.

Additionally, ProBuilder was used, which is a package of tools that integrates 3D modelling and level design, optimised for building basic geometry with the opportunity for detailed editing. ProBuilder enables rapid prototyping of buildings, terrain, and more, as well as the creation of custom collision geometry, trigger areas, and navigation grids.

In addition, the VRC Pickup component was added, which allows avatars to pick up, hold, and use objects. To add this component, Collider and Rigidbody components are required; in this case, a Box Collider was used, which is a cube-shaped collision component that, like all colliders, allows an object to come into contact with other objects, while the Rigidbody calculates the physics applied to the object.

On the other hand, the Simple Pen System was used, as well as the creation of pens using Udon technology to draw in 3D space. The pens are equipped with VRCPickup and VRCObjectSync components, which provide the basic functionality for picking up and synchronising. This allows other users to see what one user is drawing or writing at the same time.

The environment created is compatible with PCs running the Windows operating system, as well as devices running Android, which is the operating system used in virtual reality headsets. There are also options available to ‘Change build target’, allowing the user to select between Windows and Android operating systems.

VRChat can also be accessed through the official VRChat.com website, as well as through gaming client platforms such as Steam [22]. However, it is important to emphasise that this feature only allows the user to view the characteristics and descriptions of the worlds in VRChat, not the environment itself.

It should be noted that a virtual world, also called a 3D world, is an immersive environment or metaverse, described as a graphical environment that appears on the user's computer screen when they are connected [23]. This highlights how technology can create simulated spaces in which users interact almost as if they were in the physical world.

6. Results

At this point in time, all interactive features were assessed to verify they were working as expected. This was comprised of actions such as sitting in seats, picking up objects, and opening URLs from the preconfigured screen in VRChat, as well as ensuring the collisions were set up correctly, and users could not phase through walls or solid objects.

To check the status of the proposed features, UCH avatars were used. Avatars refer to digital representations created through collaboration between humans and computers, focusing on how these avatars demonstrate human presence and participation [24].

To verify the status and functionality, tests were conducted in the VRChat metaverse environment using both a PC and the Oculus Meta Quest 2. This free, multi-user virtual reality social platform allows users to represent themselves with avatars and explore various spaces around the world where they can interact with each other [25]. Therefore, the tests were conducted using UCH's own avatars.

In Figure 2, it can be seen that the UCH avatar has the ability to sit in seats that have been previously configured for sitting, thus confirming the optimal functioning of this feature.

Fig. 2 Testing the sitting functionality

In Figure 3, you can see the female avatar of UCH holding an oscilloscope. Furthermore, the usability of the screen is demonstrated by introducing a link in the VRChat metaverse.

In Figure 4, the avatar can be seen entering a link to view an introductory video in the VRC VideoSync input field. The link was manually entered into the input field presented in the metaverse.

Fig. 3 Testing objects made to be grabbable

Fig. 4 Viewing from videosync (unity)

In Figure 5, a change in position can be observed due to the animation of the clinostat experiment. This allows us to verify the animation proposed in the experiment.

Fig. 5 Capture of the clinostat animation position

In Figure 6, you can see the avatar writing ‘UCH’ in the air with a pencil imported from the VRChat SDK. This allows us to verify its optimal use.

In Figures 7 and 8, users can be seen in the metaverse laboratory using Oculus Casting. Oculus Meta Quest 2 glasses are used to observe the laboratory in virtual reality.

Fig. 6 Testing the writing functionality

Fig. 7 Screen 1 testing the laboratory from the oculus quest 2 glasses

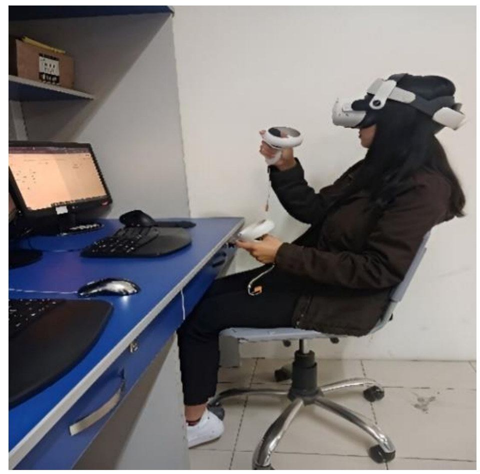

Fig. 8 Screen 2 testing the laboratory from the oculus quest 2 glasses

On the other hand, testing of the virtual laboratory was carried out to evaluate various important aspects and assess its effectiveness.

Table 1. Survey questions with a likert scale

Dimension	ID	Question
Satisfaction	1	I am satisfied with the content and environment of the virtual lab.
	2	I would recommend the virtual lab to other users.
	3	I find the tours of the labs to be enjoyable.
Accessibility	4	The controls and navigation make the labs easily accessible.
	5	The lab elements are displayed correctly at all times.
	6	Access to the lab is fluid and smooth.
Interactivity	7	The environment allows the user to interact with the different elements of the lab.
	8	I can move freely throughout the virtual environment.
	9	The response time of the environment when interacting with the elements is fast.
User experience	10	The design of the lab is easy to understand.
	11	The visual design of the environment enhances the user experience.
	12	The interaction within the environment is intuitive and enjoyable.
Content	13	The resources available encourage learning and interaction.
	14	The elements are well organized and facilitate understanding of the environment.
	15	The lab elements are attractively designed.

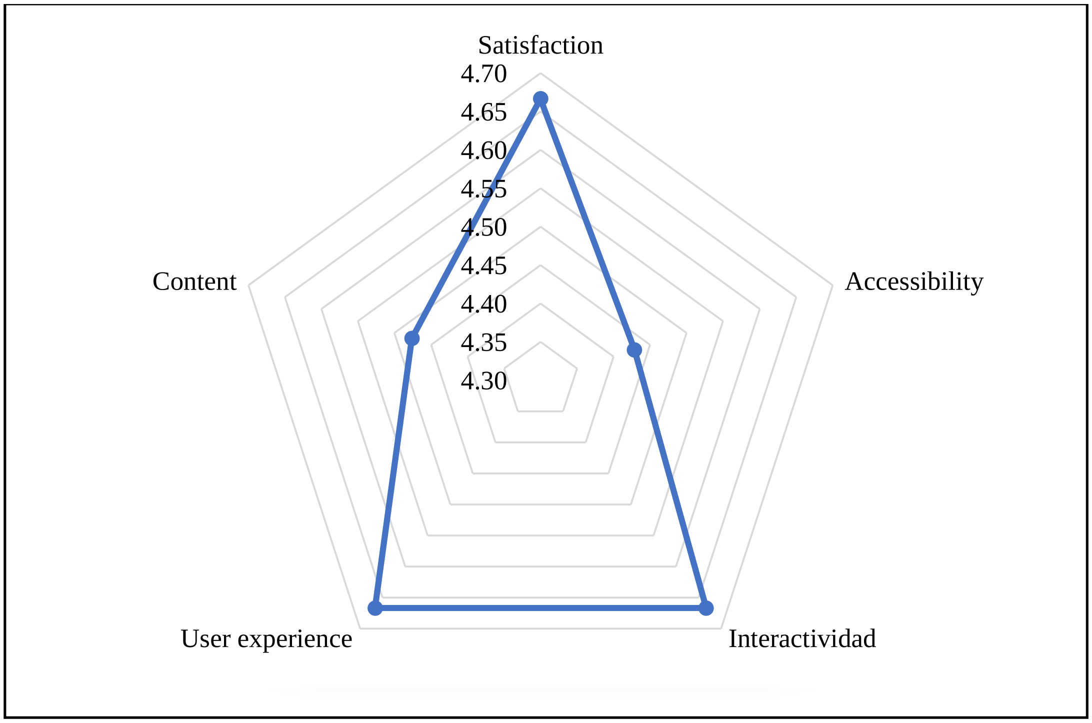

Fig. 9 Radar chart of test responses

Table 1 shows the five dimensions that were taken into account for testing: satisfaction, accessibility, interactivity, user experience, and content. These dimensions were evaluated using a Likert scale from 1 to 5, where a score of 1 indicated very low acceptance, while 5 indicated strong agreement with the dimension being evaluated.

Figure 9 shows the perception and evaluation given by users during the testing of the Intilab virtual laboratory at UCH. The satisfaction dimension was scored at 4.67, reflecting very positive results, accessibility (4.43), interactivity (4.67), user experience (4.67), and content (4.48). These results demonstrate the high acceptance and potential use of the virtual research laboratory.

7. Conclusion and Discussions

The objective of this study was achieved by developing a scientific research laboratory in the metaverse, using the VRChat platform, in order to represent an accessible and immersive research environment. As a result, a replica of the INTI-Lab laboratory was created, which effectively simulated a physical research space, offering an interactive experience for users.

The results of the laboratory testing reflect its potential use and acceptance. Overall, an average score of 4.58 was achieved, highlighting its significant impact. The dimensions with the highest scores were satisfaction, interactivity, and user experience, while accessibility and content scored slightly lower.

The literature review identified research projects that attempted to replicate laboratories with different perspectives. In [11], a laboratory was developed in VRChat for teaching pneumatics in engineering courses. Unlike the environment of this study, which focused on developing a space to visualize what a scientific research facility looks like.

On the other hand, study [12] created a system of interfaces for household appliances that uses avatars to guide users. Its methodology focused on the process of designing interactive experiences. This differed from the methodology used in this study, which covered everything from design to testing user experiences through the use of the platform.

Finally, the authors [16] discussed the creation of a virtual laboratory for practical learning in the OpenSim metaverse for education, specifically in the area of geometry. Meanwhile, the environment developed in this research is a multidisciplinary engineering laboratory.

Among the limitations of this research is the lack of familiarity of users with virtual environments. Furthermore, the use of virtual reality headsets, necessary to achieve a fully immersive experience, was not within the reach of many people.

However, it is this very capacity of virtuality to convey a tangible experience of immersion and presence that represents the main value of the term metaverse, as it allows for the possibility of simulating interactions with a certain degree of freedom, even when these are still defined [26].

Although there are limitations, previous work has shown that a virtual laboratory in the metaverse can be an effective way to democratise access to and visualisation of scientific research sites. Educational institutions are encouraged to investigate the use of the metaverse as a teaching tool and to allow free access to meaningful and enriching educational experiences.

In conclusion, the creation of a scientific research laboratory in the VRChat virtual reality environment represents a considerable advance, as it has the potential to change the way we view education and scientific research. This proposal not only represents a viable alternative to certain physical limitations but also generates new opportunities for teaching and learning through global collaboration.

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