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Virtual Visit to Research Reactor IPEN/MB-01

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Abstract: The world is currently facing a significant challenge due to the widespread dissemination of misinformation, compounded by a lack of effective strategies to combat it. The nuclear sector is particularly affected by it, with several people of the general public knowing very little or nothing at all about nuclear reactors, nuclear energy and nuclear technology, leaving them vulnerable to misinformation. The Covid-19 pandemic, alongside modern social dynamics, highlighted this modern social problem. It also forced all activities into an online environment, which was detrimental in terms of the spread of misinformation but also created educational opportunities. This paper focuses on the methodology and development of a 3D virtual environment of the IPEN/MB-01, which is an initial step in a larger educational project concerning a virtual guided tour and virtual educational environment projects of the same reactor, using education as a method of prebunking students about misinformation concerning the nuclear field, and enhancing access for students who are far from the CNEN facilities and to schools who cannot visit due to age restrictions. The work focuses on the development with a realistic approach as recent literature supports the notion that highly immersive virtual reality environments enhance learning outcomes. The final virtual environment provides a foundation for developing diverse projects, each with a specific educational focus or approach. Additionally, the methodology described here can be easily adapted to different reactors or facilities, enabling institutions to create their own educational virtual environments.

Keywords: IPEN/MB-01 nuclear reactor, educational virtual environment, Unreal Engine, science communication, 3D modelling

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Visita Virtual ao Reator de Pesquisa IPEN/MB-01

Resumo: O mundo enfrenta atualmente um desafio significativo devido à disseminação generalizada de desinformação, agravada pela falta de estratégias eficazes para combatê-la. O setor nuclear é particularmente afetado por esse fenômeno, uma vez que grande parte do público conhece muito pouco ou nada sobre reatores nucleares, energia nuclear e tecnologia nuclear, tornando-se vulnerável a informações falsas. A pandemia de Covid-19, aliada às dinâmicas sociais modernas, destacou esse problema contemporâneo. Além disso, forçou a migração de todas as atividades para o ambiente online, o que foi prejudicial em termos de propagação de desinformação, mas também criou oportunidades educacionais. Este artigo concentra-se na metodologia e no desenvolvimento de um ambiente virtual 3D do reator IPEN/MB-01, uma etapa inicial de um projeto educacional mais amplo que inclui um tour guiado virtual e ambientes educacionais virtuais do mesmo reator. O objetivo é utilizar a educação como método para prevenir a aceitação de desinformação no campo nuclear pelos estudantes ("*prebunking*"), além de ampliar o acesso para alunos distantes das instalações da CNEN e para escolas com restrições de visita devido à idade dos estudantes. O trabalho prioriza uma abordagem realista, uma vez que a literatura recente apoia a noção de que ambientes de realidade virtual altamente imersivos melhoram os resultados de aprendizagem. O ambiente virtual final serve como base para o desenvolvimento de projetos diversos, cada um com um foco ou abordagem educacional específica. Adicionalmente, a metodologia descrita aqui pode ser facilmente adaptada a diferentes reatores ou instalações, permitindo que instituições criem seus próprios ambientes virtuais educacionais.

Palavras-chave: ambiente virtual educacional, reator nuclear IPEN/MB-01, Unreal Engine, divulgação científica, modelagem 3D.

1. INTRODUCTION

In modern human history, the number of publications concerning scientific and technological work has grown steadily [1]. This reflects an increase in humanity's knowledge across various subjects, as publications are the main source of scientific communication and the driving force behind spreading discoveries and scientific knowledge. They are essential to modern science and the way it operates today [2].

Despite the growth in publications, technological advancements, and the overall expansion of human knowledge, scientific communication to broader audiences still faces major challenges – primarily due to the complexity of scientific information, the ways in which people access and process information, and the impact of social and cultural influences [3]. Modern social dynamics of communication and information sharing are affecting how information and misinformation spread [4] both in general information as well as in scientific communication, with some works being developed and published with their own biases, and their results quickly spread by big communication vehicles, causing waves of misinformation about different subjects [5]. Several strategies used to reduce the impact of misinformation appear ineffective, sometimes reinforcing misbeliefs among the general population despite subsequent presentation of factual information [6].

The nuclear sector also faces this challenge, with significant debate surrounding its benefits and harms. It is constantly influenced by media coverage, which often highlights issues, accidents, and disasters, such as Fukushima in 2011, further impacting public perception of the sector already embroiled in controversy [7, 8, 9]. This perception is worsened by the public's tendency to associate nuclear energy and technology with nuclear weapons and military equipment, which leads to further rejection [10].

The spread of misinformation was exacerbated by the recent pandemic, both due to the dynamics of global crises and the enforced social distancing imposed by this specific scenario [11]. The need for social distancing forced several estabilishments to suspend their operations, or at least their in-person activities. One such research facility was the Instituto de Pesquisas Energéticas e Nucleares (IPEN), which, as a result, had to halt visits to its nuclear facilities – an important educational initiative aimed at showcasing the institution's work [12].

This created the opportunity to further develop a larger project on virtual reality at IPEN, specifically by creating software for a virtual environment that allows the public to visit one of the institution's reactors, the IPEN/MB-01. The development of such an environment can not only enhance the user experience but also improve the educational impact by stimulating the user's senses in a more natural and vivid way. Additionally, there is evidence suggesting that the use of virtual reality as an educational tool can improve student learning outcomes [13, 14].

Various areas of knowledge, and different levels of scholarship have been displaying positive outcomes when exposed to virtual reality technologies during their learning experiences [15, 16, 17]. The positive results can be due to training exercises results, or because it allowed their courses to have access to previously unavailable field visits [18, 19, 20]. Even the nuclear sector has started using virtual reality and virtual environments, not only for training operators, but also for training in emergency scenarios, and training teams who deal with decontamination and decomissioning [21, 22, 23].

As part of a continuous effort, previous work had already been done, both by IPEN, and also by other institutions who are part of the Comissão Nacional de Energia Nuclear (CNEN) [24, 25]. Whilst the previous work done at IPEN is about a pool-type research reactor (IEA-R1), categorised as a Materials Testing Reactor (MTR) [26, 27]. The IPEN/MB-01 reactor is substantially different, a research reactor known as a critical assembly, it was built with the purpose of validating the calculation method of a reactor core.

This work, therefore, aims to define the methodology used in the creation of the virtual environment of IPEN/MB-01, which is a potential educational solution to some current problems, such as access to nuclear facilities by higher education students who are far from the CNEN institutes, where these nuclear facilities are located, and also to provide access to high school students on nuclear safety issues and without authorization to visit real nuclear facilities.

2. MATERIALS AND METHODS

The virtual environment was developed using Unreal Engine 5.4.3, a game engine developed by Epic Games, and a widely used platform for game development both by independent developers and large companies. Allowing for development in both C++, as well as a blueprint visual scripting language, it is a tool focused on the development of 3D applications [28, 29] and by allowing free usage for educational institutions and for non-commercial projects, making it one of the most suitable choices for the development of this application [30].

This paper outlines the methodology and results obtained during the development of the virtual environment for one of CNEN's reactors (IPEN/MB-01). The accompanying educational software, which offers a virtual visit to the reactor, is still under development, using this environment as its foundation.

The 3D modelling of certain specific pieces of equipment and structures requiring greater detail was carried out using the free and open-source software Blender[1], and the creation of textures used to characterise specific equipment, of specifical reactor characteristics, such as frames, plates and posters was done using the free and open-source

[1] Available at www.blender.org

software Krita[2]. A few of the 3D objects used to create the scenario were also obtained online, from websites[3] where users can post their 3D creation to sell or make them available for free.

2.1. IPEN/MB-01 Reactor Assessment

The first step was to create the virtual environment where the visit will take place. During this step it is very important to ensure that the virtual environment reflects the real world as realistically as possible to improve the final user experience [31].

The virtual environment being built is the IPEN/MB-01 nuclear reactor (Figure 1), known as a critical assembly. It was entirely developed by Brazilian researchers and engineers from IPEN in partnership with the Brazilian Navy. Its name refers to the Brazilian Navy (*Marinha do Brazil*, MB), and its construction began in 1983 and its licensing was completed in 1988, having been authorised to operate at a maximum power of 100 W [32].

The IPEN/MB-01 reactor allows for the simulation of a large reactor on a smaller scale. It was built to validate the calculation method for a reactor core used in submarine naval propulsion system. The original core had 680 fuel rods and allowed for multiple core configurations, making it quite versatile. In 2020, the core was replaced by one that uses plate-type fuel to simulate the physics of the new Brazilian Multipurpose Reactor (*Reator Multipropósito Brasileiro*, RMB). This is a new research reactor that is being developed by CNEN and the Brazilian Navy [32].

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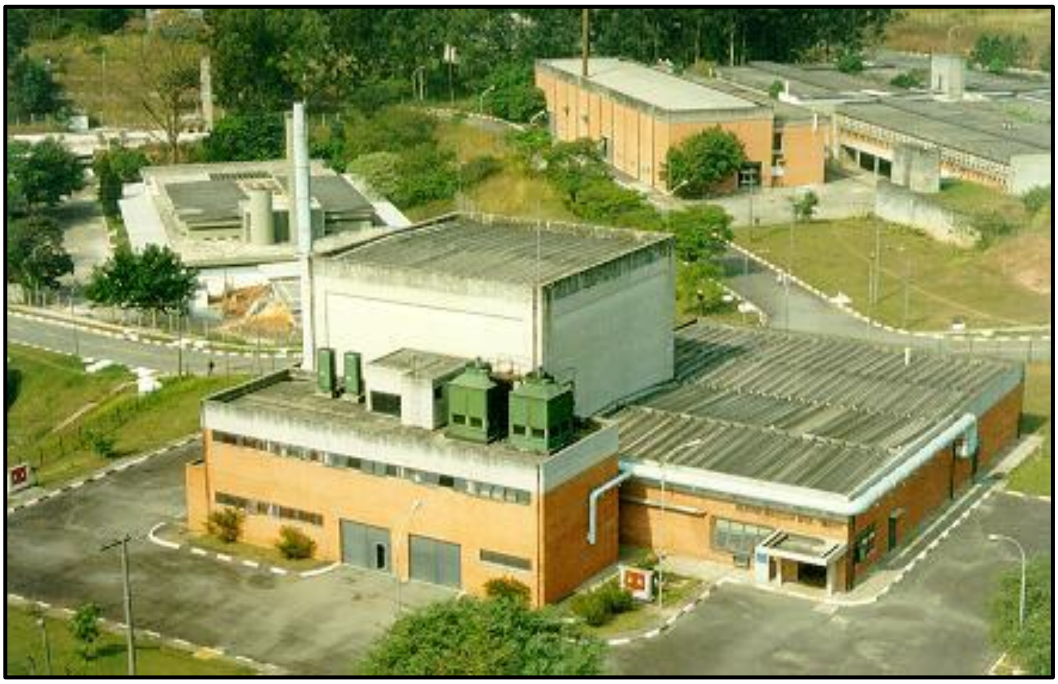
[2] Available at www.krita.org
[3] Resources were obtained from sketchfab.com

Figure 1: IPEN/MB-01 nuclear research reactor (critical assembly)



Source: IPEN, 2022.

To continue with the creation process, the original building blueprints were used to assure that every element was on the appropriate scale. The original building has 16 blueprints, with detailed information regarding walls, doors and windows dimensions, as well as information on the building heights and spaces to build the electrical, hydraulic and ventilation systems.

The development of a 3D environment does not require consideration of electrical, hydraulic, or ventilation systems. The other blueprints information was used to keep the whole environment in scale with the real building, with only minor adjustments to some walls and doors to allow for a better movement of the user character inside the virtual environment.

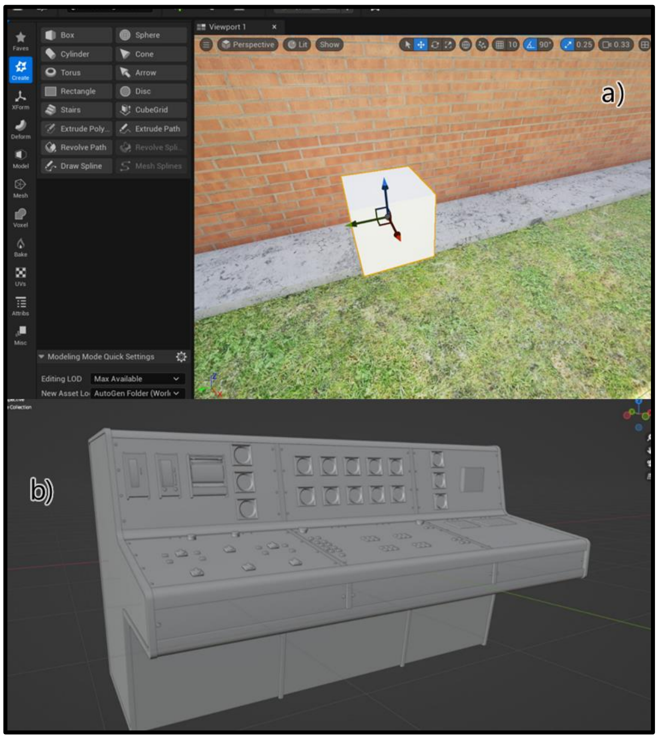
The authors visited the reactor several times, either individually, or as part of technical visits carried out by other courses and institutions, which allowed the authors to obtain photographs and record videos of the real environment. These were used as references during the modelling process, and as raw material to create textures for frames, posters etc.

In addition, the authors had the opportunity to understand the main parts of the reactor, which will allow for a more realistic experience during the visit of the virtual environment.

2.2. 3D Modelling and Texturing

The 3D modelling was different depending on the object, for objects with simple shapes, such as cabinets, tables and doorhandles, they were created using Unreal Engine own modelling tools, Figure 2 (a), whilst more complex objects, and more relevant to the visit, such as the model at the entrance, the detectors used by the radioprotection team, the structure around the reactor core, the panels at the control room and the operation table were created using Blender, Figure 2 (b).

Figure 2: Different modelling approaches

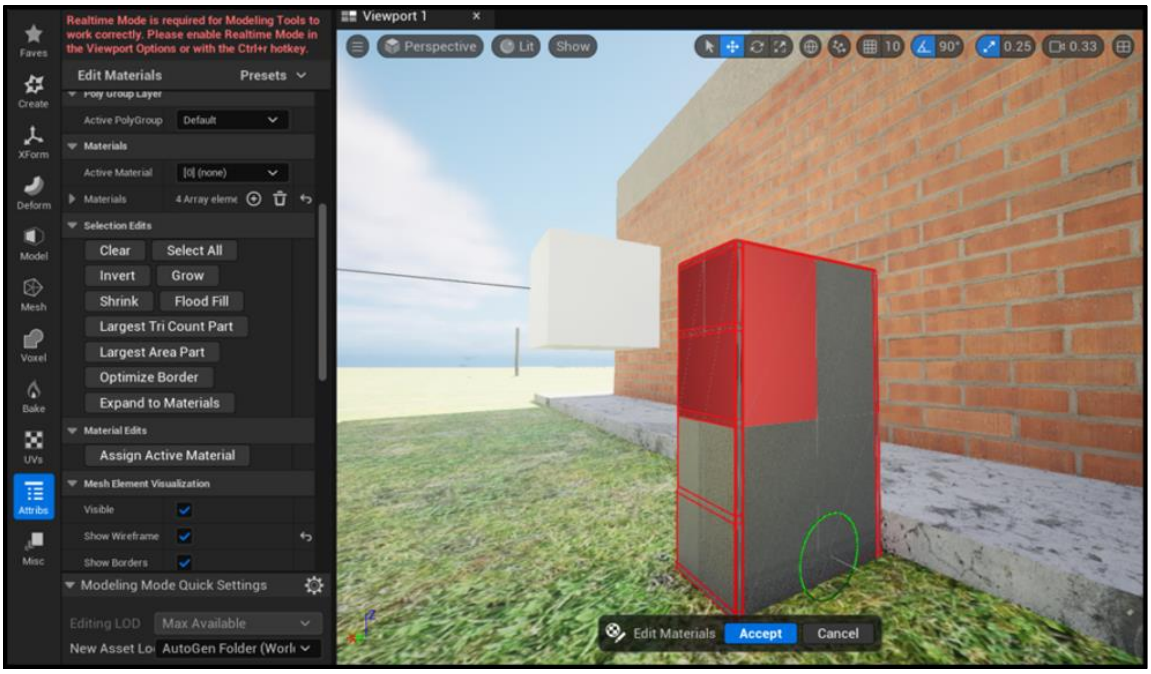


a) Unreal Engine modelling tools **b)** modelling process of reactor operation table in Blender
Source: AUTHORS, 2024.

Texturing was made depending on how the object was modelled. For example, if it was modelled in-engine, and the modelling process involved two different shapes being merged into a single object, each shape was given a material before being merged into a single object. If a single shape needed to have different materials, such as a Geiger counter, which can be visualised as a parallelepiped, one of the faces of the parallelepiped needed to have a different texture, representing the user interface of the Geiger counter. When similar cases occurred, the Unreal Engine modelling tool called “Edit Material” was used, this allowed the user to define specific areas of a mesh to apply a specific material, Figure 3.

The objects created in Blender were texturised and the materials were created externally at Blender, afterwards they were imported into the engine with the textures and materials imported with the mesh. This process allowed individual editing of each material within the mesh if and when necessary, which can potentially allow for an alteration with the software running, creating different possibilities to show what the reactor is displaying.

Figure 3: Edit Material tool in use, applying a different material to a specific part of a mesh



Source: AUTHORS, 2024.

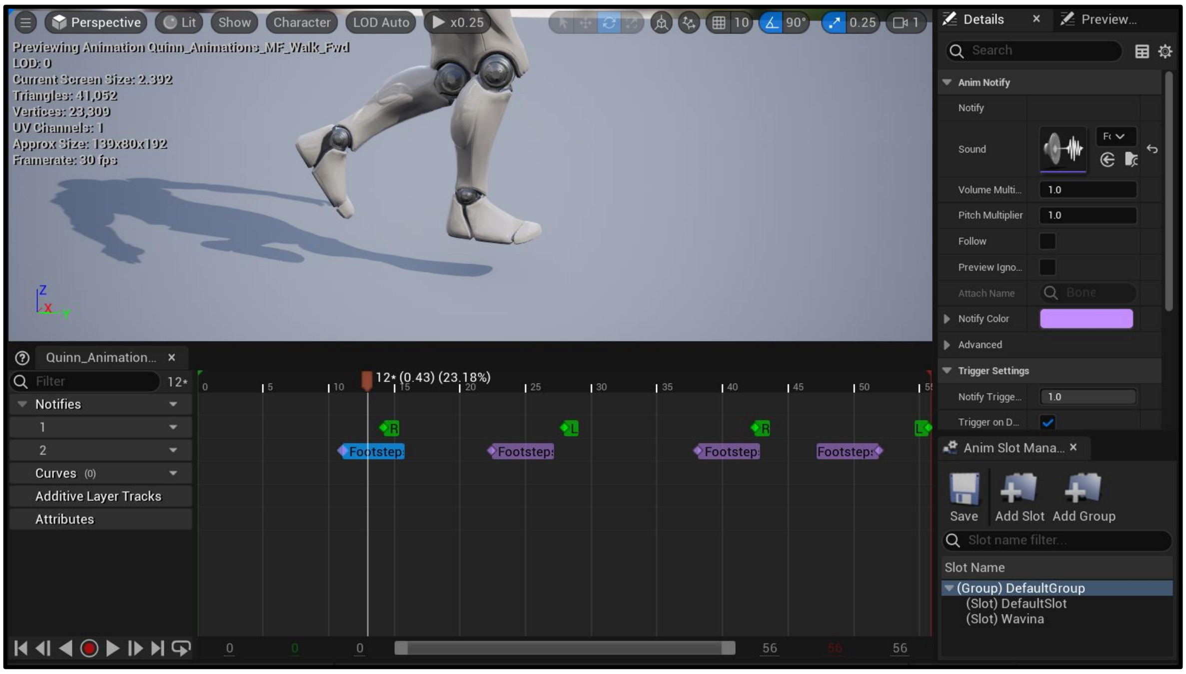
2.3. Software Development

As previously stated, Unreal Engine allows development both in C++ and their own visual script language called blueprint [28, 29]. This application was entirely developed using blueprint, with many assets imported into the engine during the project creation screen, such as pre-coded character movement, movement animations, skeleton and skeletal meshes and other assets that made for a simpler development process. The third-person game-type was selected for this application, owing to the assets imported with it.

Some modifications and implementations were made to the standard game-type in order to develop a more suited approach to a visitation software, a boolean “pause” variable was implemented, to prevent the user to move freely while interacting with some interactive objects, the user camera was changed from a third-person perspective to a first person one, the player character mesh was turned invisible to prevent it from affecting the player vision, the player collision was reduced to prevent it from start multiple interactive events at the same time, which may result in errors or glitches, and a sound element (steps) was implemented in order to provide a more realistic experience to the user.

To implement the sound element, a walking sound was downloaded from the Epic Store, and it was separated into 10 different files, each one containing a step sound. With these files, a sound cue element was created, this element randomly selects one of the sound steps, this resource is used to make the sound more dynamic and less repetitive. When a step occurs in the animation timeline a notation is created (Figure 4) and this notation triggers the sound cue, creating the walking sound.

Figure 4: Sound cue implementation in the animation timeline



Source: AUTHORS, 2024.

It was fundamental to create some interactive object within the scenario, which could allow for a better and a potentially more efficient learning experience for the user, whenever the software becomes applied as an educational tool [33, 34].

Some objects were coded to allow user manipulation, letting the user rotate and zoom in and out of it, looking at the object details, and its detailed information, such as the entrance model and a plate-type fuel elements. Other objects, such as frames allowed the user to see the information it contained in their totality, as it would be possible if the user were present in the reactor. There are also objects in which the interaction manipulates the user camera, the reactor core, when interacted takes the user camera over the moderator tank, allowing him to overview the core and see the elemens positioned inside of it.

Each one of these objects acts as an independent blueprint actor, they react to an event present within the blueprint of the user pawn when their collision boxes overlap, and the user presses the correct key. The frames are coded to create a widget with an improved quality image. This image acts as a button, when clicked, it opens the same image, but one which allows the user to read the information it contains perfectly and easily.

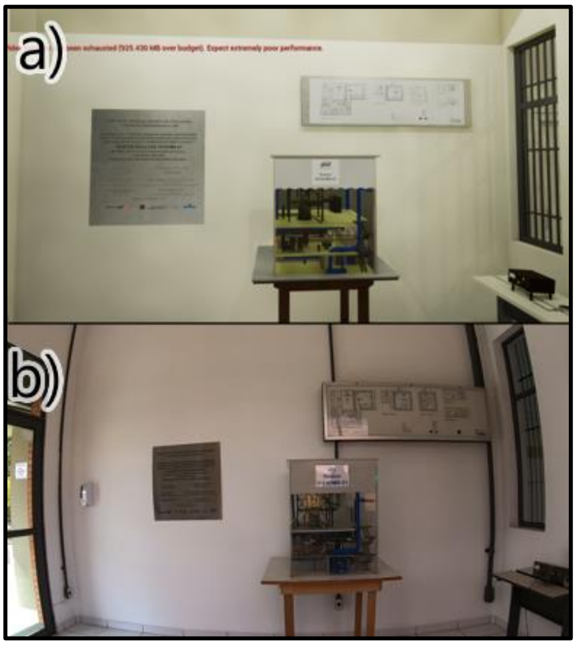
To create the code that allows the user to rotate and zoom in and out of objects, it was necessary to create a "ghost mesh" of the interactive object. This mesh is part of the user pawn, but is invisible, and cannot interact with the scenario in any way, it is also connected to a spring arm, which is connected to the user camera. When the interaction event is triggered, the scenario mesh becomes invisible. At this point, the "ghost mesh" becomes visible – this is the object the player can actually interact with, allowing for rotation relative to the world position and zooming in or out by adjusting the spring arm length. Whenever the user decides to stop interacting with it, the "ghost mesh" becomes invisible and untouchable again, and the mesh in the scenario becomes visible and, on their location, as it should be. This method prevents the user meddling with the virtual environment in a potentially damaging way, by making it messy, or buggy by throwing objects into one another.

Whenever the user is interacting with something, the player controller is in a state of pause, preventing the user from running around the virtual environment, and moving their camera, focusing entirely on the interaction.

3. RESULTS AND DISCUSSIONS

The virtual environment was built using the real ones as reference, and a realistic approach was used, providing the user with higher immersion and better experience overall when visiting the reactor. It is possible to compare the modelling results on the Figures 5 – 8, each one display a specific area of the reactor, the virtual environment modelling was designed with a realistic approach. However, some elements were not considered relevant to build, as the software is developed with an educational intent for future applications. The focus is on relevant scenario elements and not potentially distracting ones, such as electrical outlets, switches, wires, and other minor details which weren't built.

Figure 5: Nuclear reactor entrance

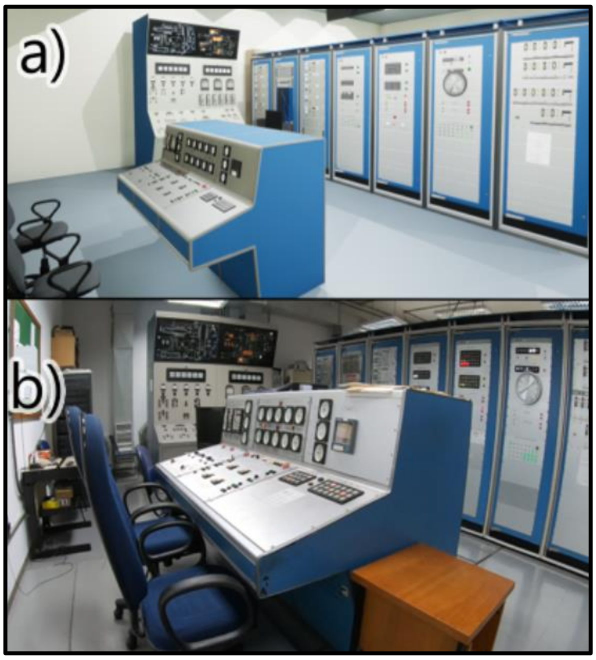


a) Virtual Environment **b)** Real Environment
Source: AUTHORS, 2024.

Figure 6: Radioprotection Room

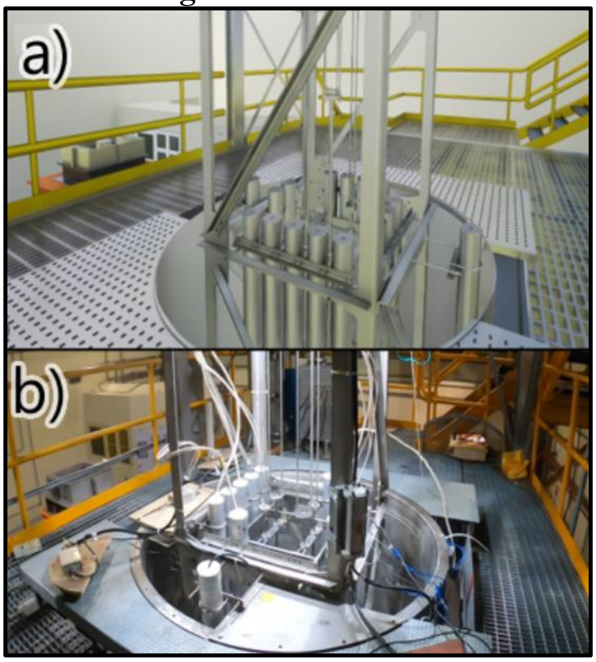
a) Real Environment **b)** Virtual Environment
Source: AUTHORS, 2024.

Figure 7: Reactor Control Room



a) Virtual Environment **b)** Real Environment
Source: AUTHORS, 2024.

Figure 8: Reactor Core



a) Virtual Environment **b)** Real Environment
Source: AUTHORS, 2024.

The virtual environment results display a remarkable similarity with the real-world environment, the noticeable differences relate to lighting, and a cleaner and more organised display, both of which are predicted differences. The virtual environment is expected to be brighter and to contain fewer elements, such as wires, due to the future educational uses of the software as previously mentioned.

4. CONCLUSIONS

Given the general public's limited understanding of nuclear reactors and nuclear energy as a whole, initiatives that shed light on the subject play a crucial role in demystifying misconceptions and correcting misinformation often accepted as common knowledge. Such efforts are of great importance to society as a whole.

The development of educational software to teach students about nuclear reactors is a viable approach. Such tools can also disseminate accurate information about nuclear technology to combat the misinformation issue via a prebunking strategy inside the classroom, with the current educational literature supporting the use of virtual environments and virtual reality as effective tools to do so.

The virtual environment here developed can also be applied to used in other educational approaches which are not exactly a visit, with the development of the reactor physics, it is possible to create a simulator, which could potentially be used in the training of future operators, as well as in one of the courses of the University of São Paulo which uses the IPEN/MB-01 reactor for students experiments[4]. Several other applications can also be thought of and be potentially developed using this reactor environment as basis, considering different educational levels, or different training objectives.

[4] IPN0025 - Física de Reatores: Experimentos no Reator Nuclear IPEN/MB-01

Overall, the creation of this virtual environment paves the way for the development of further educational tools with high pedagogical potential, which can be further replicated to other reactors as well as other nuclear technology installations, that can benefit from educational tours and scientific dissemination.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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