Experimental Immersive Practices in Teaching Sustainable Planning: Perspectives and Applications in an Academic Environment

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Abstract. Climate challenges faced by cities have their origins in water resources management. The built infrastructure ignores its ecological bases, altering ecosystems and the water cycle. Nature-Based Solutions (NBS) arise as viable alternatives to confront these problems. However, the inconsistent documentation about the systematization and functioning of NBS makes the professionals insecure about their use. New approaches using Virtual Reality (VR) facilitated the visualization and evaluation of the 3D model of a bioretention prototype. We used the headset Oculus Quest 2 and the notebook Predator Helios 300 for VR immersion. The model viewed was produced by the Archicad 26, Twinmotion, Rhinoceros 3D, and Gravity Sketch software. The experience showed that VR is effective for simulating propositive scenarios and as a learning tool in an academic environment, widening the comprehension and functioning of the subjects.

Keywords: Nature-Based Solutions (NBS), Bioretention prototype, Virtual Reality (VR) Organic Matrix, Teaching-learning devices.

1 Introduction

Climate challenges faced by cities have their origins in water resources management. Urban development traditionally used built infrastructures (gray infrastructures) that ignore their ecological bases, altering ecosystems and the water cycle (Walker & Salt, 2006). These infrastructures are planned considering their efficiency and optimization for a specific benefit, limiting them to unexpected changes and disturbances (Novotny et al., 2010). However, their disseminated use combined with the rapid population growth, enhances the vulnerability of urban communities to extreme climate and weather events (Ferreira et al., 2018; Meyer et al., 2022), making it necessary for new water management strategies capable of incorporating the dynamic functions required by urban centers (Pellegrino, 2017).

Recovering natural functions in modified spaces demands a new approach. Nature-Based Solutions (NBS) arise as viable alternatives to confront these problems. They are an umbrella concept that comprehends actions to protect, manage and restore changed ecosystems - including the use of structural and nonstructural actions (Walters et al., 2016) - that also contemplates social problems in producing adaptive responses. URBINAT (Conserva et al., 2021), expanding the NBS definition, considers socio-economic solutions that strengthen the dialogue between the physical and social aspects of the public spaces as important as soft and hard approaches. However, despite its dissemination by many institutions for about the last 20 years, the inconsistent documentation about the systematization and functioning of NBS makes the professionals insecure about their use (e.g. Environmental Services Division, 2007; Walters et al., 2016). Also, the NBS requirement of multiple knowledge and the need to be place-specific aggravates even further this difficulty. Implanting NBS on a global scale depends on the comprehension by professionals of their complete operation. Hence, the complexity of NBS demands creating a new teaching method capable of incorporating technological and social areas in the advance of more adequate solutions to the urban environment.

This article aims to build a Landscape teaching methodological tool using Virtual Reality (VR) to improve the cognition of the basic structure of a bioretention prototype. This includes the view of underground elements that the naked eye can't grasp. The tool promotes observation of layers that compose the prototype, showing the organic matrix structure. Here, we use immersive technology as an enabler for knowledge advance and also for the change of perspective on space production.

2 Virtual Reality (VR)

Landscape Architecture has many transdisciplinary concepts in its technical and theoretical scope, making it fortunate to work with visualization tools to evaluate relationships among many landscape elements. Adopting digital systems to assist with the themes studied aims to help the scene observation and interactive navigation and also to move around projected internal and external ambient (SAORIN, J. L et al., 2023). This allows the use of visualization tools both in the conception phase of the project, in the creation and development of the ideas process, and in a later phase, allowing the conduction of analysis and testing of the project.

According to Gigante (1993), Virtual Reality (VR) is a technology characterized that allows users to take part in a three-dimensional (3D) virtual environment through the use of displays, monitored and aided by sensory equipment that enables hand/body tracking and additional binaural sound in a synthetic environment. This stimulates the external visualization of the same environment. Preview studies show VR as a tool with great potential for landscape lessons, especially in higher education. Subjects such as geography, geology, and environmental sciences can gain from VR potential, as field visits are an essential part of the learning process. (AZUMA, 1997; WEBB & STAFFORD 2013; KERR, J., & Lawson, G., 2020).

VR can be a great ally in teaching processes, presenting itself as a less formal learning strategy. The immersive experience stimulates the students' autonomous learning through the flexibility presented by the virtual space. Within the Urban Planning learning process, these tools can contribute to executing spatial analysis and virtual simulations. On the microscale, using VR makes it possible to have a clearer and more precise comprehension of proposed modifications, their impacts, and their benefits.

3 Study Subject - Pilot Project Silent Garden (PPSG)

For this research, the study object used was a prototype that is a part of the Gardens Cultivation in Free Spaces institutional project. The object is in one of the Federal University of Ceará's (UFC) campuses, a product of a Landscape Architecture project, elaborated by students in a collaborative remote experience. Later, the project - named Pilot Project Silent Garden (PPSG) - was implemented in the UFC's Department of Architecture and Urbanism (DAUD-UFC).

The PPSG is based on NBS concepts and can be defined as a bioretention cell - a device defined by small regions with topographic depressions composed of draining material (base), vegetated area substrate (middle layer), and dry leaves surface (coverage). They are part of a set of techniques for water resources management in qualitative and quantitative terms through runoff control. These apparatus promote infiltration, temporary retention, evapotranspiration, and pollutant removal by the natural mechanisms of the vegetated coverage (e.g. absorption, filtration, and phytoremediation).

To simulate natural processes, an organic matrix was created, based on the Portland Manual (MARYLAND DEPARTMENT OF THE ENVIRONMENT, 2000). It was made of natural compact soil as the base; macadam, fine gravel, geotextile blanket, and sand as the drainage material; and a superficial substrate that receives the vegetation coverage. These elements working together guarantee the functionality of the prototype (Fig.01).

Figure 01. Execution and assembly of PPSG's organic matrix. Fonte: Authors, 2023**.**

Two types of bioretention cells were used on the PPJS project: rain garden and bioswales. The main difference between them is that while the first is focused on infiltrating the water on the soil, the latter has a goal of conducting the exceeding water that was not absorbed to where it would be. The combination rain garden-bioswale on the prototype was to enhance its performance, and it was determined by local conditionings - an aspect of great relevance in these types of solutions (Fig. 02).

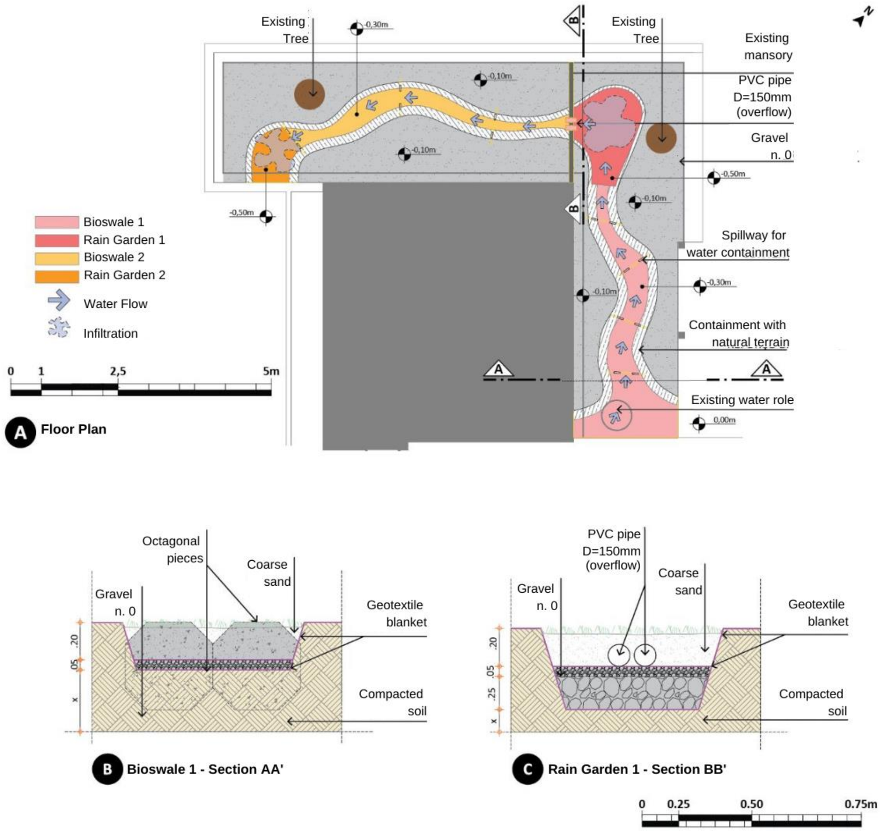

Figure 2. Execution and assembly of PPSG's organic matrix. Source: Authors, 2023.

Bioretention cell tests or pilots on a small scale offer a vast learning opportunity since they function as a trial of the use of these solutions on a bigger scale. Understanding their functioning allows the user to make adaptations without affecting their performance and reflects directly on time, costs, and work needed to execute future projects.

4 Methodology

The experiment, which has the PPSG as a subject, was developed by four researchers - two that were involved in the PPSG construction and two who did not. The PPSG form and material were registered as it is and complemented with the documentation about its execution. Two modeling processes to reproduce the PPSG in the virtual environment were made: the first to create the model, and the second to enable the VR experience. Alpha tests were conducted by researchers to verify if the model corresponded to what it envisioned. Improvements to the model were made based on feedback from the alpha until it was adequate. This method section covers the process leading up to the suitable model for the beta test - a second phase for the students to try the VR learning tool (Wurangian, 1993).

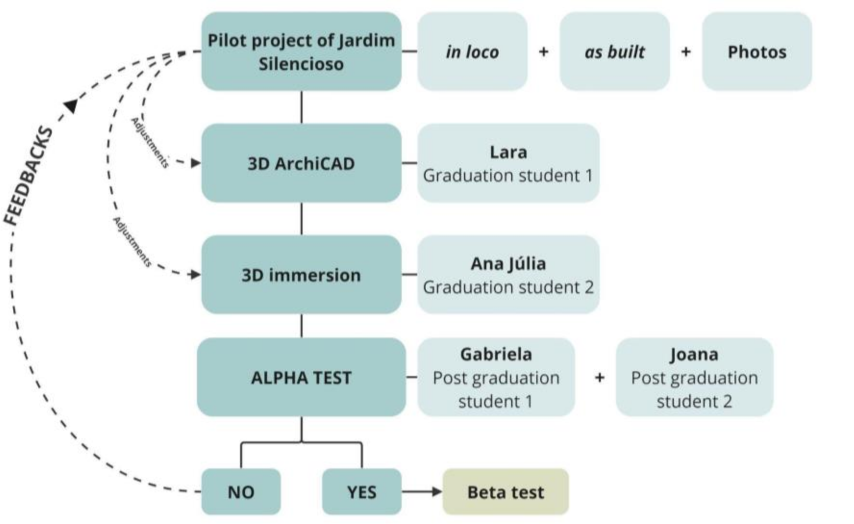

Figure 3. Flowchart showing the overall process used on the paper. Source: Authors, 2023.

4.1 Archicad 3D Model

The first 3D model was developed by a researcher that had participated in the constructive process of PPSG. This model intends to reproduce the built reality in a three-dimensional element. The software BIM Archicad 26, developed by the Hungarian company GRAPHISOFT, was used at this stage. Archicad's diverse library and the flexible tools motivated its choice. The number and types of customization of the elements make the software more adaptable to different project needs.

The modeling process began with the garden's surroundings. Archicad's mesh and magic wand tools were used to create the prototype model. Their use was based on the 2D representation of the PPSG's drawing obtained from in-loco registration, resulting in the creation of self-contained parts that could have their properties and characteristics altered. The viewing and progress of the model were facilitated by the grouping of elements in layers coherent with their execution period (Fig. 04). By the end the model was shared in the standard ArchiCAD archive (.pln), in the RHINO model (.3dm) and .obj extension.

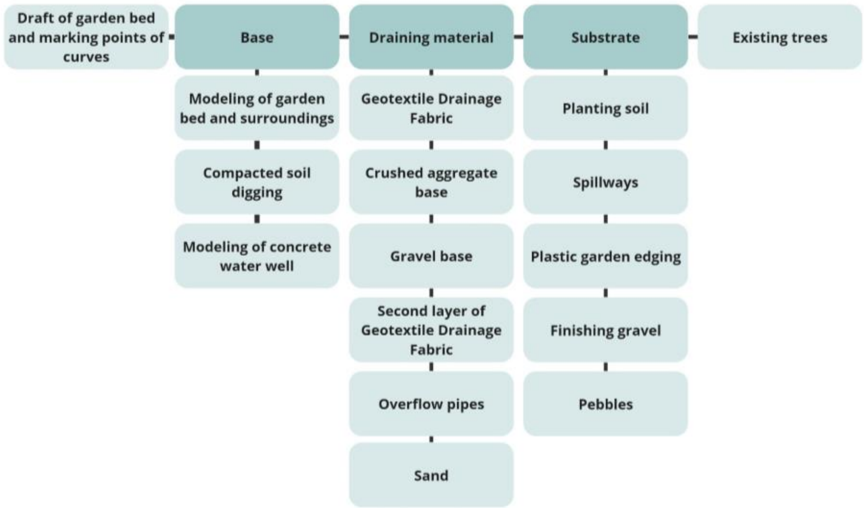

Figure 4. Flowchart showing the 5 stages and 14 sub-stages of the modeling process. Source: Authors, 2023**.**

4.2 Immersion 3D Model

Preparation and conduction of the VR study used the following equipment: Oculus Quest 2 and Predator Helios 300 notebook. The experience was executed using Twinmotion (a rendering software) and Gravity Sketch (a virtual and augmented reality software that allows the user's interaction with 3D elements), resulting in two different visualization and immersion products (Fig. 05).

The first product integrated the Archicad and Twinmotion software. The Archicad model was opened in Twinmotion - a rendering software - and visualized through its interface by a cable connection with the Oculus Quest 2 (Fig. 06)

For the development of the second product, the 3D model was transferred to Gravity Sketch. Rhinoceros 3D was used to read and simplify the object's properties presented on the Archicad model, making it lighter to be shared and imported by other software. The file was then uploaded on LandingPad - Gravity Sketch's cloud - to access via the headset's Wi-Fi connection.

In Gravity Sketch, a grouping of same level objects was made. Later, these groups were nested on layers, identified with the position of each part of the organic matrix. The materiality of elements was assigned using referenced images imported to the software (Fig. 07).

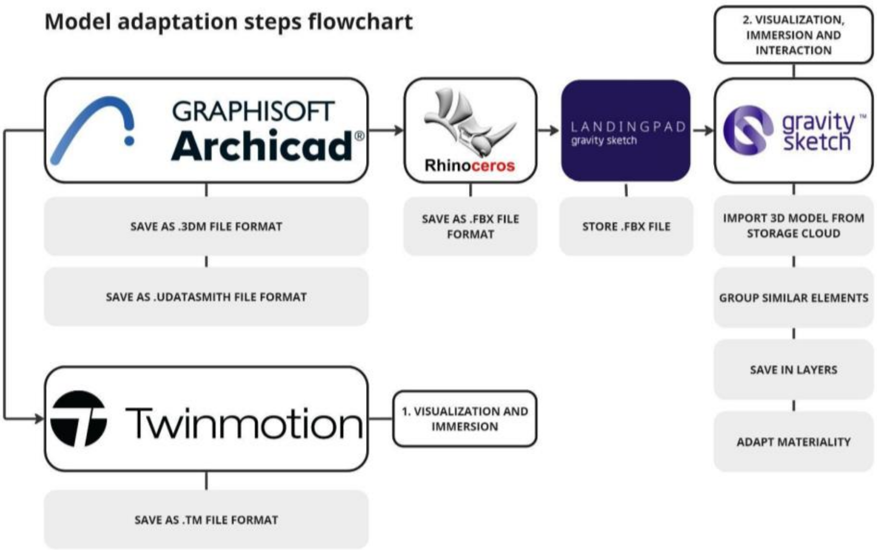

Figure 5. Flowchart showing the products' development to visualization and immersion. Source: Authors, 2023.

Figure 6. First product made using Twinmotion software. Source: Authors, 2023.

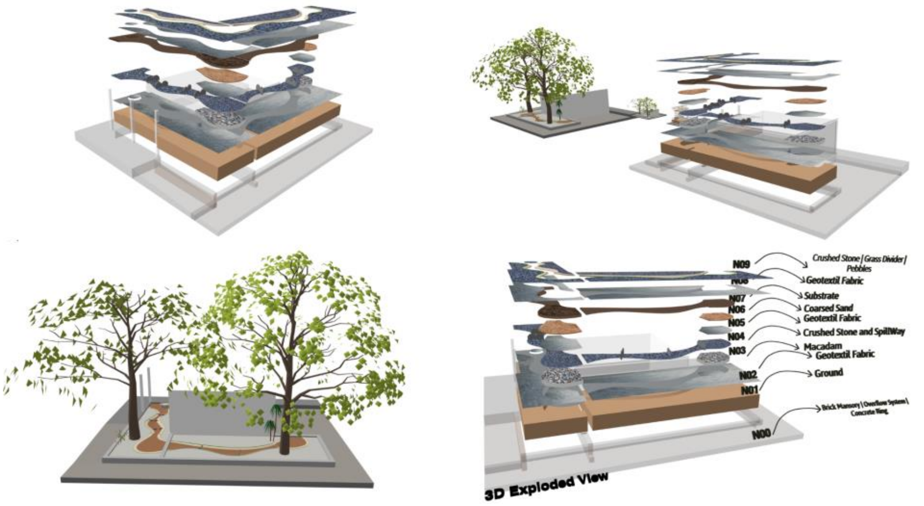

Figure 7. Second product made using Gravity Sketch software. Source: Authors, 2023.

4.3 Alpha Testing

The four team members performed the alpha test with both products. The user put the VR headset to immerse in the virtual environment while the others kept track of the visualization by the notebook's monitor.

Feedback from the alpha test led to model revision, altering the final products. New rounds of tests were conducted until there was no more negative feedback from any of the four researchers. Then, the visualization and immersion tools were ready for the next phase - the beta test.

5 Results

The Twinmotion scenery added more verisimilitude in terms of species representation, space perception, and materials. The panoramic observation and multisensory exploration gave a perception of a live environment in the VR, allowing the user to dissociate from the real world to be involved in another reality that seems familiar (SABOIA, 2004 p. 182).

Gravity Sketch presented limited accuracy of the model's materiality. However, it allowed us to observe the organic matrix components and model and layers manipulations that help understanding the functioning and organization of the prototype's components. The annotation tools enable communication between the user and observer about any doubts on the subject that may emerge from the VR. Gravity Sketch also has the advantage of seeing the external environment according to previously set boundaries established by the Oculus Quest 2. Hence, the user can move freely in the virtual environment and makes possible the use of mixed reality **-** a continuum between virtual and real worlds (MILGRAM & KISHINO, 1994; STRAND, 2020) (Fig. 8).

We observed that the two products created for visualization and immersion had different goals: the first was a more realistic view, with a more predictive potential, while the second was a more elucidator one, more adequate for pedagogical use. The choice of which product will be used will depend on the purpose.

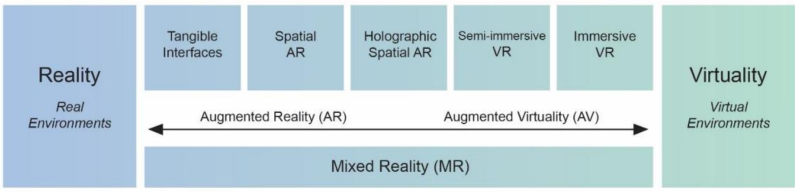

Figure 8**.** Reality-virtual continuum based on Milgram and Kishino (1994) and Augumented Reality (AR). Source: Strand, 2020**.**

6 Discussion

We concluded VR use is effective in visualizing propositive scenarios and as a teaching apparatus. Archicad's flexible tools made the first modeling process more efficient. However, the lack of interoperability between Archicad and Gravity Sketch produced a considerable amount of reworking during the alpha test.

The type of equipment influences the quality and velocity at which results are obtained. Oculus Quest 2 can be used for mixed reality, but its efficiency is low because of how the images of the surroundings are displayed - in greyscale and low resolution. More advanced devices would be necessary to guarantee the best experience for the user. Still, governmental budgetary restrictions imposed on universities can compromise the acquisition of equipment for using VR in classrooms. Also, developing this kind of tool requires qualified personnel - even the users need basic training so they can enjoy the practice with more autonomy and skills.

Knowledge exchange among graduation and post-graduation students showed that qualification is as relevant as the availability of adequate equipment. Technical advances make VR more accessible - using them to understand and plan the landscape gives us new approaches to professional education. As a next step in the research, the beta test will be implemented, and we can observe the efficiency of VR in explaining the PPSG to students that never had contact with its details.

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