Sustainable Traditional Arab Dwellings in VR: The Educational Virtual Model of Sheikh Isa House, Bahrain.

Eiman Elgewely, Thomas Tucker & Todd Ogle & David Hicks | United States

Digital technologies, including virtual reality (VR), augmented reality (AR), and, most recently, artificial intelligence (AI), open new possibilities for delivering educational content. These technologies enable educators to create dynamic, personalized learning experiences that stimulate creativity and improve the learning process. Immersive VR environments foster a deeper understanding of design principles and enhance the experiential learning of architecture and design students by providing a replica of real-world scenarios that help students actively explore architectural proportions, dimensions, materiality, and spatial relationships(Rizvic et al., 2019; Vilar et al., 2022).

The Educational Virtual Model of Sheikh Isa House in Bahrain (Figure 1) is part of a multi-phased study project that aims to study the sustainable passive solar systems applied in vernacular heritage buildings in the Arab world and the Middle East to help us learn about effective, less energy-consuming systems that could be integrated into our modern-day architecture and built environments and bring this knowledge to the classroom through an immersive, interactive, three-dimensional VR educational application that students can walk through, explore, and interact with to get a sense of its dimensions, proportions, and structure. The project also aims to highlight the regional and sociocultural factors that influenced how the inhabitants built and used the structures. This project also aims at diversifying the curriculum by educating students about areas and cultures that might be less familiar to them, in addition to the cultural aspects associated with the building's use.

Figure 1. 3D visualization of the main courtyard of the house of Sheikh Isa.

The house of Sheikh Isa in Bahrain was selected as the first building for this multi-phased study. It is a historic building in Muharraq (Yarwood, 1999, 2000), the old capital of Bahrain. The Kingdom of Bahrain is an island in the middle east that lies in the heart of the Arab world, between Saudi Arabia and Qatar. The house was built in ca.1800 and was the residence of the king of Bahrain. Today, it is a tourist attraction as part of the UNESCO Pearling Path, which includes a series of cultural heritage sites connected by a 2.17-mile visitor pathway. The site represents a testimony of the surviving instance of the pearling cultural tradition and interaction between Bahraini people and their environment and marine resources, which shaped their cultural identity

and economy(*In Pictures: Bahrain's Ancient Pearl Fishing*, n.d.; *Pearling Path*, n.d.; *Pearling, Testimony of an Island Economy*, n.d.).

Besides its cultural and historical value, the significance of this building is that it integrates passive solar cooling systems that allow adaptation to the very arid climate, which reaches around 104°F (40°C) during the summer, long before the use of electricity and air conditioners. Passive solar cooling systems are commonly used in vernacular architecture in the middle east and North Africa(Al-Sallal & Rahmani, 2019; Attia, 2014; Fardeheb, 2007) . By exposing living spaces to the sun, the passive solar design uses the sun's energy to heat and cool them. These fundamental reactions to solar heat influence design decisions, material selections, and placements that might heat or cool the built environments(Foruzanmehr & Vellinga, 2011). This project uses state-of-the-art technology to reinterpret the passive solar strategies applied in the house, including the windcatcher known as "badgir," the central courtyards, the thick mud brick walls, and the distinct summer and winter rooms (Figure 2).

Figure 2. 3D visualization of the hall connected to the windcatcher and used as the main family room.

The 3D visualization of the house was based on the results of the research sponsored by the Bahrain Authority for Culture and Antiquities (BACA) and accomplished and published in 2017 by an international research team(Barazzetti et al., 2017), which included detailed documentation of the house using photogrammetry, 3D laser scanning, and aerial drones. The virtual Model of Sheikh Isa House was created using different 3D modeling software, including SketchUp Pro, Autodesk 3DS Max, and Rhino 3D. The model's accuracy is essential for the next level of the study, which is the building performance simulation. The 3D model was then imported into Twinmotion, a real-time 3D visualization software that helped add realistic surface materials, textures, and weathering effects.

The current demo virtual application allows users to walk through the building, exploring all four house quarters: the sheik's quarters, the women's quarters, the guest quarters, and the servant quarters. Preset checkpoints (locations) are available for the user to instantly navigate around the house (e.g., Courtyard 1, Courtyard 1, Room 1, Room 2 [Figure 3]). The checkpoints are in the toolbar on the left controller, providing guidance while navigating the building. The user can also change the time of the day and month at any point to preview the building in different weather conditions. The demo VR application has been tested in two successive events, engaging a diverse audience group, including undergraduate and graduate students and a public audience of different ages and backgrounds. These events, namely the Students & Faculty-initiated Research Grant Symposium and the ICAT Creativity and Innovation Day 2023, were held at Virginia Tech University.

Figure 3. A screenshot of the VR walkthrough showing the navigation checkpoints.

A higher level of engagement within the virtual environment and interaction with the multimedia content, including audio narration and video demonstrations, are currently being developed using Unreal Engine 5 for the next version of the VR app to enrich the user experience. A digital storytelling scenario that effectively communicates the narrative of the house and its inhabitants will be the main emphasis of the multimedia content. Furthermore, the app will visually present the building simulation study results, including thermal comfort, daylight, shadow analysis, and airflow. Through the digital storytelling content, users will understand how the building's orientation, structure, use of local materials, and construction techniques contributed to its sustainable passive solar design.

The 3D Virtual model of the house of Sheikh Isa will be a versatile resource for various courses in the School of Architecture and the School of Design at Virginia Tech University. The final VR application, planned to be a free tool for educators worldwide, will be available for download from the Oculus or VIVE store.

References

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Figures

No.	Caption	Width (8 or 17 cm)
Fig. 1	3D visualization of the main courtyard of the house of Sheikh Isa.	17 cm
Fig. 2	3D visualization of the hall connected to the windcatcher and used as the main family room.	17 cm
Fig. 3	A screenshot of the VR walkthrough showing the navigation checkpoints.	17 cm