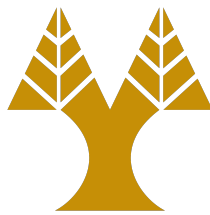


Thesis Dissertation

ORBIS: THE CONTINENTAL GALLERY

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COMPUTER SCIENCE DEPARTMENT

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Orbis: The Continental Gallery

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Thesis submitted in partial fulfilment of the requirements for the award of
degree of Bachelor in Computer Science at University of Cyprus

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Declaration of Originality

I declare that this dissertation and any accompanying software are my own original work, conducted in full compliance with the University of Cyprus Code of Conduct for Research (<https://www.ucy.ac.cy/legislation/kodikas-deontologias-kai-politikes/>), and with full accountability on my part for the accuracy, integrity, and validity of all content.

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Finally, I would like to extend my heartfelt thanks, first and foremost to my partner for their unwavering support, and my close friends for their encouragement, patience, and support throughout my studies.

Summary

This thesis presents *Orbis: The Continental Gallery*, an educational Virtual Reality (VR) museum designed to promote awareness and understanding of diverse cultural identities around the world. The application immerses users in a central hub featuring an interactive world map, from which they can navigate to dedicated country rooms that faithfully recreate the traditional domestic environments and cultural artifacts of each represented nation.

Built using Unity 2022.3 with the Universal Render Pipeline, OpenXR, and the XR Interaction Toolkit, the system leverages modern VR interaction paradigms including teleportation-based locomotion, wrist-attached information panels, and ray-based selection on an interactive world map to create an engaging educational experience. The current implementation features fully realized rooms for Cyprus and Japan, each containing traditional artifacts, architectural elements, and environmental details that reflect the cultural heritage of their respective countries.

A user study was conducted to evaluate the system across three dimensions: immersion and cultural presence, the effectiveness of interactive learning elements, and the influence of prior cultural interest on user experience. Results from the evaluation demonstrate that the VR museum environment successfully creates a sense of presence and cultural immersion, and that interactive elements such as artifact information panels contribute meaningfully to cultural learning.

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Chapter 1

Introduction

1.1 Motivation

Cultural heritage represents the collective memory of civilizations; the traditions, artifacts, architecture, cuisine, and daily practices that define the identity of a person. Understanding and preserving these cultural identities is essential in an increasingly globalized world, where homogenization threatens to erode the distinctiveness of local traditions [34]. Traditional methods of cultural education, such as textbooks, documentaries, and physical museum visits, while valuable, are limited in their ability to convey the *lived experience* of a culture. A photograph of a Cypriot village house cannot communicate the spatial feeling of its stone walls, and a textbook description of a Japanese tatami room cannot replicate the sense of scale and atmosphere one would feel standing within it.

Virtual Reality (VR) offers a transformative opportunity to bridge this gap. By immersing users in digitally reconstructed environments, VR enables experiential learning, a mode of education where knowledge is acquired through direct interaction rather than passive observation [16]. The sense of presence afforded by VR, the feeling of “being there,” has been shown to enhance engagement, retention, and emotional connection with the subject matter [29, 46]. This makes VR particularly well-suited for cultural heritage education, where the goal is not merely to transmit facts but to foster empathy, curiosity, and appreciation for ways of life different from one’s own.

1.2 Problem Statement

Despite the potential of VR for cultural education, existing virtual museum experiences tend to fall into one of two categories: high-fidelity digital twins of existing physical museums that replicate the passive viewing experience of their real-world counterparts, or gamified experiences that prioritize entertainment over educational accuracy. Few appli-

cations attempt to reconstruct the *domestic* cultural environment – the traditional home, the everyday artifacts, the sounds and spatial organization of daily life – in a way that is both culturally authentic and pedagogically effective.

Furthermore, many VR educational applications lack structured evaluation of their learning outcomes. While they may demonstrate technical competence, they often fail to measure whether users actually acquire cultural knowledge or develop greater cultural curiosity as a result of the experience.

1.3 Proposed Solution

This thesis presents *Orbis: The Continental Gallery*, an educational VR museum application that addresses these limitations. Orbis immerses the user in a central hub featuring an interactive world map, from which they can navigate to dedicated country rooms. Each room is designed to faithfully recreate the atmosphere and spatial characteristics of a traditional domestic environment from the represented country, populated with culturally significant artifacts accompanied by informative panels that provide historical and cultural context.

The key design principles of Orbis are:

- **Cultural Authenticity:** Each room is researched and designed to accurately represent the traditional domestic environment, architecture, and material culture of its respective country.
- **Experiential Learning:** Users learn through exploration and interaction rather than passive reading, leveraging the immersive properties of VR to create memorable educational experiences.
- **Intuitive VR Interaction:** The system employs natural interaction paradigms – selecting countries on a world map, reading wrist-attached panels, teleportation-based locomotion – to minimize the learning curve and maximize engagement.
- **Structured Assessment:** Each room concludes with an interactive mini-game section that allows users to self-assess their learning and reinforces key cultural concepts encountered during exploration.

1.4 Implementation Overview

Orbis is developed in Unity 2022.3 using the Universal Render Pipeline (URP) for high-quality visuals. VR interaction is powered by the XR Interaction Toolkit 2.6.5 with

OpenXR 1.14.3 as the hardware abstraction layer, ensuring broad headset compatibility. The application consists of a hub scene containing an interactive world map displayed on a curved surface, a loading scene that provides progress feedback and cultural tooltips during scene transitions, and dedicated country scenes (currently Cyprus and Japan) accessible through map interaction.

The VR interaction system includes custom scripts for map-based country selection with visual feedback, a navigation menu providing scene transitions and a position reset feature for reorientation, teleportation-based locomotion for comfortable room-scale movement, wrist-attached multi-slide information panels for artifact education, and quiz-based mini-games for end-of-room knowledge assessment.

1.5 Contribution

The primary contributions of this thesis are:

1. The design and implementation of *Orbis: The Continental Gallery*, a VR application that demonstrates how immersive environments can be used for cultural heritage education through domestic space reconstruction.
2. A structured interaction design framework for VR museums that balances educational content delivery with user agency and exploration.
3. An empirical evaluation of the system’s effectiveness across three research dimensions: immersion and cultural presence, interactive learning support, and the influence of prior cultural interest on user experience.

1.6 Thesis Outline

The remainder of this thesis is organized as follows:

- **Chapter 2** provides the theoretical background necessary to understand the technologies and concepts underlying this work, including Virtual Reality, cultural heritage preservation, educational VR, and the specific frameworks used.
- **Chapter 3** surveys existing work in virtual museums, cultural heritage VR applications, and educational VR systems, positioning *Orbis* within the broader landscape.
- **Chapter 4** describes the system architecture and design decisions, including scene structure, interaction design, and user experience considerations.

- **Chapter 5** details the technical implementation, covering the Unity project configuration, VR interaction scripts, asset pipeline, and room construction.
- **Chapter 6** presents the user study methodology, research questions, questionnaire design, and the results of the evaluation.
- **Chapter 7** summarizes the contributions, discusses limitations, and proposes directions for future work.

Chapter 2

Theoretical Background

This chapter provides the theoretical foundation for the concepts and technologies that underpin the Orbis system. It covers Virtual Reality as a medium, the field of cultural heritage preservation and digitization, educational theory as it applies to immersive environments, and the specific technical frameworks employed in the implementation.

2.1 Virtual Reality

2.1.1 Definition and Core Concepts

Virtual Reality (VR) refers to a computer-generated simulation of a three-dimensional environment that can be interacted with in a seemingly real or physical way by a person using specialized hardware, typically a head-mounted display (HMD) and hand controllers [12]. The defining characteristic of VR, as distinct from other display technologies, is its ability to create a sense of *presence* - the subjective feeling of “being there” - in the virtual environment rather than merely observing it from outside [29].

Three key properties distinguish VR from conventional media:

- **Immersion:** The degree to which the system envelops the user’s senses, replacing real-world stimuli with virtual ones. Modern HMDs achieve this through wide field-of-view stereoscopic displays, positional head tracking, and spatial audio.
- **Interaction:** The ability of the user to act upon and modify the virtual environment in real time, creating a feedback loop that reinforces the sense of agency and presence.
- **Imagination:** The capacity of VR to transport users to environments that may be impossible, impractical, or dangerous to visit in reality; including historical reconstructions, remote locations, or abstract visualizations.

2.1.2 VR Hardware

Modern consumer VR systems consist of a head-mounted display with integrated motion tracking, paired with hand controllers that enable six-degrees-of-freedom (6DoF) interaction. Standalone headsets such as the Meta Quest series have eliminated the need for external base stations or tethered PCs, making VR more accessible than ever. The OpenXR standard [15], maintained by the Khronos Group, provides a unified API that abstracts hardware differences, allowing applications to target multiple headsets without platform-specific code.

2.1.3 Presence and Immersion

Presence in VR has been extensively studied since Witmer and Singer’s foundational work on the Presence Questionnaire (PQ) [46], which identifies factors such as control, sensory richness, distraction, and realism as contributors to the sense of presence. Slater and colleagues further distinguished between *place illusion* (the sensation of being in a real place) and *plausibility illusion* (the sensation that events are really happening), both of which contribute to the overall sense of presence [28].

For educational VR applications, presence is not merely a desirable quality but a functional requirement: higher presence correlates with greater engagement, better recall, and stronger emotional responses to the content [5].

2.1.4 Cybersickness

A significant consideration in VR design is cybersickness, a form of motion sickness induced by sensory conflict between visual and vestibular input [19]. Symptoms include nausea, dizziness, disorientation, and eye strain. Design choices such as teleportation-based locomotion (rather than smooth artificial movement), stable reference frames, and appropriate frame rates can mitigate these effects. The evaluation of cybersickness before and after VR exposure is standard practice in user studies, often measured using the Simulator Sickness Questionnaire (SSQ) [14] or similar instruments.

2.2 Cultural Heritage and Virtual Museums

2.2.1 Cultural Heritage Preservation

Cultural heritage encompasses the tangible and intangible expressions of human creativity and collective identity; buildings, artifacts, traditions, languages, and practices passed down through generations [34]. The preservation and dissemination of cultural heritage

faces challenges including physical deterioration, limited accessibility, and the difficulty of conveying context and atmosphere through traditional media.

Digital technologies have increasingly been applied to heritage preservation, from 3D scanning and photogrammetry of physical artifacts [25] to the creation of virtual reconstructions of historical sites. These digital approaches complement physical preservation by enabling wider access and by capturing spatial and contextual information that photographs alone cannot convey.

2.2.2 Virtual Museums

Virtual museums are digital environments that present cultural, artistic, or scientific collections in an organized manner [26]. They range from simple web-based galleries displaying 2D images to fully immersive VR experiences that reconstruct physical spaces. Sylaiou et al. [30] identify several advantages of virtual museums over their physical counterparts:

- Accessibility regardless of geographic location
- The ability to present artifacts in their original context rather than in display cases
- Interactive and personalized experiences that adapt to user interests
- Preservation of fragile or endangered cultural sites in digital form
- The potential for experiential learning through embodied interaction

VR museums represent the most immersive end of this spectrum, offering users the sense of physically inhabiting the presented spaces. This is particularly valuable for cultural heritage, where the spatial organization of domestic environments, the scale of architectural elements, and the arrangement of everyday objects all carry cultural meaning that is lost in flat media.

2.3 Educational Theory and VR

2.3.1 Experiential Learning

Kolb's Experiential Learning Theory [16] posits that knowledge is created through the transformation of experience. Learning occurs most effectively when individuals engage in a cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation. VR aligns naturally with this framework by providing concrete

experiences (exploration of virtual environments), opportunities for reflection (information panels, guided narratives), and active experimentation (interaction with objects, self-assessment games).

2.3.2 Constructivism and Embodied Learning

Constructivist learning theory holds that learners actively construct knowledge through interaction with their environment rather than passively receiving information [22]. In VR, this manifests as embodied learning; the acquisition of knowledge through bodily engagement with spatial environments [13]. When a user physically turns to examine a traditional Cypriot clay oven from multiple angles, reaching toward it and reading contextual information displayed at their wrist, they engage multiple cognitive pathways simultaneously, creating richer and more durable memories than reading about the same artifact in a textbook.

2.3.3 Situated Learning

Situated learning theory emphasizes that knowledge is inseparable from the context in which it is acquired [18]. By placing cultural artifacts within reconstructions of their original domestic environments – a Cypriot *fournos* (clay oven) outside in the garden, Japanese lacquerware on a low *chabudai* (short-legged) table in a tatami room – Orbis provides the contextual richness that situated learning requires.

2.4 Technical Frameworks

2.4.1 Unity Engine and Universal Render Pipeline

Unity is a cross-platform game engine widely used for VR development due to its extensive XR support, large asset ecosystem, and accessible development workflow [37]. The Universal Render Pipeline (URP) provides physically-based rendering (PBR) with optimized performance for VR applications, supporting features such as real-time lighting, ambient occlusion, and high-dynamic-range imagery (HDRI) for environmental lighting.

2.4.2 OpenXR

OpenXR is an open, royalty-free standard for VR and AR application development maintained by the Khronos Group [15]. It provides a unified interface between VR applications and runtime systems, eliminating the need for headset-specific SDKs. By targeting OpenXR, applications such as Orbis can run on any compliant headset, including Meta

Quest, Valve Index, HTC Vive, and Windows Mixed Reality devices, without modification.

2.4.3 XR Interaction Toolkit

Unity’s XR Interaction Toolkit (XRI) [38] provides a component-based framework for building VR interactions. It defines a system of *Interactors* (components that initiate interaction, such as ray interactors on controllers) and *Interactables* (components attached to objects that can be interacted with). The toolkit handles:

- **Hover events:** Triggered when an interactor’s selection ray overlaps an interactable, enabling visual feedback without commitment.
- **Select events:** Triggered when the user actively engages (e.g., pressing a trigger) while hovering, confirming an interaction.
- **Locomotion:** Teleportation-based and continuous movement providers that can be configured for user comfort.
- **UI Interaction:** Ray-based interaction with Unity’s Canvas UI system, enabling familiar button and panel interfaces in 3D space.

2.4.4 ProBuilder

ProBuilder [35] is a Unity package for rapid 3D level design directly within the editor. It enables the creation and modification of 3D geometry without requiring external modeling software, making it suitable for prototyping room layouts and architectural elements. In Orbis, ProBuilder was used to construct the structural geometry of the country rooms, including walls, floors, and architectural features.

2.4.5 Blender

Blender [6] is a free and open-source 3D modeling, sculpting, and rendering application. It supports the full 3D asset creation pipeline, from modeling and UV unwrapping to texturing and export in formats compatible with Unity (such as FBX and glTF). In Orbis, Blender was used to create custom 3D assets for the Cyprus room where suitable pre-made models were not available. Specifically, two traditional Cypriot bread-making implements were modeled: the *tapsothiki* (a long wooden board with half-sphere indentations where bread dough is left to rise in a warm space) and the *skafi* (a trapezoid-shaped wooden trough used for mixing dough ingredients). These artifacts are highly specific to Cypriot

domestic culture and are not available in standard asset libraries, making custom modeling necessary.

2.4.6 TextMeshPro

TextMeshPro (TMP) [36] is Unity’s advanced text rendering system, providing high-quality text display using Signed Distance Field (SDF) rendering. Unlike traditional bitmap fonts, SDF text remains sharp at any scale and viewing distance, a critical requirement in VR where text must be legible from varying distances and angles. All information panels in Orbis use TextMeshPro for their educational content.

2.4.7 GIMP

GIMP (GNU Image Manipulation Program) [31] is a free and open-source raster graphics editor used for image manipulation and editing. In Orbis, GIMP 3.2.4 was used to modify material textures obtained from asset libraries, adjusting saturation, brightness, and overall color balance to ensure visual consistency across assets from different sources and to match the intended atmospheric tone of each country room.

2.4.8 Inkscape

Inkscape [11] is a free and open-source vector graphics editor. In Orbis, Inkscape was used to generate the individual country shapes that serve as both the visual meshes and interaction colliders for the interactive world map in the hub scene. By tracing country outlines as vector paths and exporting them as SVGs, precise and clean geometry was produced for each selectable country on the map.

Chapter 3

Related Work

This chapter surveys existing work in three areas relevant to Orbis: virtual museums and cultural heritage VR applications, educational VR systems, and immersive cultural experiences. For each category, representative systems are described and their relationship to the present work is discussed.

3.1 Virtual Museums and Cultural Heritage Applications

3.1.1 Google Arts & Culture

Google Arts & Culture provides virtual tours of hundreds of museums worldwide using 360-degree photography and high-resolution artifact imagery [10]. While the platform offers unparalleled breadth of content, its approach is fundamentally that of a *virtual tour* rather than an immersive experience; users view panoramic photographs rather than navigating freely in 3D space. The platform lacks the spatial presence and interactive engagement that VR affords.

3.1.2 The Virtual Museum of Iraq

The Virtual Museum of Iraq [21] is a web-based 3D environment that allows users to explore reconstructions of eight halls representing different periods of Mesopotamian civilization. The project demonstrates the potential of virtual environments for cultural preservation, particularly for heritage sites that have been damaged or destroyed. However, as a desktop application, it lacks the embodied presence that characterizes VR experiences.

3.1.3 Museum of Underwater Antiquities

Liarokapis et al. [20] developed a VR museum for underwater archaeological artifacts, allowing users to examine ancient shipwrecks and recovered objects in their reconstructed underwater context. This work is notable for its emphasis on *contextual presentation*; showing artifacts not in isolation but within the environment where they were found. Orbis adopts a similar philosophy by presenting cultural artifacts within reconstructed domestic spaces rather than as isolated museum exhibits.

3.2 Educational VR Applications

3.2.1 Virtual Rome

Pietroni et al. [23] created an immersive reconstruction of ancient Rome that allows users to walk through historically accurate street scenes, enter buildings, and observe daily life. The project demonstrates how VR can make historical education experiential rather than didactic. However, the focus is on architectural reconstruction rather than material culture and domestic life, which is the emphasis of Orbis.

3.3 Immersive Cultural Experiences

3.3.1 Nefertari: Journey to Eternity

Nefertari: Journey to Eternity [8] is a VR experience that allows users to explore the tomb of Queen Nefertari in Egypt, which is normally closed to the public for preservation. The experience uses photogrammetry and high-resolution textures to achieve photorealistic fidelity. While impressive in visual quality, the experience is primarily observational; users can look but not interact with the environment. Orbis extends this approach by adding interactive educational elements and self-assessment components.

3.3.2 The Dawn of Art

The Dawn of Art [4] transports users to the Chauvet Cave in France to experience 36,000-year-old cave paintings in their original spatial context. The application demonstrates the power of VR for accessing inaccessible heritage sites and emphasizes the importance of spatial context for understanding cultural artifacts. Orbis applies similar principles to domestic rather than archaeological contexts.

3.4 Summary and Positioning

Table 3.1 summarizes the key characteristics of the surveyed works in comparison to Orbis.

Table 3.1: Comparison of Orbis with related work.

System	VR	Interactive	Cultural	Educational	Evaluated
Google Arts & Culture	No	Limited	Yes	Passive	No
Virtual Museum of Iraq	No	Yes	Yes	Passive	No
Underwater Antiquities	Yes	Yes	Yes	Passive	Yes
Virtual Rome	Yes	Limited	Yes	Passive	Yes
Nefertari VR	Yes	Limited	Yes	Passive	No
Dawn of Art	Yes	Limited	Yes	Passive	No
Orbis	Yes	Yes	Yes	Active	Yes

Orbis distinguishes itself from existing work in several ways. First, it focuses specifically on *domestic cultural environments* rather than formal museum spaces or archaeological sites, presenting artifacts in the context of daily life. Second, it combines immersive exploration with structured educational elements (information panels) and active assessment (mini-games), creating a complete learning cycle rather than a purely observational experience. Third, it is designed as an extensible platform where additional country rooms can be added over time, rather than a single-purpose experience for one cultural site. Finally, it employs a rigorous evaluation methodology informed by established VR research practices.

Chapter 4

Architecture and Design

This chapter describes the high-level architecture of Orbis, the design principles that guided its development, and the user experience decisions that shape the interaction model. The goal is to provide a clear picture of *what* the system does and *why* it is structured as it is, before the following chapter details *how* it is implemented.

4.1 System Overview

Orbis follows a hub-and-spoke architecture where a central hub scene serves as the entry point and navigation nexus, connecting to individual country room scenes via an interactive world map interface. Figure 4.1 illustrates this structure.

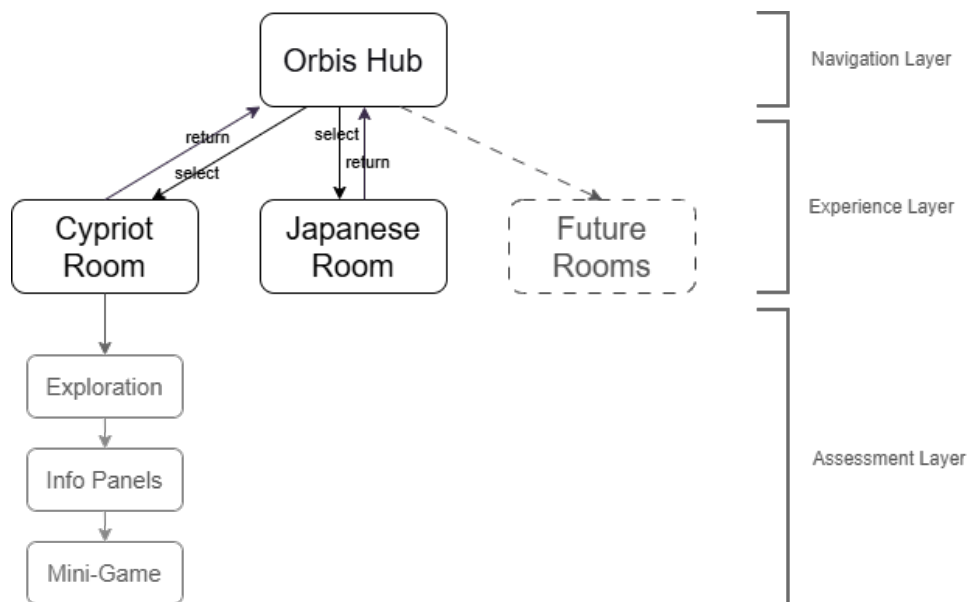


Figure 4.1: High-level system architecture of Orbis.

The system comprises three primary layers:

1. **Navigation Layer:** The hub scene and world map interaction system that allows users to select and travel to country rooms.
2. **Experience Layer:** The country room scenes containing cultural artifacts, environmental design, information panels, and spatial audio.
3. **Assessment Layer:** Quiz-based mini-games at the end of each room, consisting of multiple-choice and true/false questions that test and reinforce the cultural knowledge encountered during exploration.

4.2 Scene Architecture

4.2.1 The Hub (OrbisHub)

The hub serves as the user’s first point of contact with the application and functions as both an orientation space and a navigation interface. It contains:

- An interactive world map displayed on a slightly curved quad plane, positioned centrally and serving as the primary navigation mechanism. Each selectable country is a separate mesh with its own collider, generated using Inkscape vector tracing.
- A parquet wood floor and glass-panel side walls that frame the world map without competing for visual attention.
- An HDRI skybox depicting the Earth from space, providing a striking visual backdrop of clouds, continents, and the sun rising over the horizon. The skybox is static and serves purely as an aesthetic element to reinforce the global theme.

The hub is intentionally designed as a calm, low-stimulus environment that contrasts with the richly detailed country rooms. This serves both a practical purpose (allowing the user to orient themselves and understand the navigation system without distraction) and a pedagogical one (creating anticipation for the detailed cultural environments they are about to enter). The navigation menu is not present in the hub, as there is no need for a “Return to Hub” or “Reset Position” function when the user is already at the starting point.

4.2.2 Loading Scene

When a user selects a country from the world map, they do not transition directly to the country room. Instead, the screen fades to black (handled by the FadeController script) and the application loads an intermediate loading scene. This scene serves two purposes:

- **Progress feedback:** A loading message is displayed, followed by a finalizing message once the country room assets are nearly ready, keeping the user informed during what may otherwise feel like an unresponsive pause.
- **Cultural tooltips:** While the country room loads in the background, the loading scene displays tooltips themed to world culture in general, providing educational content even during wait times.

This intermediate scene ensures a smooth perceptual transition between the hub and the country rooms, avoiding the jarring effect of a sudden scene swap while large asset loads occur.

4.2.3 Country Rooms

Each country room is a self-contained scene representing the domestic cultural environment of its respective nation. The rooms share a common structural pattern:

1. **Entry Zone:** The user spawns at a designated entry point, oriented to face the main room. A brief moment of orientation allows the user to take in the overall atmosphere.
2. **Exploration Zone:** The main body of the room, populated with cultural artifacts. Users explore freely, approaching artifacts of interest to read their information panels.
3. **Assessment Zone:** Located at the far end of the room, this area contains a quiz-based mini-game consisting of multiple-choice and true/false questions that test the user's recall of cultural information encountered during exploration.

The physical shape of each room is inspired by the geographic outline of its country, creating a subtle spatial connection between the room's form and the culture it represents.

Cyprus Room

The Cyprus room recreates a traditional Cypriot village house, featuring:

- Stone walls and terracotta-tiled architectural elements characteristic of Cypriot vernacular architecture.
- Traditional artifacts including pottery, woven textiles, agricultural tools, and kitchen implements.

- Traditional Cypriot fauna representations (donkeys, cats) placed in contextually appropriate locations.
- Local flora (olive trees, grape vines, citrus) visible through openings or integrated into the environment.
- Traditional Cypriot food items (halloumi, commandaria wine, dried herbs) arranged in kitchen areas.
- Ambient sound design incorporating natural soundscapes (cicadas, gentle breeze) to reinforce the Mediterranean atmosphere.

Japan Room

The Japan room recreates a traditional Japanese dwelling organized across several interconnected spaces:

- A genkan (entrance hall) with traditional threshold elements and decorative tanuki statues.
- A main traditional room featuring a tokonoma alcove, a chabudai (low table) with a tea set, a kotatsu, and traditional instruments such as the koto and shamisen.
- A bedroom with futon bedding laid on tatami mat flooring and a calligraphy table.
- A kitchen area with an irori (sunken hearth), a sunken doma area containing a kamado (traditional stove), various food items, and sake gourds.
- An exterior garden with a temple structure and sakura (cherry blossom) trees, connected to the interior by an engawa (covered wooden veranda).

4.3 Interaction Design

The interaction design of Orbis prioritizes naturalness, accessibility, and minimal cognitive load. All interactions use the XR Interaction Toolkit's event-driven model, ensuring consistent behavior across different VR headsets.

4.3.1 World Map Navigation

The primary navigation mechanism is a hover-and-select interaction on the world map:

1. The user points their controller ray at the world map. Only countries with implemented rooms have mesh colliders on the map; countries without rooms have no collider and therefore no visual mesh overlay, making it immediately apparent which destinations are available.
2. When the ray intersects a selectable country, the country's color shifts to provide immediate visual feedback. Each country uses a distinct color scheme: Cyprus highlights from yellow to light yellow, while Japan highlights from red to light red/pink.
3. Pressing the select button (trigger) while hovering over a highlighted country initiates a fade-to-black transition followed by loading of the corresponding country room.

This interaction model leverages the familiar metaphor of pointing at a location on a map to “go there,” making the navigation system immediately understandable even to first-time VR users.



(a) Overview of the interactive world map



(b) A country highlighted by the controller ray

Figure 4.2: Country selection on the world map. The user's ray highlights a selectable country.

4.3.2 Information Panels

Educational content is delivered through wrist-attached information panels; a design inspired by a clipboard or guidebook that a visitor might carry in a physical museum:

- Panels are attached to the user's non-dominant hand, positioned slightly offset for comfortable reading without obstructing the view.
- Each artifact's panel contains multiple slides that can be navigated with next/previous buttons using the dominant hand's ray interactor.

- Panel activation occurs when the user approaches and interacts with an artifact, ensuring information is delivered in context rather than requiring the user to navigate a separate menu system.
- Audio feedback accompanies panel interactions (panel open/close) to provide non-visual confirmation of actions.

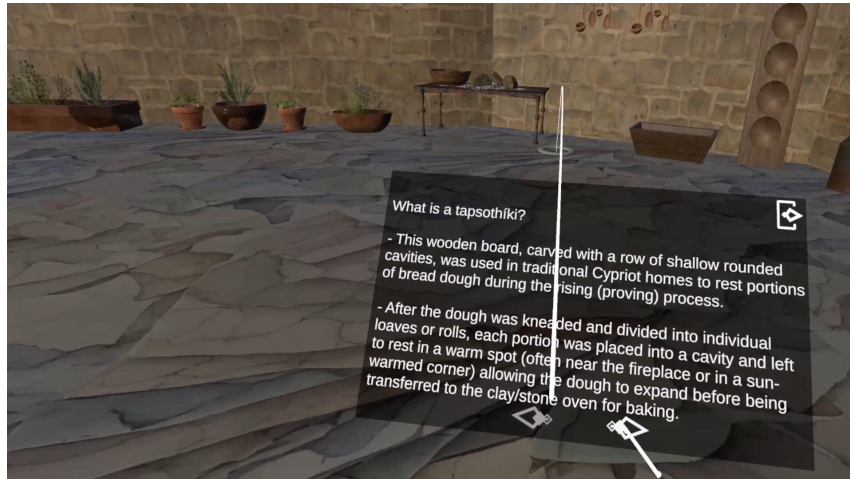


Figure 4.3: Wrist-attached information panel displaying cultural context for an artifact, with slide navigation buttons.

4.3.3 Navigation Menu

A system menu provides utility functions accessible at any time within country rooms:

- **Toggle activation:** The menu is shown/hidden via a dedicated controller button (mapped through InputActionReference), preventing accidental activation during exploration.
- **Return to Hub:** Loads the hub scene, allowing the user to select a different country.
- **Reset Position:** Teleports the user back to the room's spawn point, useful if they become disoriented or clip through geometry.
- **Tooltip System:** Contextual tooltips appear when hovering over menu items, providing explanatory text for each option.



Figure 4.4: The navigation menu providing Return to Hub and Reset Position options.

4.4 Audio Design

Sound plays a crucial role in establishing cultural atmosphere and providing interaction feedback:

- **Ambient soundscapes:** Each room features a spatialized audio environment (e.g., Mediterranean wildlife sounds in the Cyprus room) that reinforces cultural immersion.
- **Interaction audio:** Button clicks, panel transitions, and selection confirmations use subtle audio cues to provide feedback without breaking immersion.
- **Spatial positioning:** Audio sources are positioned in 3D space, so sounds grow louder and more directional as the user approaches their source.

4.5 Design Rationale

Several key design decisions warrant explicit justification:

- **Teleportation over smooth locomotion:** To minimize cybersickness, scene transitions use instant loading rather than animated travel, and within rooms, users move by physically walking (room-scale) or using teleportation. Figure 4.5 shows the teleportation reticle as it appears during use.
- **Wrist panels over floating UI:** Attaching information to the user's wrist maintains spatial consistency (the panel is always in the same relative position) and mimics the natural gesture of checking a guidebook.

- **Geographic room shapes:** Shaping rooms after country outlines creates a sub-conscious geographic association and makes each room feel unique in its spatial organization.
- **No textual navigation menus for room selection:** Using a world map rather than a list or menu for country selection maintains the geographic and exploratory theme of the application while providing a more engaging and memorable interaction.

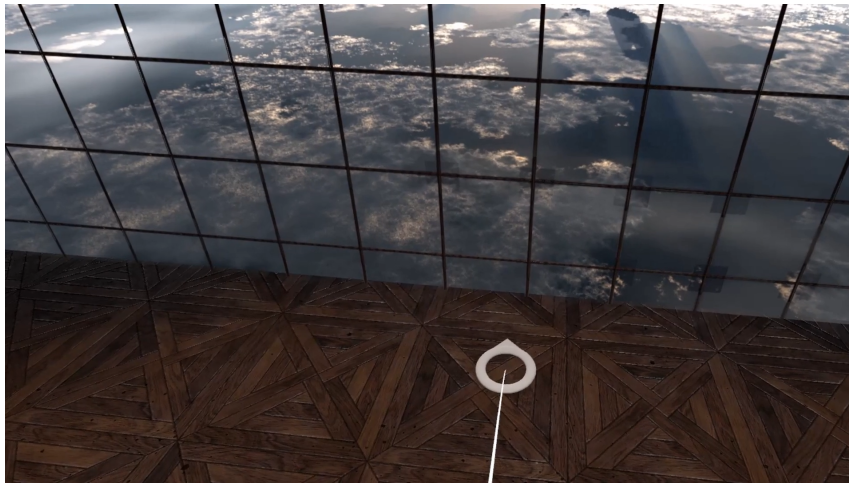


Figure 4.5: The teleportation reticle indicating a valid landing point within a country room.

Chapter 5

Implementation

This chapter details the technical implementation of Orbis, covering the project configuration, the core VR interaction scripts, the asset pipeline, and the construction of the country rooms.

5.1 Project Configuration

5.1.1 Unity Setup

Orbis is built on Unity 2022.3 (LTS), chosen for its stability and comprehensive XR support. The project uses the Universal Render Pipeline (URP) for its balance of visual quality and VR performance requirements. Key project settings include:

- **Render Pipeline:** Universal Render Pipeline with VR-optimized settings (single-pass instanced rendering, forward rendering path).
- **Color Space:** Linear color space for physically accurate lighting calculations.
- **Target Platform:** Android (for standalone headsets such as Meta Quest) and Windows (for PC-tethered headsets).

5.1.2 Package Dependencies

Table 5.1 lists the primary packages used in the project.

Table 5.1: Key Unity packages used in Orbis.

Package	Version	Purpose
XR Interaction Toolkit	2.6.5	VR interaction framework
OpenXR Plugin	1.14.3	Hardware abstraction layer
Universal RP	–	Rendering pipeline
TextMeshPro	3.0.7	High-quality text rendering
ProBuilder	5.2.4	In-editor level design
XR Plugin Management	–	XR lifecycle management
Input System	–	Action-based input handling

5.1.3 XR Configuration

The OpenXR plugin is configured with the following interaction profiles:

- Meta Quest Touch Pro controller profile
- Oculus Touch controller profile (for Quest 2/3 compatibility)
- Generic XR controller fallback

Input actions are defined using Unity’s Input System package with action maps for:

- Locomotion (thumbstick movement, teleportation)
- Interaction (trigger for select, grip for grab)
- UI (menu button for navigation panel toggle)

5.2 Core Scripts

The application logic is organized into two categories: VR interaction scripts that handle user-facing interactions through the XR Interaction Toolkit and Unity’s Input System, and scene transition scripts that manage the flow between scenes.

5.2.1 InteractableCountry

This script handles the map-based country selection in the hub scene. It is attached to individual country mesh objects on the world map and leverages the `XRI XRSimpleInteractable` component for event handling.

```

1 public class InteractableCountry : MonoBehaviour{
2     [Header("Colours")]
3     public Color normalColor= Color.white;
4     public Color hoverColor= Color.yellow;
5
6     [Header("Scene_Transition")]
7     public string sceneToLoad;
8
9     private Renderer rend;
10    private Material mat;
11    private XRSimpleInteractable interactable;
12
13    private Dictionary<string, string> sceneDisplayNames= new Dictionary<string,
        string>(){
14        { "CyprusScene", "Cyprus" },
15        { "JapanScene", "Japan" },
16    };
17
18    void Start(){
19        rend= GetComponent<Renderer>();
20        mat= rend.material;
21        mat.color= normalColor;
22
23        interactable= GetComponent<XRSimpleInteractable>();
24        interactable.hoverEntered.AddListener(OnHoverEnter);
25        interactable.hoverExited.AddListener(OnHoverExit);
26        interactable.selectEntered.AddListener(OnSelected);
27    }
28
29    void OnHoverEnter(HoverEnterEventArgs args){
30        mat.color= hoverColor;
31    }
32
33    void OnHoverExit(HoverExitEventArgs args){
34        mat.color= normalColor;
35    }
36
37    void OnSelected(SelectEnterEventArgs args){
38        StartCoroutine(FadeAndLoad());
39    }
40
41    private IEnumerator FadeAndLoad(){
42        //fade to black
43        yield return StartCoroutine(FadeController.Instance.FadeOut());
44
45        //trigger the loading screen
46        string displayName= sceneDisplayNames.ContainsKey(sceneToLoad)
47            ? sceneDisplayNames[sceneToLoad]
48            : sceneToLoad;
49        LoadingManager.LoadSceneWithLoading(sceneToLoad, displayName);
50    }
51
52    void OnDestroy(){
53        interactable.hoverEntered.RemoveListener(OnHoverEnter);
54        interactable.hoverExited.RemoveListener(OnHoverExit);
55        interactable.selectEntered.RemoveListener(OnSelected);
56    }

```

Listing 5.1: InteractableCountry – Globe interaction logic

The script operates through the following mechanism:

1. Each selectable country on the world map has its own mesh with a collider and XRSimpleInteractable component.
2. When the user's ray interactor hovers over a country, the `hoverEntered` event fires, changing the material color to a lighter color as visual feedback.
3. When the ray exits, the color reverts to its original hue.
4. On select (trigger press), the corresponding country scene is loaded via Unity's `SceneManager`.

5.2.2 NavigationMenu

The navigation menu script manages the in-experience utility panel, handling menu visibility, scene transitions, and position resets.

```

1 public class NavigationMenu : MonoBehaviour{
2     [Header("Country Settings")]
3     public string countryName= "Country";
4     public Transform spawnPoint;
5
6     [Header("Scene Settings")]
7     public string hubSceneName= "OrbisHub";
8
9     [Header("UI References")]
10    public GameObject menuPanel;
11    public TextMeshProUGUI countryTitle;
12    public TextMeshProUGUI tooltipText;
13
14    [Header("XR References")]
15    public Transform xrRig;
16    public InputActionReference menuButtonAction;
17
18    private const string RESET_TOOLTIP= "Are you stuck? Teleport back to the start
19        of the room.";
20    private const string HUB_TOOLTIP= "Finished exploring? Return to the world map
21        .";
22    private bool menuVisible= false;
23
24    void Start(){
25        if(countryTitle != null)
26            countryTitle.text= countryName;
27
28        menuPanel.SetActive(false);
29
30        if(menuButtonAction != null){
31            menuButtonAction.action.Enable();

```

```

30         menuButtonAction.action.performed+= OnMenuButtonPressed;
31     }
32 }
33
34 void OnDestroy(){
35     if(menuButtonAction != null)
36         menuButtonAction.action.performed-= OnMenuButtonPressed;
37 }
38
39 private void OnMenuButtonPressed(InputAction.CallbackContext context){
40     ToggleMenu();
41 }
42
43 public void ToggleMenu(){
44     menuVisible= !menuVisible;
45     menuPanel.SetActive(menuVisible);
46
47     if(menuVisible){
48         Camera cam= Camera.main;
49         menuPanel.transform.position= cam.transform.position + cam.transform.
            forward * 0.6f;
50         menuPanel.transform.rotation= Quaternion.LookRotation(menuPanel.
            transform.position - cam.transform.position);
51         ClearTooltip();
52     }
53 }
54
55 public void ResetPosition(){
56     if(xrRig!=null && spawnPoint!=null){
57         xrRig.position= spawnPoint.position;
58         xrRig.rotation= spawnPoint.rotation;
59     }
60     CloseMenu();
61 }
62
63 public void ReturnToHub(){
64     LoadingManager.LoadSceneWithLoading(hubSceneName, "Orbis_Hub");
65 }
66
67 public void CloseMenu(){
68     menuVisible= false;
69     menuPanel.SetActive(false);
70 }
71
72 public void OnResetPositionHover() => SetTooltip(RESET_TOOLTIP);
73 public void OnReturnToHubHover() => SetTooltip(HUB_TOOLTIP);
74 public void OnButtonExit() => ClearTooltip();
75
76 private void SetTooltip(string msg){
77     if(tooltipText != null)
78         tooltipText.text= msg;
79 }
80
81 private void ClearTooltip(){
82     if(tooltipText != null)
83         tooltipText.text= "";
84 }

```

Listing 5.2: NavigationMenu – Menu management

Key design decisions in this implementation:

- The menu uses `InputActionReference` rather than polling specific buttons, maintaining hardware abstraction through the Input System.
- The tooltip system provides contextual help without cluttering the always-visible UI.
- Position reset uses the XR Origin transform rather than the camera, ensuring correct positional tracking offset after reset.

5.2.3 InfoPanelController

The information panel controller manages the wrist-attached educational content display, handling multi-slide navigation and audio feedback.

```

1 public class InfoPanelController : MonoBehaviour{
2     [Header("Slide_Arrows_(UI_Images)")]
3     [SerializeField] private Image leftArrowImage;
4     [SerializeField] private Image rightArrowImage;
5
6     [Header("Close_Button")]
7     [SerializeField] private Button closeButton;
8
9     [Header("Slide_Audio")]
10    [SerializeField] private AudioSource uiAudioSource;
11    [SerializeField] private AudioClip slideChangeSound;
12
13    [Header("UI_Text")]
14    [SerializeField] private GameObject infoCanvas;
15    [SerializeField] private TMP_Text infoTextAreaUI;
16
17    [Header("Slides")]
18    [SerializeField][TextArea(3, 10)] private string infoText;
19    [SerializeField][TextArea(3, 10)] private string[] infoSlides;
20
21    [Header("Wrist_Anchor")]
22    [SerializeField] private Transform leftHandTransform;
23
24    [Space(10)]
25    [SerializeField] private UnityEvent openEvent;
26    [SerializeField] private UnityEvent closeEvent;
27
28    private bool isOpen = false;
29    private int currentSlideIndex;
30
31    public bool IsOpen => isOpen;
32
33    void Start(){

```

```

34         infoCanvas.SetActive(false);
35     }
36
37     public void ShowInfo(){
38         if(isOpen)
39             return;
40         if(GetSlideCount() == 0)
41             return;
42
43         //close other open panels first
44         InfoPanelController[] allPanels= FindObjectsOfType<InfoPanelController>();
45         foreach (InfoPanelController panel in allPanels){
46             if(panel!=this && panel.IsOpen)
47                 panel.DisableInfo();
48         }
49
50         BindButtons();
51
52         currentSlideIndex= 0;
53         RefreshSlideText();
54         UpdateArrowState();
55
56         //attach canvas to left wrist
57         infoCanvas.transform.SetParent(leftHandTransform);
58         infoCanvas.transform.localPosition= new Vector3(0, 0.1f, 0);
59         infoCanvas.transform.localRotation= Quaternion.Euler(45, 0, 0);
60
61         infoCanvas.SetActive(true);
62         openEvent.Invoke();
63         isOpen= true;
64     }
65
66     public void DisableInfo(){
67         //unparent before hiding
68         infoCanvas.transform.SetParent(null);
69         infoCanvas.SetActive(false);
70         closeEvent.Invoke();
71         isOpen = false;
72     }
73
74     void BindButtons(){
75         if(closeButton != null){
76             closeButton.onClick.RemoveAllListeners();
77             closeButton.onClick.AddListener(DisableInfo);
78         }
79
80         Button leftBtn= leftArrowImage?.GetComponent<Button>();
81         Button rightBtn= rightArrowImage?.GetComponent<Button>();
82
83         if(leftBtn != null){
84             leftBtn.onClick.RemoveAllListeners();
85             leftBtn.onClick.AddListener(PreviousSlide);
86         }
87         if(rightBtn != null){
88             rightBtn.onClick.RemoveAllListeners();
89             rightBtn.onClick.AddListener(NextSlide);
90         }

```

```

91     }
92
93     int GetSlideCount(){
94         if(infoSlides!=null && infoSlides.Length>0)
95             return infoSlides.Length;
96
97         return string.IsNullOrEmpty(infoText) ? 0 : 1;
98     }
99
100    void RefreshSlideText(){
101        if(infoTextAreaUI == null)
102            return;
103
104        if(infoSlides!=null && infoSlides.Length>0){
105            currentSlideIndex= Mathf.Clamp(currentSlideIndex, 0, infoSlides.Length
106                - 1);
107            infoTextAreaUI.text= infoSlides[currentSlideIndex];
108            return;
109        }
110
111        infoTextAreaUI.text= infoText;
112    }
113
114    public void NextSlide(){
115        int slideCount= GetSlideCount();
116        if(slideCount <= 1)
117            return;
118        if(currentSlideIndex >= slideCount-1)
119            return;
120
121        currentSlideIndex++;
122        RefreshSlideText();
123        UpdateArrowState();
124        PlaySlideChangeSound();
125    }
126
127    public void PreviousSlide(){
128        int slideCount= GetSlideCount();
129        if(slideCount <= 1)
130            return;
131        if(currentSlideIndex <= 0)
132            return;
133
134        currentSlideIndex--;
135        RefreshSlideText();
136        UpdateArrowState();
137        PlaySlideChangeSound();
138    }
139
140    void UpdateArrowState(){
141        int slideCount= GetSlideCount();
142        bool hasManySlides= slideCount > 1;
143
144        if(leftArrowImage != null){
145            leftArrowImage.gameObject.SetActive(hasManySlides);
146            leftArrowImage.raycastTarget= hasManySlides && currentSlideIndex > 0;
147            leftArrowImage.color= currentSlideIndex > 0 ? Color.white : new Color

```

```

147         (1f, 1f, 1f, 0.35f);
148     }
149     if(rightArrowImage != null){
150         rightArrowImage.gameObject.SetActive(hasManySlides);
151         rightArrowImage.raycastTarget= hasManySlides && currentSlideIndex <
            slideCount - 1;
152         rightArrowImage.color= currentSlideIndex < slideCount - 1 ? Color.
            white : new Color(1f, 1f, 1f, 0.35f);
153     }
154 }
155
156 void PlaySlideChangeSound(){
157     if(slideChangeSound == null)
158         return;
159     if(uiAudioSource != null)
160         uiAudioSource.PlayOneShot(slideChangeSound);
161 }
162
163 private void Update(){
164     if(!isOpen)
165         return;
166 }
167 }

```

Listing 5.3: InfoPanelController – Wrist panel management

The script operates through the following mechanism:

1. The InfoPanelController component is attached directly to each artifact GameObject that should display educational information.
2. The number of slides and their content are configured entirely in the Unity Inspector, allowing each artifact to have a custom number of pages covering history, cultural significance, usage, and related artifacts.
3. When the user interacts with the artifact, the info canvas is parented to the left hand transform and positioned at a local offset of (0,0.1,0) with a 45-degree X-axis rotation, placing it at a comfortable reading angle similar to holding a book or clipboard.
4. Navigation arrows allow the user to move between slides using the dominant hand's ray interactor, with arrow visibility and interactivity updating dynamically based on the current slide position.
5. Audio feedback accompanies each slide transition, and a close button allows the user to dismiss the panel at any time.

5.2.4 QuizPanel

The QuizPanel script manages the assessment mini-game at the end of each country room. It supports both multiple-choice questions and true/false questions, each displayed on its own independent board in the assessment zone.

```
1 public class QuizPanel : MonoBehaviour{
2     [Header("Question_Setup")]
3     [TextArea(3, 6)]
4     public string question= "Enter_your_question_here";
5
6     public enum QuestionType { MultipleChoice, TrueFalse }
7     [Tooltip("MC=3 choices (A/B/C) | T/F=uses buttons A and C")]
8     public QuestionType questionType= QuestionType.MultipleChoice;
9
10    [Header("Answers_(MC)")]
11    public string answerA= "Answer_A";
12    public string answerB= "Answer_B";
13    public string answerC= "Answer_C";
14
15    [Range(0, 2)]
16    [Tooltip("Index_of_the_correct_answer: A=0, B=1, C=2 | T/F: T=0, F=2")]
17    public int correctAnswerIndex= 0;
18
19
20    [Header("UI_References")]
21    public TextMeshProUGUI questionText;
22    public Button[] answerButtons= new Button[3];
23    public TextMeshProUGUI[] answerTexts= new TextMeshProUGUI[3];
24    public Image feedbackOverlay;
25
26    [Header("Text_Colour_Feedback")]
27    public Color defaultTextColor= Color.white;
28    public Color correctTextColor= new Color(0.55f, 0.95f, 0.55f, 1f);
29    public Color grayTextColor= new Color(0.5f, 0.5f, 0.5f, 0.45f);
30
31    [Header("Unanswered_Indicator")]
32    public Image unansweredIndicator;
33    public float pulseSpeed= 2f;
34    [Range(0f, 1f)]
35    public float pulseMinAlpha= 0.3f;
36    [Range(0f, 1f)]
37    public float pulseMaxAlpha= 1f;
38
39
40    [Header("Feedback_Overlay_Settings")]
41    public Color correctOverlayColor= new Color(0.1f, 0.8f, 0.2f, 0.35f);
42    public Color incorrectOverlayColor= new Color(0.9f, 0.15f, 0.15f, 0.35f);
43    public float fadeDuration= 0.5f;
44    public float feedbackHoldTime= 1.5f;
45
46    [Header("Audio")]
47    public AudioSource audioSource;
48    public AudioClip correctSFX;
49    public AudioClip incorrectSFX;
50
51
```

```

52     private bool isAnswered= false;
53     private bool isBusy= false;
54     private Coroutine feedbackRoutine;
55     private Coroutine pulseRoutine;
56
57     private int[] activeIndices;
58
59     private void Start(){
60         SetupPanel();
61     }
62
63     private void SetupPanel(){
64         if(questionText != null)
65             questionText.text= question;
66
67         if(questionType == QuestionType.TrueFalse){
68             activeIndices= new int[] { 0, 2 };
69
70             SetAnswerButton(0, "True");
71             SetAnswerButton(2, "False");
72
73             if(answerButtons.Length > 1 && answerButtons[1] != null)
74                 answerButtons[1].gameObject.SetActive(false);
75         }
76         else{
77             activeIndices= new int[] { 0, 1, 2 };
78
79             SetAnswerButton(0, answerA);
80             SetAnswerButton(1, answerB);
81             SetAnswerButton(2, answerC);
82         }
83
84         foreach(int i in activeIndices){
85             if(i < answerTexts.Length && answerTexts[i] != null)
86                 answerTexts[i].color= defaultTextColor;
87         }
88
89         if(feedbackOverlay != null){
90             Color c= feedbackOverlay.color;
91             c.a= 0f;
92             feedbackOverlay.color= c;
93         }
94
95         if(unansweredIndicator != null){
96             unansweredIndicator.gameObject.SetActive(true);
97             pulseRoutine= StartCoroutine(PulseIndicator());
98         }
99     }
100
101     private void SetAnswerButton(int index, string text){
102         if(index >= answerButtons.Length || answerButtons[index] == null)
103             return;
104
105         if(index < answerTexts.Length && answerTexts[index] != null)
106             answerTexts[index].text= text;
107
108         int captured= index;

```

```

109         answerButtons[index].onClick.AddListener(() => OnAnswerSelected(captured))
110     };
111 }
112
113 public void OnAnswerSelected(int selectedIndex){
114     if(isAnswered || isBusy)
115         return;
116
117     bool correct= (selectedIndex == correctAnswerIndex);
118
119     if(correct){
120         isAnswered= true;
121         PlaySFX(correctSFX);
122         HideUnansweredIndicator();
123
124         SetCorrectColors(selectedIndex);
125         ShowFeedback(correctOverlayColor, disableAfter: true);
126     }
127     else{
128         PlaySFX(incorrectSFX);
129         GrayOutAnswer(selectedIndex);
130         ShowFeedback(incorrectOverlayColor, disableAfter: false);
131     }
132 }
133
134 private void SetCorrectColors(int correctIndex){
135     foreach (int i in activeIndices){
136         if(i<answerTexts.Length && answerTexts[i]!=null){
137             answerTexts[i].color= (i == correctIndex) ? correctTextColor :
138                 grayTextColor;
139         }
140     }
141
142 private void GrayOutAnswer(int index){
143     if(index<answerButtons.Length && answerButtons[index]!=null)
144         answerButtons[index].interactable= false;
145
146     if(index<answerTexts.Length && answerTexts[index]!=null)
147         answerTexts[index].color= grayTextColor;
148 }
149
150 private void ShowFeedback(Color targetColor, bool disableAfter){
151     if(feedbackRoutine != null)
152         StopCoroutine(feedbackRoutine);
153
154     feedbackRoutine= StartCoroutine(FeedbackFadeRoutine(targetColor,
155         disableAfter));
156 }
157
158 private IEnumerator FeedbackFadeRoutine(Color targetColor, bool disableAfter){
159     isBusy= true;
160
161     yield return StartCoroutine(FadeOverlay(Color.clear, targetColor,
162         fadeDuration));
163     yield return new WaitForSeconds(feedbackHoldTime);

```

```

162         yield return StartCoroutine(FadeOverlay(targetColor, Color.clear,
163             fadeDuration));
164
165         isBusy= false;
166
167         if(disableAfter)
168             DisableAllButtons();
169     }
170
171     private IEnumerator FadeOverlay(Color from, Color to, float duration){
172         if(feedbackOverlay == null)
173             yield break;
174
175         float elapsed= 0f;
176         while(elapsed < duration){
177             elapsed+= Time.deltaTime;
178             feedbackOverlay.color= Color.Lerp(from, to, elapsed / duration);
179
180             yield return null;
181         }
182         feedbackOverlay.color= to;
183     }
184
185     private IEnumerator PulseIndicator(){
186         while(!isAnswered){
187             float t= (Mathf.Sin(Time.time * pulseSpeed) + 1f) / 2f;
188             float alpha= Mathf.Lerp(pulseMinAlpha, pulseMaxAlpha, t);
189
190             if(unansweredIndicator != null){
191                 Color c= unansweredIndicator.color;
192                 c.a= alpha;
193                 unansweredIndicator.color= c;
194             }
195
196             yield return null;
197         }
198     }
199
200     private void HideUnansweredIndicator(){
201         if(pulseRoutine != null){
202             StopCoroutine(pulseRoutine);
203             pulseRoutine= null;
204         }
205
206         if(unansweredIndicator != null)
207             unansweredIndicator.gameObject.SetActive(false);
208     }
209
210     private void DisableAllButtons(){
211         foreach(var btn in answerButtons){
212             if(btn != null)
213                 btn.interactable= false;
214         }
215     }
216
217     private void PlaySFX(AudioClip clip){

```

```

218         if(audioSource != null && clip != null)
219             audioSource.PlayOneShot(clip);
220     }
221
222     public void ResetPanel(){
223         isAnswered= false;
224         isBusy= false;
225
226         if(feedbackRoutine != null)
227             StopCoroutine(feedbackRoutine);
228
229         if(feedbackOverlay != null){
230             Color c= feedbackOverlay.color;
231             c.a= 0f;
232             feedbackOverlay.color= c;
233         }
234
235         for(int i=0; i<answerButtons.Length; i++){
236             if(answerButtons[i] != null){
237                 bool show= !(questionType == QuestionType.TrueFalse && i == 1);
238                 answerButtons[i].gameObject.SetActive(show);
239                 answerButtons[i].interactable = true;
240             }
241
242             if(i < answerTexts.Length && answerTexts[i] != null)
243                 answerTexts[i].color= defaultTextColor;
244         }
245
246         if(unansweredIndicator != null){
247             unansweredIndicator.gameObject.SetActive(true);
248             pulseRoutine= StartCoroutine(PulseIndicator());
249         }
250     }
251 }

```

Listing 5.4: QuizPanel – Quiz board controller

The script operates through the following mechanism:

1. The QuizPanel component is attached to each individual quiz board GameObject in the assessment zone. Each board is self-contained, displaying a single question with its answer options.
2. In the Unity Inspector, the creator selects the question type (multiple-choice or true/false), writes the question text and potential answers, and marks which answer is correct. This inspector-driven workflow allows easy authoring without modifying code.
3. The user approaches a quiz board and selects an answer by pointing their controller ray at one of the answer buttons.
4. On answer selection, the board provides both audio and visual feedback: a correct answer triggers a green flash and a confirmation sound, while an incorrect answer

triggers a red flash and an error sound.

5. There is no cumulative score or sequential progression between boards. This is a deliberate design choice: the assessment zone is intended as a reinforcement of what the user has learned during exploration, not as a formal test. Users are free to approach the quiz boards in any order and at their own pace.

The remaining two scripts handle scene transitions rather than direct VR interaction.

5.2.5 FadeController

The FadeController script manages the visual transition when a user selects a country from the world map. Rather than abruptly switching scenes, the screen smoothly fades to black before the loading scene is loaded, providing a comfortable perceptual transition.

```
1 public class FadeController : MonoBehaviour{
2     public static FadeController Instance;
3
4     [Header("References")]
5     public CanvasGroup fadeCanvasGroup;
6
7     [Header("Settings")]
8     public float fadeDuration= 0.6f;
9
10    void Awake(){
11        Instance= this;
12        DontDestroyOnLoad(gameObject);
13    }
14
15    public IEnumerator FadeOut(){ //transparent -> black
16        fadeCanvasGroup.alpha= 0f;
17        float elapsed= 0f;
18
19        while(elapsed < fadeDuration){
20            elapsed+= Time.deltaTime;
21            fadeCanvasGroup.alpha= Mathf.Clamp01(elapsed / fadeDuration);
22            yield return null;
23        }
24        fadeCanvasGroup.alpha= 1f;
25    }
26
27    public IEnumerator FadeIn(){ //black -> transparent
28        fadeCanvasGroup.alpha= 1f;
29        float elapsed= 0f;
30
31        while(elapsed < fadeDuration){
32            elapsed+= Time.deltaTime;
33            fadeCanvasGroup.alpha= 1f - Mathf.Clamp01(elapsed / fadeDuration);
34            yield return null;
35        }
36        fadeCanvasGroup.alpha= 0f;
37    }
38 }
```

Listing 5.5: FadeController – Screen fade transition

The fade effect is achieved through a full-screen Canvas with a CanvasGroup component, whose alpha value is interpolated from 0 (transparent) to 1 (fully opaque black) over the configured duration.

5.2.6 LoadingManager

The LoadingManager script controls the intermediate loading scene that appears between the hub and a country room. It manages the asynchronous loading of the destination scene while displaying progress feedback and cultural tooltips to keep the user engaged during the wait.

```
1 public class LoadingManager : MonoBehaviour{
2     public static LoadingManager Instance;
3
4     [Header("UI References")]
5     public GameObject loadingCanvas;
6     public TextMeshProUGUI sceneTitleText;
7     public TextMeshProUGUI tipText;
8     public TextMeshProUGUI statusText;
9
10    [Header("Settings")]
11    public float minimumLoadTime= 1.5f;
12
13    private static string targetScene;
14    private static string targetSceneTitle;
15
16    private string[] tips= new string[]{
17        "Look around - every object in the room has a story.",
18        "Every culture on Earth has a unique way of welcoming guests.",
19        "Over 7,000 languages are spoken across the world today.",
20        "Food is one of the most universal ways cultures express identity.",
21        "Traditional crafts are often passed down through generations by hand.",
22        "Architecture tells the story of a civilization's values and beliefs.",
23        "Music exists in every known human culture on Earth.",
24        "Many everyday objects you use have roots in ancient civilizations.",
25        "Clothing and textiles often carry deep cultural and spiritual meaning.",
26        "Trade routes throughout history connected cultures across continents.",
27        "Almost every culture has its own unique coming-of-age traditions.",
28        "The world's oldest known recipes are over 4,000 years old.",
29        "Storytelling is one of the oldest forms of human communication.",
30        "Many cultural traditions were shaped by the geography around them.",
31        "Festivals and celebrations are a window into what a culture values most."
32    },
33
34    void Awake(){
35        Instance= this;
36    }
37
38    void Start(){
```

```

39         if(sceneTitleText != null && !string.IsNullOrEmpty(targetSceneTitle))
40             sceneTitleText.text= targetSceneTitle;
41
42         if(tipText != null)
43             tipText.text= tips[Random.Range(0, tips.Length)];
44
45         StartCoroutine(LoadScene());
46     }
47
48     public static void LoadSceneWithLoading(string sceneName, string displayTitle
49         = ""){
50         targetScene= sceneName;
51         targetSceneTitle= displayTitle;
52         SceneManager.LoadScene("LoadingScreen");
53     }
54
55     private IEnumerator LoadScene(){
56         float elapsed= 0f;
57         AsyncOperation operation= SceneManager.LoadSceneAsync(targetScene);
58         operation.allowSceneActivation= false;
59
60         while(operation.progress<0.9f || elapsed<minimumLoadTime){
61             elapsed+= Time.deltaTime;
62             yield return null;
63         }
64
65         if(statusText != null)
66             statusText.text= "Finalising...";
67
68         DontDestroyOnLoad(loadingCanvas);
69
70         operation.allowSceneActivation= true;
71
72         while(!operation.isDone)
73             yield return null;
74
75         yield return new WaitForSeconds(0.3f);
76
77         if(FadeController.Instance != null)
78             yield return StartCoroutine(FadeController.Instance.FadeIn());
79
80         Destroy(loadingCanvas);
81     }

```

Listing 5.6: LoadingManager – Loading scene controller

The script uses Unity’s `AsyncOperation` to load the destination scene in the background. The `allowSceneActivation` flag is held at false until loading reaches 90% completion (Unity’s threshold for a fully loaded scene ready to activate), at which point the status message changes to “Finalizing” and the scene is activated. Meanwhile, a separate coroutine cycles through an array of cultural tooltips themed to world culture in general.

5.3 Asset Pipeline

5.3.1 3D Models and Materials

Cultural artifacts are represented using high-quality 3D models with PBR materials. The asset pipeline follows this workflow:

1. **Research:** Reference materials are gathered for each artifact, including photographs, measurements, and historical documentation.
2. **Acquisition:** 3D models are sourced from online asset libraries, primarily CGTrader [7] and Sketchfab [27], ensuring cultural accuracy and appropriate visual quality. Textures for architectural surfaces (such as tatami flooring and wall materials) are sourced from ambientCG [2].
3. **Material Setup:** PBR materials are configured with appropriate albedo, normal, metallic, and roughness maps for realistic appearance under VR lighting conditions. Where necessary, textures are post-processed in GIMP [31] to adjust saturation, brightness, and color balance for visual consistency across assets from different sources.
4. **Optimization:** Models are optimized for VR performance through LOD (Level of Detail) configuration and appropriate polygon budgets.
5. **Placement:** Assets are positioned within the room environments at culturally and spatially appropriate locations.

5.3.2 Environmental Lighting

Each scene uses a combination of:

- **HDRI Skyboxes:** High-dynamic-range environment maps that provide ambient lighting and realistic reflections. The hub uses an earth from space HDRI, while country rooms use location-appropriate HDRIs (Mediterranean sky and sea for Cyprus, overcast sky for Japan).
- **Baked Lighting:** Pre-computed global illumination for static geometry, providing realistic indirect lighting without runtime cost.
- **Real-time Lights:** Selective use of real-time lights for dynamic elements and focused illumination of key artifacts.

5.3.3 Audio Assets

Audio assets are organized into categories:

- **Ambient loops:** Continuous environmental soundscapes (cicadas, wind, water) played through spatialized audio sources positioned around the room perimeter.
- **Interaction sounds:** Short audio clips triggered by user actions (button clicks, panel transitions, selection confirmations).

5.4 Room Construction

5.4.1 Methodology

Country rooms are constructed through an iterative process:

1. **Research Phase:** Documentation of traditional domestic architecture, common artifacts, spatial organization, and cultural significance of everyday objects for the target country.
2. **Layout Phase:** Room geometry is created using ProBuilder, establishing walls, floors, doors, and major architectural features. The room's outline is inspired by the country's geographic shape.
3. **Population Phase:** Cultural artifacts are placed within the room at contextually appropriate locations, with consideration for exploration flow and visual composition.
4. **Information Phase:** Educational content is authored for each artifact's information panels, covering history, cultural significance, and usage.
5. **Polish Phase:** Lighting, audio, and visual refinements are applied to achieve the desired atmospheric quality.

5.4.2 Cyprus Room Implementation

The Cyprus room (scene: `CyprusScene.unity`) recreates a traditional Cypriot village house. The room contains stone walls constructed with ProBuilder, wooden beam ceilings, limestone floor tiles, and traditional arched doorways. It is populated with traditional furniture, kitchen implements, flora and fauna, and cultural artifacts, all accompanied by a Mediterranean ambient soundscape featuring cicadas and waves crashing on the shore.

The following artifacts were selected as representative highlights of Cypriot domestic culture. Each was chosen to illustrate a distinct aspect of traditional Cypriot life, from craftsmanship and cuisine to agriculture and daily living.

Lefkaritika (Lefkara Lace)

Lefkaritika is a traditional form of lace embroidery originating from the village of Lefkara, recognized by UNESCO as an Intangible Cultural Heritage of Humanity. It was included to represent the rich textile craftsmanship of Cyprus and its international cultural significance. The lace is displayed on picture frames in the entrance of the room and draped over tables in the living and kitchen areas, reflecting how it would be found in a traditional Cypriot home. The 3D model was sourced from CGTrader [7].



(a) In-game view 1



(b) In-game view 2



(c) Real-life reference [33]

Figure 5.1: Lefkaritika (Lefkara lace): in-game representations (top) and real-life reference (bottom).

Souvlakia

Souvlakia (grilled meat skewers) are one of the most iconic dishes of Cypriot cuisine, deeply embedded in the island's social and culinary culture. They were included to represent the food traditions of Cyprus, which play a central role in family gatherings and daily life. The souvlakia are placed in the kitchen area alongside other traditional food items. The 3D model was sourced from CGTrader [7].



(a) In-game representation



(b) Real-life reference [44]

Figure 5.2: Souvlakia (grilled meat skewers): in-game representation (left) and real-life reference (right).

Canopy Bed

The traditional Cypriot canopy bed (*krevati me ouranos*) is a hand-carved wooden bed with an overhead fabric canopy, commonly found in affluent village homes. It was included to represent the bedroom culture and craftsmanship of traditional Cypriot furniture making. The bed serves as the centerpiece of the bedroom area in the room. The base bed model and bedframe were sourced from CGTrader [7] and modified to include the draping fabric and curtains.



(a) In-game representation



(b) Real-life reference [17]

Figure 5.3: Traditional Cypriot canopy bed: in-game representation (left) and real-life reference (right).

Pitharia

Pitharia are large clay storage jars traditionally used for storing olive oil, wine, and grain. They are a ubiquitous element of Cypriot rural life and were included to represent the agricultural storage traditions of the island. The pitharia are positioned in the kitchen and

courtyard areas, as they would be in a real village house. The 3D models were sourced from CGTrader [7].



(a) In-game representation



(b) Real-life reference [24]

Figure 5.4: Pitharia (large clay storage jars): in-game representation (left) and real-life reference (right).

Ceramic Jugs

Traditional Cypriot ceramic jugs were used for serving water, wine, and other beverages, and are characteristic of the island's pottery traditions dating back millennia. They were included to represent everyday domestic pottery and the importance of ceramics in Cypriot material culture. The jugs are arranged on tables and shelves throughout the room. The 3D models were sourced from CGTrader [7] and Sketchfab [27].



(a) In-game representation



(b) Real-life reference [3]

Figure 5.5: Traditional Cypriot ceramic jugs: in-game representation (left) and real-life reference (right).

Cats

Cyprus has one of the oldest known associations between humans and domestic cats, with archaeological evidence of cat domestication on the island dating to approximately 7500 BCE. Cats were included to represent this unique aspect of Cypriot natural and cultural

history, and are placed throughout the room in resting positions. The 3D model was sourced from Sketchfab [27].



(a) In-game representation



(b) Real-life reference [39]

Figure 5.6: Cats in the Cyprus room: in-game representation (left) and real-life reference (right).

Olive Trees

The olive tree is a symbol of Mediterranean identity and holds deep significance in Cypriot agriculture, cuisine, and tradition. Olive oil production has been central to the island's economy for thousands of years. Olive trees were included to represent the agricultural landscape and are placed in the outdoor and courtyard areas of the room. The 3D model was sourced from CGTrader [7].



(a) In-game representation



(b) Real-life reference [9]

Figure 5.7: Olive trees in the courtyard area: in-game representation (left) and real-life reference (right).

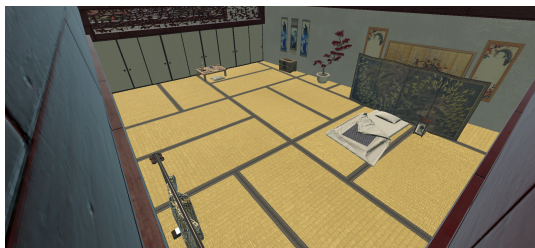
5.4.3 Japan Room Implementation

The Japan room (scene: `JapanScene.unity`) recreates elements of a traditional Japanese dwelling, organized across several interconnected spaces: a genkan (entrance hall), a main traditional room with artistic and cultural objects, a bedroom, a kitchen, and an exterior garden with a temple structure. The room features fusuma screen panels as architectural dividers, an engawa (covered wooden veranda) connecting interior and exterior spaces through shouji screens, and ambient soundscapes evoking a tranquil Japanese atmosphere.

The following artifacts were selected to represent key aspects of traditional Japanese domestic life, architecture, spirituality, and aesthetics.

Tatami Flooring

Tatami mats are the traditional flooring of Japanese rooms, made of woven rush grass over a rice straw core. They define the spatial organization of Japanese interiors, as room sizes are traditionally measured in tatami units. Tatami flooring was included as the foundational architectural element of the Japanese room, covering the main living areas and bedroom. The tatami textures were sourced from ambientCG [2] and applied to ProBuilder geometry to achieve the correct proportional grid layout.



(a) In-game representation



(b) Real-life reference [45]

Figure 5.8: Tatami mat flooring: in-game representation (left) and real-life reference (right).

Tokonoma

The tokonoma is a recessed decorative alcove found in traditional Japanese reception rooms, used to display prized objects such as hanging scrolls, ikebana (flower arrangements), or ceramics. It was included to represent the Japanese aesthetic principle of displaying beauty through restraint and careful curation. The tokonoma is positioned in the main room as a focal point for the space. The tokonoma was made by extruding the wall and placing objects within it, sourced from CGTrader [7] and Sketchfab [27].



(a) In-game representation

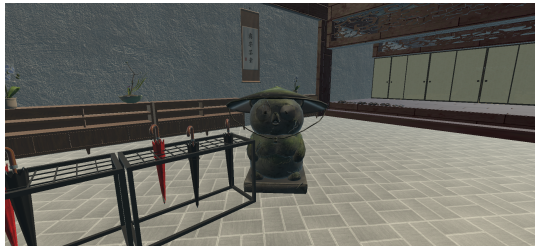


(b) Real-life reference [1]

Figure 5.9: The tokonoma (decorative alcove): in-game representation (left) and real-life reference (right).

Tanuki Statues

Tanuki (raccoon dog) statues are a common sight at the entrances of Japanese homes and businesses, believed to bring good fortune and prosperity. They were included in the genkan (entrance area) to represent Japanese folk beliefs and the tradition of placing protective or auspicious figures at thresholds. The 3D model was sourced from Sketchfab [27].



(a) In-game representation

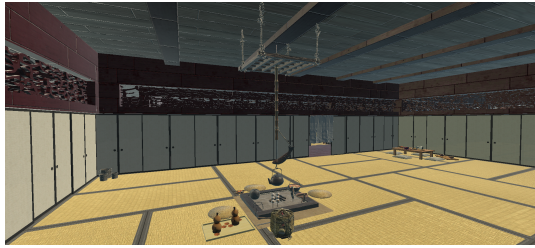


(b) Real-life reference [32]

Figure 5.10: Tanuki statues in the genkan (entrance hall): in-game representation (left) and real-life reference (right).

Irori

The irori is a traditional sunken hearth built into the floor of Japanese homes, used for heating, cooking, and as a social gathering point for the household. It was included to represent the communal heart of the Japanese domestic space and the central role of the hearth in daily life. The irori is positioned in the kitchen area alongside the kamado (traditional stove) in a sunken doma section. The 3D model was sourced from CGTrader [7].



(a) In-game representation



(b) Real-life reference [41]

Figure 5.11: The irori (sunken hearth): in-game representation (left) and real-life reference (right).

Kimono

The kimono is Japan's most recognizable traditional garment, worn for centuries and carrying deep cultural significance through its patterns, colors, and the occasions on which it is worn. A kimono was included to represent Japanese textile arts and the importance of clothing in cultural identity. It is displayed on a stand in the main room. The 3D model for the stand was sourced from Sketchfab [27] and the kimono itself from CGTrader [7].



(a) In-game representation

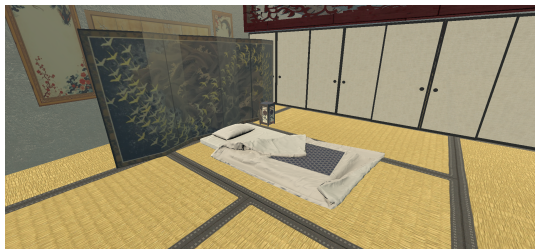


(b) Real-life reference [42]

Figure 5.12: A kimono on display: in-game representation (left) and real-life reference (right).

Futon Bed

The futon is the traditional Japanese sleeping arrangement – a foldable mattress placed directly on the tatami floor and stored in a closet during the day, reflecting the Japanese principle of flexible, multipurpose living spaces. It was included to represent the bedroom culture and spatial efficiency of traditional Japanese homes. The futon is laid out in the bedroom area. The 3D model was sourced from Sketchfab [27].



(a) In-game representation



(b) Real-life reference [40]

Figure 5.13: A futon bed on tatami flooring: in-game representation (left) and real-life reference (right).

Shrine and Sakura Trees

The exterior garden features a shrine structure surrounded by sakura (cherry blossom) trees, representing the spiritual and natural dimensions of Japanese culture. Shrines are central to Japanese religious life spanning both Shinto and Buddhist traditions, while cherry blossoms symbolize the transient beauty of life, a core concept in Japanese aesthetics known as *mono no aware*. These elements were included to provide an outdoor contemplative space that contrasts with the domestic interior. The 3D models were all sourced from CGTrader [7].



(a) In-game representation



(b) Real-life reference [43]

Figure 5.14: Shrine and sakura trees in the exterior garden: in-game representation (left) and real-life reference (right).

5.5 Performance Considerations

VR applications must maintain a minimum of 72 frames per second (90 fps preferred) to avoid discomfort. The following optimization strategies are employed:

- **Single-pass Instanced Rendering:** Renders both eyes in a single draw call pass, nearly halving the rendering cost compared to multi-pass.
- **LOD Groups:** Distant objects use simplified geometry.
- **Baked Lighting:** Reduces real-time light calculations.
- **Object Pooling:** Reusable UI elements (tooltips, panel slides) are pooled rather than instantiated at runtime.

Chapter 6

Evaluation

This chapter presents the evaluation methodology employed to assess the effectiveness of Orbis across its three research dimensions. It describes the research questions, the study design, the questionnaire instruments, participant demographics, and the results of the evaluation.

6.1 Research Questions

The evaluation of Orbis is structured around three research questions:

- **RQ1:** How effectively does a VR museum environment create a sense of immersion and cultural presence for users?
- **RQ2:** To what extent do interactive elements such as artifact panels and mini-games support the learning of cultural heritage within the experience?
- **RQ3:** How does prior interest in world cultures influence the overall user experience in a VR cultural museum?

These questions address, respectively, the technical and experiential quality of the VR environment (RQ1), the pedagogical effectiveness of the interactive design (RQ2), and the role of individual differences in shaping the user experience (RQ3).

6.2 Study Design

6.2.1 Procedure

The evaluation follows a single-session within-subjects design. Each participant completes the following protocol:

1. **Pre-session briefing:** Participants are informed about the study purpose, given a brief introduction to VR controls.
2. **Pre-experience cybersickness assessment:** Participants rate their baseline cybersickness symptoms on a 7-point scale.
3. **VR Experience:** Participants don the VR headset and freely explore the Orbis application, navigating from the hub to the country rooms and interacting with artifacts and information panels. No time limit is imposed, but participants are encouraged to explore thoroughly.
4. **Post-experience questionnaire:** Immediately after removing the headset, participants complete the full evaluation questionnaire covering cybersickness, immersion, interaction quality, learning outcomes, and open feedback.

6.2.2 Apparatus

The evaluation uses the following hardware:

- Meta Quest 2 standalone VR headset with Oculus Touch controllers
- A controlled indoor space with adequate room-scale tracking area
- The Orbis application running at a stable frame rate

6.3 Questionnaire Design

The evaluation questionnaire is administered via Google Forms and consists of seven sections, designed to address the three research questions while also capturing cybersickness data and qualitative feedback.

6.3.1 Section 1: Demographics and Background

This section establishes participant profiles and prior experience levels:

- Age range (Under 18 / 18–24 / 25–34 / 35+)
- Gender (Male / Female / Non-binary / Prefer not to say)
- Familiarity with Cypriot culture (Likert 1–7)
- Familiarity with Japanese culture (Likert 1–7)

- Frequency of actively seeking to learn about other cultures (Never / Rarely / Sometimes / Often / Always)
- Frequency of playing video games (Never / Rarely / Sometimes / Often / Very often)
- Frequency of using VR/AR/XR technologies (Never / Rarely / Sometimes / Often / Very often)

The cultural familiarity and learning frequency items directly support RQ3 by establishing a baseline measure of prior cultural interest that can be correlated with experience ratings.

6.3.2 Section 2: Cybersickness (Pre-Experience)

Participants rate their current level of six cybersickness symptoms on a 1–7 scale (1 = Absent, 7 = Extreme):

- Nausea
- Dizziness
- Disorientation
- Postural instability (feeling unbalanced)
- Visually induced fatigue (eye strain)
- Visually induced discomfort (headache, blurred vision)

This pre-experience measurement establishes a baseline to which post-experience scores can be compared, isolating VR-induced symptoms from pre-existing conditions.

6.3.3 Section 3: Cybersickness (Post-Experience)

Identical items to Section 2, administered after the VR experience. The difference between pre and post scores indicates the degree of cybersickness induced by the application.

6.3.4 Section 4: Immersion and Presence

This section addresses RQ1 through seven Likert-scale items (1 = Strongly Disagree, 7 = Strongly Agree):

1. The VR museum felt like an engaging and immersive environment.

2. I felt a sense of presence, as if I was actually inside the museum space.
3. The visual quality of the museum contributed to a believable cultural atmosphere.
4. Navigating between the hub and the country rooms felt natural and intuitive.
5. The world map in the central hub made it clear how to access each country room.
6. The Cypriot room felt like an authentic representation of Cypriot culture and lifestyle.
7. The Japanese room felt like an authentic representation of Japanese culture and lifestyle.

An additional open-ended item asks: “Was there anything in either room that felt out of place or culturally inaccurate?” This qualitative item captures specific cultural authenticity concerns that Likert scales cannot detect.

Items 1–3 measure general immersion and presence, items 4–5 assess navigation design quality, and items 6–7 evaluate cultural authenticity; all components of the broader construct of “cultural presence” addressed by RQ1.

6.3.5 Section 5: Interactive Elements and Learning

This section addresses RQ2 through five Likert-scale items (1–7) and two additional items:

1. The information panels for each artifact were clear and easy to understand.
2. The information panels gave me enough context to understand each artifact’s cultural significance.
3. The mini-game was enjoyable to play.
4. The mini-game helped reinforce what I learned from the artifacts and panels.
5. The interactive elements made learning about culture feel more engaging than traditional methods (e.g., textbooks, documentaries).

Additional items:

- Mini-game difficulty rating (Too easy / About right / Too hard)
- Open-ended: “What did you find most useful or interesting about the information panels?”

6.3.6 Section 6: Educational Value and Cultural Curiosity

This section captures overall learning outcomes and attitudinal changes:

- “After the experience, I feel I learned something meaningful about at least one culture.” (Likert 1–7)
- “This experience made me more curious about world cultures.” (Likert 1–7)
- Comparative effectiveness versus traditional methods (Much worse / Slightly worse / About the same / Better / Much better)
- Experience characterization (I learned something new / It confirmed things I already knew / I felt curious to learn more / I felt confused or overwhelmed / Other)

These items support both RQ2 (learning effectiveness) and RQ3 (influence of prior interest on outcomes) when cross-referenced with demographic data.

6.3.7 Section 7: Open Feedback

Four open-ended items capture qualitative insights:

1. What did you enjoy most about the experience?
2. What was the most confusing or frustrating part?
3. What cultural artifacts, features, or rooms would you like to see added?
4. Any other comments or suggestions?

6.4 Results

6.4.1 Statistical Methods

Because Likert-scale responses are ordinal rather than interval data, and because the sample size ($N = 12$) is too small to assume a normal distribution, all analyses use non-parametric tests. Three test types are used throughout this chapter and are explained below.

Wilcoxon Signed-Rank Test. This test is used for paired pre/post comparisons (cybersickness before and after the experience). For each participant, the difference between their post- and pre-experience score is computed. These differences are ranked by absolute size, and the test statistic W is the smaller of the sum of positive-difference ranks and the sum of negative-difference ranks. A value of $W = 0$ is the most extreme outcome

possible: it means every participant's score changed in the same direction, so the sum of ranks on the other side is zero. A small W therefore corresponds to a small p -value. This test asks: *is there a consistent directional change between the two measurements?*

One-Sample Wilcoxon Signed-Rank Test. This test is used to determine whether a set of Likert ratings is significantly above the neutral midpoint of 4 (the mid-point of the 1–7 scale, representing neither agreement nor disagreement). Each score is shifted by subtracting 4, and the standard Wilcoxon procedure is applied to the non-zero differences. Because the hypothesis is directional (scores are expected to be *above* 4, not merely *different* from it), one-tailed p -values are reported. Again, $W = 0$ means all scores exceeded 4, the most decisive possible result. This test asks: *did participants rate this item significantly above neutral?*

Mann-Whitney U Test. This test is used to compare two independent groups (participants with low versus high cultural interest). For every observation in one group, the test counts how many observations in the other group it exceeds; summing these counts across all pairs gives the statistic U . A non-significant result means the two groups cannot be statistically distinguished. Two-tailed p -values are reported since no direction was hypothesised. This test asks: *did the two groups rate their experience differently?*

The significance threshold is $\alpha = .05$ throughout. The following column labels appear in the results tables:

- **Pre M (SD) / Post M (SD):** Mean and standard deviation of the symptom rating before and after the VR experience, respectively.
- Δ : The mean change from pre to post (Post – Pre). A positive value indicates an increase in the symptom.
- W : Wilcoxon test statistic (see above). A value of 0.0 indicates a unanimous directional result.
- p : The probability of observing a test result at least as extreme as the one obtained, assuming the null hypothesis is true. Values below .05 indicate a statistically significant result.
- M / SD : Mean and standard deviation of a Likert item's ratings.
- **Mdn**: Median rating. Reported alongside the mean for ordinal data, as the median is less sensitive to skew.
- **Low M (SD) / High M (SD):** Group mean and standard deviation for the low- and high-interest groups in the RQ3 comparisons.
- U : Mann-Whitney test statistic (see above).

6.4.2 Participant Demographics

Twelve participants took part in the study. Table 6.1 summarises their profiles.

Table 6.1: Participant demographic and background characteristics ($N = 12$).

Variable	Category	<i>n</i>	%
Age	18–24	11	92
	25–34	1	8
Gender	Male	6	50
	Female	6	50
Seek to learn about cultures	Rarely	6	50
	Sometimes	6	50
Play video games	Very Often	7	58
	Sometimes	2	17
	Rarely	2	17
	Often	1	8
VR/AR/XR usage	Never	8	67
	Rarely	3	25
	Sometimes	1	8

The sample was evenly split by gender and predominantly aged 18–24 (92%), consistent with university recruitment. Participants were moderately familiar with Cypriot culture ($M = 5.58$, $SD = 1.00$) but reported considerably lower familiarity with Japanese culture ($M = 2.83$, $SD = 1.34$), reflecting the local recruitment context. The majority of participants had never used VR before (67%), making the sample representative of general-public novice users rather than technology enthusiasts.

6.4.3 Cybersickness Analysis

Table 6.2 presents the pre- and post-experience symptom means and the results of pairwise Wilcoxon signed-rank tests.

Table 6.2: Pre- and post-experience cybersickness ratings (1–7 scale) with Wilcoxon signed-rank test results ($N = 12$).

Symptom	Pre M (SD)	Post M (SD)	Δ	W	p
Nausea	1.08 (0.29)	1.75 (0.87)	+0.67	0.0	.031
Dizziness	1.08 (0.29)	1.92 (0.90)	+0.83	0.0	.008
Disorientation	1.08 (0.29)	1.92 (1.08)	+0.83	0.0	.016
Postural Instability	1.08 (0.29)	2.17 (1.40)	+1.08	0.0	.016
Visual Fatigue	1.33 (0.65)	2.50 (1.45)	+1.17	0.0	.016
Visual Discomfort	1.33 (0.49)	2.00 (1.28)	+0.67	0.0	.125

Five of the six symptoms showed statistically significant increases from pre- to post-experience ($p < .05$). Visual Discomfort was the only symptom that did not reach significance ($p = .125$). However, it is important to contextualise these increases: all post-experience means remain well below the scale midpoint of 4, with the highest reported mean being Visual Fatigue ($M = 2.50$). The largest absolute increase was also Visual Fatigue ($\Delta = +1.17$), likely attributable to the sustained eye movement involved in reading information panels in a stereoscopic display. Open-ended responses corroborated this, with some participants noting that their eyes eventually became tired during the session. Overall, the cybersickness profile is consistent with what would be expected from a teleportation-based locomotion design and does not indicate a problematic level of discomfort.

6.4.4 RQ1: Immersion and Cultural Presence

Table 6.3 presents descriptive statistics and one-sample Wilcoxon test results for the seven immersion and presence items (tested against the neutral midpoint of 4). The $W = 0.0$ value for all items reflects the fact that every participant rated each item above the neutral midpoint of 4, leaving no negative ranks in the test and producing the most extreme possible result.

Table 6.3: RQ1 – Immersion and cultural presence ratings ($N = 12$, scale 1–7). One-sample Wilcoxon tests against neutral midpoint 4 (one-tailed).

Item	M	SD	Mdn	W	p
Engaging & immersive	6.67	0.49	7.0	0.0	.0002
Sense of presence	6.42	0.79	7.0	0.0	.0002
Visual quality – atmosphere	6.33	0.89	6.5	0.0	.0005
Navigation intuitive	6.75	0.45	7.0	0.0	.0002
World map clear	6.17	0.72	6.0	0.0	.0002
Cypriot room authentic	6.83	0.39	7.0	0.0	.0002
Japanese room authentic	6.75	0.45	7.0	0.0	.0002
Overall RQ1	6.56	0.65			

All seven items were rated significantly above the neutral midpoint ($p \leq .0005$), indicating strongly positive responses across all dimensions of immersion and cultural presence. The overall mean across all RQ1 items was $M = 6.56$ ($SD = 0.65$) on a 7-point scale, approaching the theoretical maximum.

The highest-rated item was cultural authenticity of the Cypriot room ($M = 6.83$, $SD = 0.39$), followed closely by navigation intuitiveness ($M = 6.75$, $SD = 0.45$) and Japanese room authenticity ($M = 6.75$, $SD = 0.45$). The world map clarity item received the lowest mean score among RQ1 items ($M = 6.17$, $SD = 0.72$), though this still represents a strongly positive rating and may reflect the novelty of map-based VR navigation for participants with no prior VR experience.

Qualitative responses to the open-ended authenticity question reinforced the quantitative findings. Of the 9 participants who provided substantive responses, all affirmed the cultural accuracy of the rooms. Representative quotes include: “No, everything was related to the core of each culture”, “No, everything was an accurate depiction”, and “Nothing seemed out of place, the cultural experience felt authentic and very informative”. No participant identified a specific cultural inaccuracy.

6.4.5 RQ2: Interactive Learning Effectiveness

Table 6.4 presents results for the five interactive elements and learning items. As with RQ1, $W = 0.0$ for all items indicates that every participant rated each item above the

neutral midpoint.

Table 6.4: RQ2 – Interactive elements and learning ratings ($N = 12$, scale 1–7). One-sample Wilcoxon tests against neutral midpoint 4 (one-tailed).

Item	M	SD	Mdn	W	p
Panels clear & understandable	6.75	0.45	7.0	0.0	.0002
Panels sufficient cultural context	6.75	0.45	7.0	0.0	.0002
Mini-game enjoyable	6.50	0.80	7.0	0.0	.0002
Mini-game reinforced learning	6.67	0.49	7.0	0.0	.0002
Interactive elements > traditional	6.75	0.45	7.0	0.0	.0002
Overall RQ2	6.68	0.54			

All five items were rated significantly above the neutral midpoint ($p = .0002$), with an overall mean of $M = 6.68$ ($SD = 0.54$). The information panels received particularly strong ratings for both clarity ($M = 6.75$) and provision of cultural context ($M = 6.75$). Mini-game enjoyment ($M = 6.50$) and learning reinforcement ($M = 6.67$) were also highly rated. The item comparing interactive learning with traditional methods ($M = 6.75$) reached the highest level of consensus, with all 12 participants rating the interactive experience as superior to conventional learning approaches.

Mini-game difficulty was uniformly rated “About right” by all participants (100%, $n = 12$), indicating the quiz content was appropriately calibrated.

The two educational value items further support these findings. Participants strongly agreed that they had learned something meaningful ($M = 6.83$, $SD = 0.39$), the highest mean across the entire questionnaire. The curiosity item showed slightly greater variance ($M = 5.58$, $SD = 0.90$), suggesting that while nearly all participants felt a stronger interest in world cultures after the experience, the effect was less uniform than the other measures. All 12 participants rated the experience as better than traditional methods (75% “Much better”, 25% “Better”). When asked to characterise how the experience made them feel, 50% selected “I felt curious to learn more” and 50% selected “I learned something new”, with no participant reporting confusion or feeling overwhelmed.

Qualitative feedback on the information panels clustered around two themes. The first was the value of consistent, digestible structure, with participants appreciating the predictable format across artifacts: “*The panels had the same structure of information every time and that made it easier to read them, understand and learn*” and “*short panels*

- *easy to read and understand in a fun and informative way.*” The second theme was depth and engagement of content: “*There are sections which pin the use and the history of each artifact*” and “*It made facts sound interesting.*”

6.4.6 RQ3: Influence of Prior Cultural Interest

To address RQ3, participants were divided into two groups using two independent splitting criteria, and Mann-Whitney U tests were used to compare RQ1, RQ2, and educational value scores between groups.

Split 1 – Culture-seeking behaviour: Participants were split by their reported frequency of actively seeking to learn about other cultures: “Rarely” ($n = 6$) versus “Sometimes” ($n = 6$). Table 6.5 presents the results.

Table 6.5: RQ3 – Mann-Whitney U tests by culture-seeking behaviour ($N = 12$).

Measure	Low M (SD)	High M (SD)	U	p
RQ1: Immersion	6.45 (0.67)	6.67 (0.61)	710.5	.071
RQ2: Interaction	6.80 (0.48)	6.57 (0.57)	551.5	.057
Educational Value	6.00 (1.04)	6.42 (0.79)	56.0	.332

Split 2 – Cultural familiarity: Participants were split by a median split on their average cultural familiarity score (mean of Cypriot and Japanese familiarity ratings): low familiarity (≤ 4.0) versus high familiarity (> 4.0). Table 6.6 presents the results.

Table 6.6: RQ3 – Mann-Whitney U tests by cultural familiarity median split ($N = 12$).

Measure	Low M (SD)	High M (SD)	U	p
RQ1: Immersion	6.55 (0.63)	6.57 (0.69)	750.5	.712
RQ2: Interaction	6.70 (0.52)	6.65 (0.59)	412.5	.811
Educational Value	6.19 (0.98)	6.25 (0.89)	63.0	.974

Neither split produced a statistically significant difference on any measure ($p > .05$). Under the culture-seeking split, immersion ($p = .071$) and interaction ($p = .057$) approached but did not reach significance, and the direction of the difference was inconsistent across measures (the “Rarely” group actually rated RQ2 interaction slightly higher than the “Sometimes” group). Under the familiarity median split, all p -values were well

above threshold ($p > .70$), indicating no meaningful relationship between prior cultural familiarity and experience ratings.

These null results are interpreted positively: Orbis appears to engage participants with equal effectiveness regardless of how much prior interest in world cultures they bring to the experience. High ratings were not concentrated among participants who were already culturally curious; rather, the experience appeared to be equally compelling for both groups.

6.5 Discussion

6.5.1 RQ1: Immersion and Cultural Presence

The results provide strong evidence that Orbis successfully creates a sense of immersion and cultural presence. All seven RQ1 items were rated significantly above the neutral midpoint, and the overall mean of $M = 6.56$ out of 7 places the experience in the upper range of what users would describe as fully immersive. The near-perfect scores on cultural authenticity for both the Cypriot ($M = 6.83$) and Japanese ($M = 6.75$) rooms, combined with qualitative responses in which no participant identified any cultural inaccuracy, suggest that the design methodology – domestic environment reconstruction, contextual artifact placement, and ambient soundscaping – was effective at conveying cultural identity.

The presence and immersion items ($M = 6.67$ and $M = 6.42$ respectively) align with findings from prior VR cultural heritage work. Liarokapis et al. [20], whose VR museum for underwater antiquities was also empirically evaluated, similarly found that contextual presentation of artifacts in their original environment substantially elevated the perceived cultural value of the experience. The navigation intuitiveness score ($M = 6.75$) is particularly encouraging given that 67% of participants had never used VR before; this suggests that the map-based, point-and-select interaction model is accessible to novice users.

6.5.2 RQ2: Interactive Learning Effectiveness

The interactive elements of Orbis received the strongest ratings across the entire study, with an overall RQ2 mean of $M = 6.68$ and 100% of participants rating the experience as better than traditional learning methods. The information panels were rated highly for both clarity and cultural depth, and the qualitative themes around consistent structure and engaging content suggest that the multi-slide wrist-panel design achieved its intended pedagogical function.

The mini-game results are equally positive: enjoyment ($M = 6.50$) and learning reinforcement ($M = 6.67$) were both high, and every participant found the difficulty appro-

priately calibrated. The deliberate design choice to omit a cumulative score and allow free-order question navigation appears to have succeeded in removing evaluative pressure while maintaining engagement.

The educational value items further reinforce these findings. A mean of $M = 6.83$ for “learned something meaningful” is the highest single-item score in the study, and the equal split between “learned something new” and “felt curious to learn more” suggests that Orbis serves different users’ needs simultaneously – delivering new knowledge for those unfamiliar with the cultures while stimulating further curiosity in those who already had some background. This is consistent with Pietroni et al.’s [23] observation in Virtual Rome that experiential learning in VR is more effective at inducing curiosity and engagement than passive media, even when the content itself is familiar.

Notably, one participant flagged an actionable design limitation: the absence of visible indicators on interactable artifacts made it difficult to know which objects could be engaged with. This feedback points to a clear improvement for future iterations – a highlighting or glow effect on artifacts with information panels would lower the discovery barrier and ensure users do not miss educational content.

6.5.3 RQ3: Prior Cultural Interest as a Moderator

The null results across both group-comparison analyses indicate that prior cultural interest does not moderate the Orbis experience to a significant degree. This is a notable positive finding: it means the system does not merely “preach to the converted” by engaging only those who are already culturally curious. Participants with low and high cultural familiarity, and those who rarely versus sometimes seek cultural learning, rated the experience at near-identical levels.

One possible explanation is that the domestic environment framing – everyday spaces rather than formal museum exhibits – lowers the perceived “cultural barrier” and makes the content feel accessible and relatable regardless of prior knowledge. Another is the ceiling effect: with group means ranging from 6.00 to 6.83 on a 7-point scale, there is very little room for differences to emerge.

6.5.4 Implications for VR Museum Design

The results suggest several design principles worth generalising. First, domestic space reconstruction is an effective basis for cultural VR: participants responded strongly to rooms that replicated daily life rather than gallery-style displays. Second, wrist-attached multi-slide panels are a functional and well-received mechanism for delivering educational content without interrupting the sense of immersion. Third, quiz-based assessment with immediate visual and audio feedback is an appropriate end-of-room mechanism, but

the absence of interactable-object indicators and of explanatory feedback per quiz answer represent missed opportunities that should be addressed in future iterations.

6.6 Threats to Validity

6.6.1 Internal Validity

The study uses a single-session, pre/post within-subjects design with no control condition. The absence of a control group means it is not possible to isolate the specific contribution of VR immersion versus simply receiving the cultural information through any medium. Practice effects may also have influenced results: participants who gained familiarity with VR controls in the first room they visited may have felt more comfortable and rated subsequent rooms more positively as a result. Room exploration order was not controlled – participants chose freely which country room to visit first – so individual differences in exploration sequence cannot be accounted for in the analysis.

6.6.2 External Validity

The sample of $N = 12$ is small and drawn almost entirely from the 18–24 age bracket (92%), recruited from a university context. This limits generalisability to other populations, in particular older adults, non-students, and users from non-Western cultural backgrounds. Furthermore, with participants predominantly familiar with Cypriot culture ($M = 5.58$) and largely unfamiliar with Japanese culture ($M = 2.83$), the authenticity ratings for the two rooms cannot be directly compared as equivalent tests. A cross-cultural sample would be required to evaluate each room against a baseline of true cultural insiders.

6.6.3 Construct Validity

All learning outcomes are measured through self-report Likert scales rather than objective knowledge assessments. Participants may over-report learning due to social desirability bias – particularly in a study context where the researcher is present and the application is a student project. The high ceiling observed across most items (many medians at 7.0) makes it difficult to discriminate between genuinely excellent and merely good performance on any given dimension. A pre/post knowledge quiz would provide a more objective measure of actual learning.

6.6.4 Statistical Conclusion Validity

With $N = 12$, all tests are underpowered, increasing the risk of Type II errors. The Mann-Whitney tests for RQ3 in particular are sensitive to this: the marginal p -values observed under the culture-seeking split (RQ1: $p = .071$; RQ2: $p = .057$) may reflect true underlying effects that a larger sample would detect. Non-parametric tests were used appropriately given the ordinal scale and small sample, but their reduced power relative to parametric alternatives must be acknowledged when interpreting the null results for RQ3.

Chapter 7

Conclusion

This chapter summarizes the work presented in this thesis, discusses its contributions and limitations, and proposes directions for future development.

7.1 Summary

This thesis presented *Orbis: The Continental Gallery*, an educational Virtual Reality museum designed to promote cultural heritage awareness through immersive exploration of reconstructed domestic environments. The system allows users to navigate from a central hub via an interactive world map to dedicated country rooms that faithfully recreate traditional living spaces, populated with culturally significant artifacts accompanied by educational information panels.

The application was developed in Unity 2022.3 using the Universal Render Pipeline, OpenXR 1.14.3, and the XR Interaction Toolkit 2.6.5. The implementation includes core interaction systems: map-based country selection with hover feedback, a toggleable navigation menu providing scene transitions and position resets, wrist-attached multi-slide information panels for artifact education, quiz-based mini-games for knowledge assessment, and teleportation-based locomotion. Two country rooms were developed: a fully realized Cyprus room containing traditional Cypriot domestic artifacts, architecture, flora, fauna, and ambient soundscapes; and a Japan room featuring a genkan, traditional room, bedroom, kitchen, and an exterior garden with a temple and sakura trees.

A user study ($N = 12$) was conducted to evaluate the system across three research dimensions. Results demonstrate that *Orbis* successfully achieves its core objectives. Immersion and cultural presence were rated highly, with an overall mean of $M = 6.56$ out of 7 and near-unanimous qualitative confirmation of cultural authenticity. Interactive learning elements received the strongest ratings in the study, with an overall mean of $M = 6.68$; all participants rated the experience as better than traditional learning methods,

and $M = 6.83$ for “learned something meaningful” was the highest single score across the entire questionnaire. Prior cultural interest was found to have no significant moderating effect, indicating that Orbis engages users equally regardless of their cultural background. Cybersickness was present but mild, with all post-experience symptom means remaining well below the scale midpoint, consistent with the teleportation-based locomotion design. These findings suggest that immersive, domestic-environment-centred VR is a viable and effective paradigm for cultural heritage education.

7.2 Contributions

The primary contributions of this work are:

1. **A novel approach to cultural heritage VR:** Orbis demonstrates that domestic space reconstruction – recreating traditional homes and everyday environments rather than formal museum galleries – is an effective paradigm for cultural education in VR. By situating artifacts within their original domestic context, the system leverages situated learning principles to create more meaningful cultural encounters than decontextualized museum displays.
2. **An extensible VR museum architecture:** The hub-and-spoke design with a map-based navigation system provides a scalable framework that can accommodate additional countries without architectural changes. Each country room is a self-contained scene that can be developed independently, making the platform suitable for incremental expansion.
3. **An integrated learning cycle:** Unlike many VR cultural experiences that are purely observational, Orbis combines exploration (discovering artifacts), education (reading information panels), and assessment (mini-games) into a complete learning cycle within a single immersive session.
4. **Empirical evaluation:** The user study provides empirical data on the effectiveness of VR for cultural heritage education, contributing to the growing body of evidence on immersive learning outcomes.

7.3 Limitations

Several limitations of the current work should be acknowledged:

- **Content scope:** Only two country rooms are currently implemented. While both the Cyprus and Japan rooms are fully realized, the system’s ability to demonstrate broad cross-cultural comparison remains limited by the number of available rooms.

- **Mini-game scope:** The assessment mini-games currently use multiple-choice and true/false questions. While effective for testing factual recall, more varied game formats (such as artifact matching or spatial placement challenges) could engage different cognitive skills and provide a richer assessment experience.
- **Cultural validation:** While care was taken to research and accurately represent the cultural content, the artifacts and environments have not been formally validated by cultural heritage experts or anthropologists. Community validation would strengthen the authenticity claims.
- **Accessibility:** The system requires a VR headset and a minimum level of physical mobility (standing, head movement, hand controller use), which limits accessibility for users with physical disabilities or those without access to VR hardware.
- **Single-language content:** All educational content is currently in English. Multilingual support would be necessary for deployment in culturally diverse contexts.
- **Evaluation scope:** The user study is limited to a single session with a small ($N = 12$), predominantly 18–24-year-old, university-drawn sample. The sample is also locally recruited, meaning most participants were already familiar with Cypriot culture. Longitudinal studies, objective pre/post knowledge tests, and more diverse participant pools would substantially strengthen the findings.

7.4 Future Work

Several directions for future development are envisioned:

7.4.1 Additional Country Rooms

The most immediate priority is expanding the collection of country rooms. Each new room would follow the established methodology of research, layout design, artifact population, and information authoring. Priority countries could be selected based on user interest (as indicated by evaluation feedback) or educational relevance. Potential additions include rooms representing Egyptian, Mexican, and Austrian domestic cultures.

7.4.2 Interactable Artifact Indicators

User study feedback highlighted that participants found it difficult to identify which objects in the room had associated information panels. Adding a subtle visual indicator – such as a glow effect, a floating icon, or a pulsing highlight – to artifacts with panel content

would lower the discovery barrier and ensure users do not inadvertently miss educational material during free exploration.

7.4.3 Mini-map

Users exploring multi-space country rooms – such as the Japan room, which spans a genkan, main room, bedroom, kitchen, and exterior garden – may lose track of which areas they have already visited or where they currently are within the space. A toggleable mini-map, accessible via a dedicated controller button, would display a top-down schematic of the current room with an indicator of the user’s present position and orientation. Keeping it toggleable ensures it does not permanently occupy the field of view and disrupt immersion, yet remains immediately available whenever the user needs a spatial overview. To remain accessible, the mini-map should support adjustable scale and opacity so that it does not obscure the cultural environment while still being legible for users with varying visual needs.

7.4.4 Mini-Game Expansion and Feedback

The current mini-game system uses multiple-choice and true/false questions to assess cultural knowledge acquired during exploration. Participants suggested adding explanatory feedback per question – a brief note on why an answer is correct or incorrect – which would deepen the learning value of the assessment. An optional final score summary could also be offered as an opt-in feature for users who want a more structured review. Beyond feedback improvements, future iterations could expand the game formats to include artifact matching, room assembly tasks, or timed challenge modes.

7.4.5 Multiplayer Support

Adding collaborative exploration capabilities would allow users to experience cultural rooms together, discuss artifacts, and engage in cooperative mini-games. This could be particularly valuable in classroom settings where a teacher guides a group of students through the experience.

7.4.6 Photogrammetric Artifacts

Integrating photogrammetry-scanned real-world artifacts would increase the visual fidelity and cultural authenticity of the displayed objects. Partnerships with museums and cultural institutions could provide access to physical artifacts for scanning.

7.4.7 Adaptive Content

Implementing a system that adjusts educational content based on user behavior – spending more time on topics the user engages with, offering additional depth for interested users, and simplifying content for those who appear overwhelmed – would personalize the learning experience.

7.4.8 Longitudinal Studies

Future evaluations should include pre/post knowledge tests to objectively measure learning outcomes, longitudinal follow-ups to assess knowledge retention over time, and cross-cultural studies comparing how users from different backgrounds experience the same cultural rooms.

7.4.9 Accessibility Features

Adding seated mode support, voice-activated navigation, adjustable text size, and audio descriptions of artifacts would broaden the system’s accessibility to users with diverse physical and sensory capabilities.

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