Games in Cultural Venues Using Public VR: Designing Motion-Tracked and Story-Driven Experiences

Anastasios Theodoropoulos
Department of Performing and Digital Arts, University of the Peloponnese
Nafplio, Greece
ttheodor@uop.gr

Angeliki Antoniou
University of West Attica, Greece
angelant@uniwa.gr

George Lepouras
HVI-VR Laboratory, Greece
gl@uop.gr

ABSTRACT

This paper explores the potential of Virtual Reality (VR) to enhance public engagement in cultural contexts, focusing on experiences designed for the MobiCave platform. By integrating the MDA (Mechanics, Dynamics, Aesthetics) framework with the Framework for Immersive Virtual Environments (FIVE), we examine how VR experiences can be designed to maximize usability, engagement, and educational outcomes. Particular attention is given to the interplay of interaction design, immersion, and spectator roles in shared VR spaces. Case studies from the MobiCave demonstrate how these frameworks guide the balance between entertainment and educational objectives, while also addressing the dynamics of multi-user interaction and bystander engagement. The work highlights the value of combining game mechanics, emotional engagement, and accessibility to create impactful and memorable cultural experiences.

Keywords

VR Games, Immersive Game Design, MobiCave, Public Engagement, Cultural Heritage

1. Introduction

Over the last years more and more cultural institutions use Virtual Reality (VR) to provide their visitors with opportunities for immersion and interactivity and thus engage them further with the cultural content (Koutsabasis, 2020; Shih, 2015). There are many examples of museums across the world that use VR to transform the cultural experience (Shehade et al., 2020), like the Han Dynasty Haihunhou Ruins Museum (Han et al., 2021).

Proceedings of DiGRA 2025

Wishing to further study the potential of VR and games in Cultural Heritage, the present work will focus on multiple interactions in VR environments. More specifically, we will focus on single vs. multiplayer, storydriven and motion-tracked interactions, to understand their contribution to the overall cultural experience of players and bystanders. The MobiCave (Theodoropoulos et al., 2023), a room sized VR CAVE designed to support immersive and shared gaming experiences, will be used to study the edutaining and engaging aspect of VR cultural experiences. Thus, the current study positions itself at the intersection of game design, public engagement, and immersive technologies in the context of cultural heritage.

The following research questions (RQ) will be explored:

RQ1: How can VR gaming experiences be designed to maximize public engagement in cultural venues?

RQ2: How do different modes of VR interaction (e.g., single-player, collaborative, spectator engagement) influence usability and motivation?

RQ3: What is the impact of integrating gaming, entertaining and educational elements in VR experiences on user engagement and learning outcomes?

RQ4: How can bystander intervention and spectator roles be effectively incorporated into VR (gaming) experiences for public engagement?

The rest of this paper is structured as follows: In our review of the literature we discuss past research efforts in games for cultural heritage. This is followed by a theoretical Framework for MobiCave, which combines the MDA with the FIVE framework. The paper then presents 3 Case Studies, showcasing games developed and implemented at the MobiCave, highlighting their design and impact on user engagement. Then, the Design Considerations section, addresses the practical challenges faced in creating VR gaming experiences, particularly in a public setting. Finally, the paper concludes with a summary of the findings and their implications for future VR-based cultural engagements.

2. Related Work

2.1 Games in Cultural Heritage

Games and Cultural heritage are tightly connected, not only because humans played games throughout history (Huizinga, 1949), as a way to explore (Lazzaro, 2009), learn (Roussou, 2004) and socialise (Glasberg et al., 1998), making them a large part of human heritage, but also because through games people can discover heritage (e.g. Anderson et al., 2010; Mortara et al., 2014; Malegiannaki et al., 2017). Regarding cultural heritage, researchers have recognised the educational value of games (Papastergiou 2009), since they support critical thinking (Franco et al., 2009), improve situational learning (De Aguilera et al., 2003), have clear cognitive benefits (Verhaegh et al., 2007), especially for children with learning difficulties (Paniagua et al., 2009) and support cultural heritage understanding (Bellotti et al., 2013).

Because games have many different characteristics, they can be classified in numerous ways. Thus, games can be educational or non educational, can be rather

simple or complex requiring players to learn a complex set of rules, or they can be single or multiplayer. They can also target different aspects of the cultural experience like need for further information, communication or creativity. Games in cultural heritage can use different types of technologies and have different modes of interaction and they can have different themes, like action, labyrinth, strategy etc. (Antoniou et al., 2011).

Although games seem to play a very important role in cultural heritage understanding and engagement, there seem to be few holistic frameworks for their development. In fact, most games for cultural heritage seem to follow bottom up processes and they are case specific (Anderson et al., 2010). Among the holistic frameworks that support top down processes, is the work of Bellotti et al., (2013) where they describe a task based learning approach that allows players to engage in cognitive tasks within information rich environments. Due to its holistic nature, this approach simplifies game design for cultural heritage. The approach allows designers to easily analyze the specific characteristics of heritage sites and guides game design accordingly. The games that result seem to increase learning. Similarly, the FRACH framework also provides concrete steps that support the entire game design processes, making games that increase visitor satisfaction, entertainment and learning (Andreoli et al., 2017). Furthermore, attempts to apply top down processes can be also found in works that employ game platforms that allow them to create several different games for different sites (De Paolis et al., 2010; 2011). For example, De Amicis et al., (2009) used such a platform and designed multiple games for different heritage sites. Apostellis and Daradoumis (2010) studies the potential of games for various types of heritage theatres. Mikovec et al., (2009) present past efforts for creation of generic methodologies for games in cultural heritage. Finally, Antoniou et al. (2013) provide a theoretical framework for the study and creation of games in cultural heritage that considers different game characteristics (e.g. mechanics, scope, interaction mode, etc), player characteristics (e.g. personality, visitor type, etc) and organizational issues, like budget, demands on personnel etc.

2.2 VR for Public and Cultural Engagement

VR setups in cultural venues can be quite advanced systems utilizing body movements and social interaction. Following the enaction paradigm explaining that humans learn more efficiently when they have the opportunity to act (Bonini, 2008) and the embodiment theory where experience is materialised through the entire body (Kenderdine, 2015), cultural institutions employed VR systems as a way to engage visitors' body and mind. Studies revealed that embodiment increases when the virtual self shares common characteristics with the physical self, like gender and race (Do et al., 2024). VR systems in museums allow users not only to experience the virtual cultural environment with a sense of presence, but also allow them to interact directly with it. For example, visitors can use gestures to manipulate 3D cultural objects and interact with the virtual world (Drossis et al., 2018).

Moreover, the cultural experience is also a social one, since people can have multiple social interactions in cultural venues (Vayanou et al., 2020). In this sense, VR cultural experiences should also support socialisation processes, as an important element of the overall cultural experience. Thus, researchers are also investigating the way visitors represent themselves in VR cultural environments and how they interact with other users within them. Once inside the VR worlds, people seem to create novel

identities and new ways of virtual social interactions (Freeman & Maloey, 2021). The VR cultural experiences could focus on tangible (e.g. object handling, etc.) or intangible heritage (e.g. oral traditions, etc.) (Liu et al., 2022). Despite the type of heritage they represent, VR cultural experiences often use games and/or gamification elements to enhance user engagement (Liu et al., 2022).

The historical use of CAVEs in public-facing installations has been widely explored in the context of both artistic practice and immersive education. Compared to HMDs, CAVEs support a form of collective immersion, making them particularly suitable for cultural venues and group exploration. Notable implementations, such as early Disney prototypes and public museum installations, emphasized the social affordances of the CAVE format (Freyermuth, 2022). Studies such as Tcha-Tokey et al. (2018) propose that immersive virtual environments—such as CAVEs—can support high levels of presence, immersion, and engagement, particularly in educational contexts, depending on interaction design and system usability. However, this advantage is now being reassessed. Recent studies (Combe et al., 2023; Nunes de Vasconcelos et al., 2019) suggest that for tasks such as distance estimation, object manipulation, or educational engagement, the experiential differences between CAVEs and HMDs have become less pronounced, prompting a reevaluation of their respective roles. Moreover, while CAVEs offer a shared space for co-presence, HMDs provide individualized immersion, which can be preferable for narrative focus or personal reflection (Cheng, 2022; Zhao, 2023). The debate between collective and individual immersion continues to evolve as cultural heritage applications increasingly adopt mixed setups tailored to audience and venue needs (Campesan, 2024; Ronchi, 2023).

2.3 VR Games in Cultural Heritage

The immersive nature of VR and its ability to allow users to “travel” to different places in space and time, makes a significant impact when used in games. VR games allow players to have an immersive experience and become a part of the heritage space they explore (Sherman & Craig, 2018). However, when games are used to allow players to experience cultural heritage, numerous challenges emerge, like the need to provide a scientifically accurate game environment (Razuvalova & Nizamutdinov, 2015). For example, a game in ancient Rome should be able to reconstruct the historical surroundings based on archaeological knowledge. This challenge can be targeted when the historical grounds are available for 3D scanning. In past studies, historical buildings were 3D scanned and the scans were processed with a game engine, resulting in an efficient and cost-effective way to provide the VR game world (Franczuk et al., 2022; Smith et al., 2019). Another crucial element in VR games for cultural heritage is the engaging storytelling employed to introduce players to the cultural content (Liarokapis et al., 2020). Apart from the difficulties and challenges, VR games seem to have many cognitive benefits for players, like positive learning outcomes (Vocaturo et al., 2019). The interactivity they allow with the cultural 3D objects, increases the hands-on experience and learning engagement (Li & Huang, 2022). In the known challenges, the possibility of cyber nausea is a known phenomenon that affects the usability of VR games and raises issues about the duration of game play (Shafer et al., 2019).

In a recent study (Theodoropoulos & Antoniou (2022) reviewed 265 research publications on VR games for cultural heritage and found that VR games for cultural

heritage are increasing in popularity. The majority of such games were single player and only 5 involved others in game playing, showing that more efforts are required for the development of multiplayer VR games. In addition, most games used HMDs. In addition, players reported high levels of immersion and learning gains were also found.

3. MobiCave

This section briefly introduces MobiCave, an interactive VR environment built to facilitate shared gaming experiences. The MobiCave is a room-sized implementation of a CAVE system that consists of three walls and 15 screens and a floor projection, each one led by a different GPU. This creates an interactive space, allowing players to move freely as though they were physically inside the game world, and instead of relying on wearables or traditional controllers, the system captures the full body movements of the player, translating them into meaningful actions within the virtual world (Figure 1). This enables a hands-free, natural form of interaction, where every gesture—from reaching to walking—becomes a direct input. The player's movements in the MobiCave aren't just functional—they are performative. As the player moves, their physical actions become a part of the game's narrative. Whether grabbing objects, walking through spaces, or gesturing to solve puzzles, every action is a form of performance within the virtual environment.

Figure 1: Left, the MobiCave VR environment; Right, process followed for the development, adopted from (Theodoropoulos et al., 2023).

4. Integrating a (VR) Game Framework for MobiCave

MDA and FIVE frameworks serve as foundational models that inform the design of engaging, accessible, and emotionally impactful VR gaming experiences. These established frameworks offer essential guidelines that, when applied to VR, help address the unique challenges and opportunities presented by immersive technology.

The MDA framework breaks down the game experience into three primary components: Mechanics, which define how the game operates (e.g., motion tracking

and multiplayer interactions); Dynamics, which emerge from player interactions within the game world (e.g., collaboration, competition, or problem-solving); and Aesthetics, which focus on the emotional responses elicited through gameplay, especially important in VR experiences where emotional immersion is key to cultural engagement.

The FIVE framework dives deeper into making VR experiences by offering more specific insights into the elements that shape user engagement in VR environments. It focuses on getting the technology to run without glitches (Functionality), ensuring players can do everything smoothly in the virtual world (Interaction), and guaranteeing the virtual environment is motivational, keeping players fully engaged (Visual Design). Additionally, there is a major emphasis on Engagement and Emotional Impact, since players should keep coming back, feeling emotionally aroused to create memorable experiences that stand out.

Together, MDA and FIVE provide a solid foundation for understanding VR game design, and help us comprehend why VR approach design, especially for places such as the MobiCave, is of such significant consequence (Table 1). The core mechanics of a game designed for public spaces should define the fundamental rules and interactions, ensuring they align with the physical constraints of a CAVE. For example, using redirected walking or spatial audio can enhance player immersion while respecting the limited movement space. Additionally, immersive capabilities such as haptic feedback or environmental cues should be leveraged to deepen engagement, drawing on FIVE's emphasis on sensory immersion. Player interaction should incorporate cooperative or competitive elements that encourage players to interact with one another and their surroundings. These dynamics should naturally emerge from well-designed mechanics. Furthermore, the design should promote emergent gameplay to create environments that encourage exploration and unexpected player-driven outcomes, enhancing the sense of presence and agency. To evoke emotional resonance, the game should create visually striking, narratively compelling experiences that stir emotional responses. The aesthetics should align with immersive priorities, ensuring the experience resonates emotionally. Additionally, the game should be designed to captivate a broad audience, even those who are merely passing by. The aesthetics should have the ability to attract and intrigue casual spectators.

Aspect	MDA Framework	FIVE Framework
Core Components	Game design elements: - Mechanics: Rules and systems - Dynamics: Interaction between elements - Aesthetics: Emotional and sensory impact	User interaction experience: - Functionality: Core mechanics and usability - Interaction: User engagement and interaction modes - Visual Design: Visual aspects - Emotional Impact: User's emotional response - Engagement: User involvement in the experience
Application in VR	Creating engaging mechanics and dynamics to drive meaningful user experiences in VR	Focusing on how the system functions and emotionally connects users to the content

UX	Focusing on dynamics and how users interact with the system and its underlying rules	Focusing heavily on user experience design, including accessibility and emotional engagement in VR
Educational Value	Focusing on Aesthetics and how they can drive the emotional connection with educational content in VR	Focusing on emotional impact and engagement relate to how educational content resonates with users, making learning more memorable
Social Interaction	Focusing on multiplayer dynamics and collaborative play which are key to social engagement	Focusing on how engagement explores the sense of community or cooperative interaction, enhancing the public experience
Customization and Adaptability	Focusing on how mechanics may allow for different difficulty levels or story choices	Focusing on how interaction and functionality can be adjusted based on user needs, including accessibility features
Cultural Sensitivity	Focusing on how mechanics and dynamics should be sensitive to cultural narratives, ensuring accurate portrayal	Focusing oh how visual design ensures culturally respectful and accurate representation

Table 1: MDA and FIVE Frameworks for analyzing VR gaming experiences in public cultural venues.

Figure 2 builds on Table 1 by visualizing how the MDA and FIVE frameworks interrelate across seven key design concerns: Core Components, Application in VR, UX, Educational Value, Social Interaction, Customization & Adaptability, and Cultural Sensitivity. These dimensions were distilled from the design and evaluation of the MobiCave case studies and reflect recurring themes in VR game development for cultural heritage contexts.

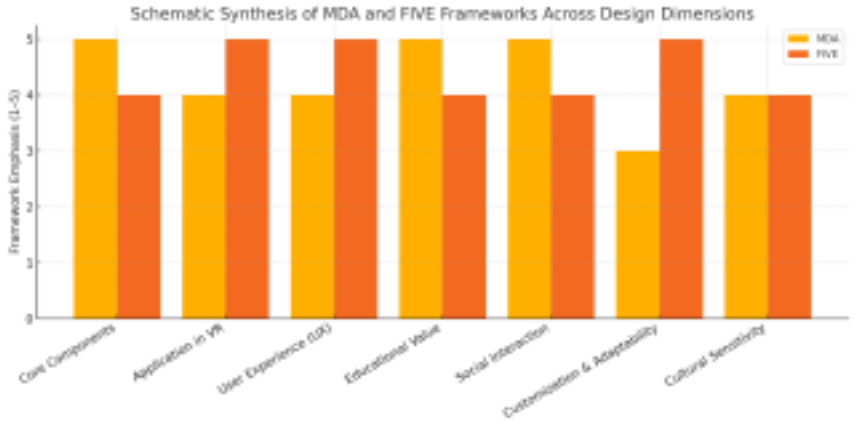

Figure 2: Schematic synthesis of the MDA and FIVE frameworks across seven dimensions of VR game design for cultural heritage.

The schematic presents a progression from foundational mechanics to broader socio-cultural impact. Rows 1 to 5 emphasize increasing layers of player experience — starting with core mechanics (row 1), moving through interaction quality and system fluency (rows 2–3), and culminating in educational engagement and

emotional resonance (rows 4–5). Rows 6 and 7 highlight adaptability and cultural relevance, which are especially crucial in public-facing, educational VR installations like those found in museums. This synthesis demonstrates the complementary strengths of the two frameworks: MDA offers a structure for gameplay elements and player motivation, while FIVE captures the affordances of immersive environments, interaction design, and the embodied nature of presence

Moreover, an iterative refinement process should be in place, with playtesting focusing on how mechanics influence dynamics and aesthetics. The design should be adaptable to allow for testing how rules and systems influence the game's look and feel. The public space should be optimized to ensure accessibility for all players, regardless of their experience levelThus, the need to make controls that are easy to understand and instructions that do not confuse people increases . Incorporating strategies that keep players coming back, such as leaderboards, collaborative tasks, or spectator-friendly visuals tasks that players have to work together to complete, should be implemented to attract and retain a diverse audience.

Therefore, combining the MDA and FIVE frameworks can result in significantly more engaging VR games. The MDA part delves into game design elements helping to ensure that the interactive and emotional aspects of the gaming experience are thoughtfully integrated. It highlights how the rules, interactions, and the emotional responses triggered by the experience can shape user engagement, which is crucial in designing immersive cultural experiences. On the other hand, the FIVE framework complements this by focusing on the broader user experience, examining the functionality, interaction, visual design, emotional impact, and engagement of the VR setup. This is incredibly useful for observing player interactions with VR settings, such as in MobiCave. By analyzing their enjoyment, learning experiences, and emotional engagement, we can gain valuable insights into how to optimize VR games for public cultural venues. This combined approach, considering both the design of the experience (MDA) and the user's engagement (FIVE), ensures a comprehensive analysis.

5. Case Studies - Games for MobiCave

The section presents three distinct games each showcasing unique approaches to immersive storytelling and interactive design tailored for the MobiCave platform (Table 2).

Game - Experience	Mode	Duration	Engagement	Purpose
Prometheus Unbound-Escape Room	Single-player	~10 min	Physical interaction	Entertainment
Turtle Heroes - Serious Game	Co-op (2 players)	~5 min	Educational + bystanders	Mixed (Fun + Learn)
Sacred Places - 360° Narration	Passive	~4 min	Non-interactive	Entertainment

Table 2: Games designed for MobiCave.

5.1 Game1: “Prometheus Unbound” - Immersive Escape Room

In the “Prometheus Unbound” game, the MobiCave enhances the experience of exploring Ancient Methoni by making the player’s interaction with the historical setting more tangible. The primary goal was to promote the rich cultural heritage and natural beauty of the Peloponnese region, particularly focusing on the Castle of Methoni, located on the southwestern coast of the Peloponnese in Greece. To achieve this, we centered our design around the specific site, carefully considering elements such as narrative setting, environmental design, and plot development. We took into account the historical and social context of the area, ensuring that every aspect of the game contributed to an immersive experience that authentically reflects the significance of this landmark.

Moving through the castle, solving puzzles, and interacting with objects becomes a performative exploration of history, where the player's actions tie them to the cultural narrative (Figure 2). A key milestone of our project was incorporating gameplay mechanics that utilize the human body as a joystick for interaction and movement. The game used a ZED 2 stereo depth camera to enable full-body motion tracking, allowing participants to control in-game movement and interactions through natural body gestures. Instead of relying on handheld controllers, players navigated the virtual environment using their own body as the input device — essentially turning the body into a joystick. Gesture mapping was implemented to recognize directional hand movements (e.g., pointing or reaching), turning motions (via shoulder rotation), and walking in place to simulate locomotion. These gestures were calibrated to support smooth, intuitive interaction without the need for complex onboarding, making the experience accessible to diverse public users. On-screen tutorial prompts within the VR environment visually illustrated these gestures, helping participants learn the mechanics through visual cues and reinforcement (see Figure 2). We aimed to create an experience that was not only easy to navigate but also immersive, ensuring a seamless connection between gameplay and narrative from a ludonarrative perspective. To achieve this, we infused the gameplay with a sense of physicality by using the trope of time travel—specifically malfunctioning time travel—as a narrative entry point. This allowed us to merge the fictional experience of being in another dimension with the corporeal nature of gameplay. Also, we chose a game genre that emphasized simple body movements, such as walking, climbing, and grabbing, which players could easily master. Additionally, we introduced time as the main opponent, creating a compelling challenge that heightened the sense of urgency and engagement within the game. This approach not only enhanced the players' physical interaction but also was intended to support narrative immersion, and participants reported high engagement.

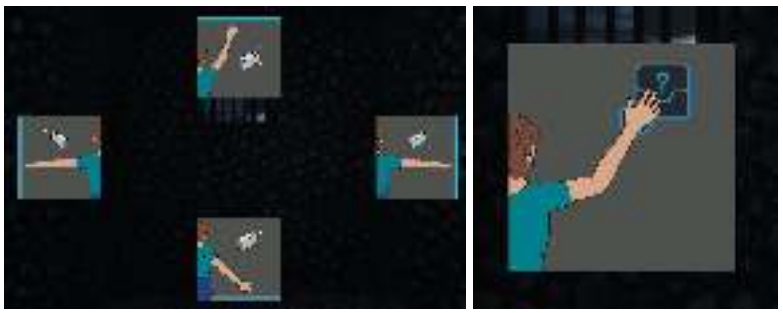

Figure 2: In-game gesture tutorials guiding interaction.

To evaluate our design and gameplay mechanics, we conducted a series of experiments. The first was a preliminary study with students aimed at testing the mechanics of using the body as a controller. This experiment focused on understanding how players' physical movements translated into the game world, providing valuable insights into the effectiveness of our embodied interaction approach. Following this, we carried out a follow-up experiment that delved into the overall game experience. In this phase, we measured key aspects such as embodiment and immersion, and examined how the performative nature of interaction influenced players' sense of presence within the virtual environment. These experiments were crucial for assessing the impact of our design choices on player engagement and the overall gaming experience. The findings revealed that the VR experience was highly immersive and enjoyable, appealing to both players and bystanders.

Figure 3: Player solving riddle in "Prometheus Unbound" game.

In "Prometheus Unbound", the combined framework emphasizes the use of body motion controls to enhance embodied interaction, which fosters a higher degree of immersion. By utilizing puzzles that integrate physical actions with narrative progression, players' movements, such as walking or reaching, become part of the core mechanics. The experience results in a strong sense of presence and engagement, particularly due to the hands-free interactions of the MobiCave system

and while the experience is single-player, it fosters social interaction among bystanders, who can discuss the puzzles and offer insights. This engagement encourages dialogue and makes the game more collaborative which aligns with the framework's focus on public appeal and social inclusivity in public VR spaces. Furthermore, the game promotes both learning and entertainment by exploring historical artifacts and time-travel mechanics and incorporating context into the puzzles.

5.2 Game2: "Turtle Heroes" – A Serious Game for Environmental Awareness

"Turtle Heroes" is a serious game designed to raise awareness among children and young adults about environmental challenges and the endangered Caretta caretta sea turtles, the project combines innovative gameplay with educational goals. The game is a co-operative third-person shooter game aimed at players aged ten and above (Figure 4). While shooter games are not typically used in serious game design, their popularity and inherent mechanics offer unique opportunities to engage players in meaningful ways. "Turtle Heroes" uses satire and humor to address the destructive behaviors threatening sea turtles. Players assume the role of volunteer rescuers tasked with protecting turtle nests and guiding hatchlings to the sea. The gameplay unfolds in two phases. During the day, players must repel zombie-enemies using seashells to prevent them from reaching and damaging turtle nests. An energy system adds a layer of strategy, as players must maintain their energy levels by successfully targeting enemies or receiving boosts from their co-player. At night, the focus shifts to combating an "unidentified object" that emits light onto the beach, disorienting hatchlings. Collaboration between players is central to the game, with mechanics encouraging teamwork, communication, and shared problem-solving. Players can activate power-ups and provide energy boosts to one another, fostering a sense of camaraderie and shared responsibility. The game uses hand-tracking technology where players use gestures to aim and throw seashells, enhancing the physicality of the experience and promoting immersion. The setup also provides an opportunity to study the social and technological dynamics of gameplay, including how players interact with each other and the system, and how they interpret the educational messages embedded in the game.

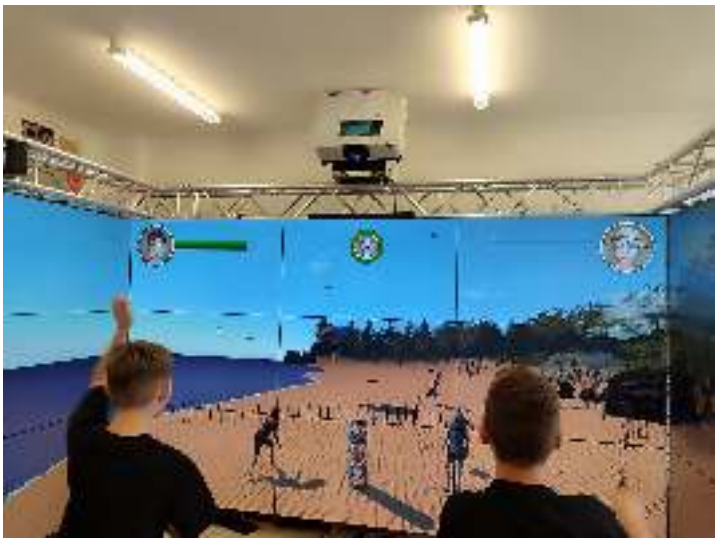

Figure 4: Co-op playing in the "Turtle Heroes" game.

Figure 5: Bystanders watching.

In "Turtle Heroes", the gameplay mechanics, such as gesture-based aiming and throwing, are key to user engagement. The cooperative gameplay enhances interaction by requiring players to collaborate for in-game success while the use of satire in the mechanics ensures the educational message about sea turtle conservation remains engaging without losing its seriousness (Figure 5). Moreover, the gameplay necessitates active communication between players, and the shared responsibility not only promotes collaboration but also ensures that players are highly engaged with each other throughout the game. Conservation concepts are delivered through playful mechanics, such as seashell throwing and energy boosts. balancing between entertainment and learning. Finally, the adaptive difficulty and simplified controls ensure that younger audiences can easily participate in the cooperative dynamics.

5.3 Game3: "Sacred Places" - 360° Videos

In this game, the user assumes the role of a hero called Frankie, a third-generation Greek-Australian immigrant visiting the Peloponnese for the first time. Through their journey across sites of exceptional natural beauty, such as the Geopark of Agios Nikolaos Voion and Lake Taka, Frankie delves into family memories and images of a shared past. As they explore the diverse landscapes of the Peloponnese (360 videos filmed with several views e.g., through ground, water or air), the user not only encounters the region's natural splendor but also its human geography, deeply marked by its migration history (Figure 6). The user navigates their narrative pathway by interacting with the system through simple tap-based mechanics. They can listen to sounds, view specific objects, or transition to new locations. The project is designed as a collaborative experience highlighting the natural beauty of the Peloponnese using 360° VR video and skeleton tracking technology. The core concept revolves around shared locations we've visited and where we've left traces of ourselves. The narrative emphasizes the lived experience of a place, where sensory input is intertwined with collective memory. Through "Sacred Places", participants

are invited to explore locations that may resonate with personal memories of the past or offer a sense of belonging through shared experiences. Even when these locations are new to the user, the journey fosters a sense of connection, making them part of a shared participatory experience rooted in our relationship with the place.

Figure 6: 360 video navigation in "Sacred Places".

While players do not interact directly with the environment, the cinematic visuals paired with spatial audio deliver an engaging experience that promotes reflection and emotional engagement with the narrative of migration and place. While the game does not emphasize direct collaboration or competitive dynamics, the shared viewing experience in public settings fosters group discussions and collective reflection. The game fosters emotional and sensory engagement with the natural beauty of the Peloponnese, promoting cultural understanding through passive storytelling, so the design's emphasis ensures that users are drawn into the narrative flow of the experience, even if they have minimal control over the interaction.

6. Discussion

6.1 Design Considerations

The design and application of VR gaming experiences in public settings, as demonstrated by the MobiCave games, can be examined through the lens of a combined framework (Table 3) that integrates gameplay mechanics, social dynamics, educational content, aesthetics and controls, and accessibility.

Aspect	Game1: Escape Room	Game2: Co-op serious	Game3: 360° Videos
Core Components	Mechanics: Time-travel puzzles Dynamics: Interaction with historical artifacts Aesthetics: Immersive environment rooted in Methoni Castle	Mechanics: Simple co-op gameplay Dynamics: Team collaboration and bystander engagement Aesthetics: Vibrant marine ecosystem	Mechanics: Passive storytelling Dynamics: Linear narrative flow Aesthetics: Cinematic visuals

Application in VR	Immersive exploration of historical site Motion-tracking for body-as-controller interactions	Focus on playful learning	Immersive storytelling experience with minimal interaction
UX	Intuitive body movements for navigation and puzzle-solving High embodiment and presence	Simplified controls for younger audiences Strong emphasis on accessibility and collaboration	Emphasis on passive, cinematic viewing
Educational Value	Promotes understanding of local history and cultural heritage	Teaches conservation concepts through playful engagement	Minimal educational focus; primarily for entertainment
Social Interaction	Primarily single-player, but fosters discussions among bystanders	Co-op gameplay encourages teamwork and bystander participation	Limited to shared viewing experience
Customization and Adaptability	Adjustable difficulty in puzzles Incorporates historical context tailored to the audience	Adaptive game modes for different skill levels Allows flexible play durations	No customization; designed as a fixed viewing experience
Cultural Sensitivity	Integration of Methoni Castle's historical and social context	Highlights environmental issues with humor, avoiding targeted criticism	Landscapes of particular natural beauty in 360, from different perspectives e.g. water, soil, air

Table 3: A (VR) Game Framework for MobiCave regarding different games.

***RQ1**: How can VR gaming experiences be designed to maximize public engagement in cultural venues?*

VR gaming experiences should appeal to a wide audience, especially when focused on cultural connections. To do this, things such as cultural context, aesthetic design, sensory engagement, and public appeal should all be part of the action plan. In contrast, playing skills in a VR setup like MobiCave let people be part of the action by moving around, which makes the whole experience significantly more fun and interesting. The approach regarding the Methoni Castle in "Prometheus Unbound" makes players feel a connection with the location on a deeper level. Games need to have a special feeling, induced not only with top-notch graphics, but with the surroundings and stories that make players feel closer to the culture and location they are exploring, similar to "Sacred Places". In addition, games like the ones described above draw players in, whether they decide to just look around or really get into it. This is why it is crucial to be easy to use, allowing all types of players to join the gaming experience. By allowing simple ways to move like in "Prometheus Unbound", or letting players pick their difficulty like in "Turtle Heroes", it ensures that anyone can have fun without getting frustrated. This inclusivity is key for making everybody excited about games and cultural heritage. Engaging in activities such as including old artifacts in puzzles keeps everyone's interest and makes them want to delve deeper. VR gaming experiences should be designed by keeping in mind how to make players more than just observers, turning them into actual participants in rich, cultural experiences.

***RQ2**: How do different modes of VR interaction (e.g., single-player, collaborative, spectator engagement) influence usability and motivation?*

How we interact in VR games really matters when it comes to fun and staying interested. For instance, in games like “Prometheus Unbound”, where players get to move around and solve riddles, being part of the story excites them because they are doing activities, not only watching. These experiences are even more impactful when they combine puzzles with ancient artifacts to engage and inspire players. In games like “Turtle Heroes”, which is primarily focused on teaming up, it makes players desire to continue because they have to pool resources with their friends, plan together, and reach the same goal. It is not simply the rush of the game, but feeling connected with co-players that hooks them in. Furthermore, games such as "Sacred Places" provide a more spectator-oriented experience, although players can still engage with the material through group discourse and joint reflection.This setup can really attract people, even in places where people might simply be relaxing and not wishing interact directly with the game.

***RQ3**: What is the impact of integrating gaming, entertaining and educational elements in VR experiences on user engagement and learning outcomes?*

Blending games, learning material, and fun elements together, it really increases how interested everyone is and how much they actually learn. For example in “Prometheus Unbound”, players seem to like the story and end up learning a lot about an important venue like Methoni Castle, simply by using the game. Since people in the game have to be active and learn by doing, the experience seems to be fun and not a strictly educational one.Similarly, “Turtle Heroes” is focused on saving the sea turtles but in a way that is truly enjoyable and can make a pretty serious topic stick in players’ mind, without sounding like a school lesson. The part where everyone gets to work together also helps players become proficient with the content since they are sharing the learning experience with others. Finally, games like “Sacred Places” take a different approach by providing a subtle story and giving rich information in a non intrusive manner.

***RQ4**: How can bystander intervention and spectator roles be effectively incorporated into VR (gaming) experiences for public engagement?*

Getting bystanders involved in a VR game in public spaces is a major challenge. A great example here is games such as “Turtle Heroes”, where people participate in the game even if they are not directly involved. Then in games such as “Prometheus Unbound”, bystanders can observe the player’s progress and participate by providing suggestions to solve the riddles. s. And finally, in games like “Sacred Places”, even if bystanders do control the videos, they can join in talking about how marvelous or important the places they see are. This way, everyone gets to share their thoughts, making it more about having a shared cultural experience than being alone.

6.2 Limitations and Future Evaluation

Some of the design decisions discussed in this paper build upon earlier empirical work (Theodoropoulos et al., 2023), where user testing provided quantitative and qualitative insights into embodiment, presence, and player engagement within motion-tracked VR environments. However, for the new use cases presented here,

including Turtle Heroes and Sacred Places, evaluation was primarily based on formative, in-situ observations during public demos, as well as informal feedback from participants and facilitators. While this has informed the framework synthesis and design reflections, it does not yet constitute structured empirical validation.

Moreover, several limitations should also be acknowledged. First, although gesture-based input via the ZED 2 stereo camera enabled full-body interaction and "body-as-joystick" functionality, tracking accuracy occasionally suffered due to occlusion, user height variability, or lighting conditions. This sometimes impacted the smoothness of interaction, especially in multi-user scenarios. Second, while the MobiCave offers room-scale immersion, the physical constraints of the space restrict navigation-based mechanics and require tailored scene design to avoid disorientation or fatigue. Third, despite efforts to ensure intuitive onboarding and accessible gameplay, delivering inclusive interaction for broad public audiences, including younger, older, or VR-inexperienced visitors, remains a key challenge. Clearer guidance, multimodal interaction options, and adaptive difficulty are ongoing areas of improvement.

Future work will include targeted empirical studies (e.g., interviews, surveys, behavioral tracking) to investigate learning outcomes, narrative engagement, and emotional resonance across different demographics and settings. We also plan to explore the integration of ambient floor projections that visually extend the virtual world into the physical play area, and to pilot olfactory stimuli in selected scenes — aiming to heighten affective immersion and spatial memory. These enhancements, combined with more rigorous evaluation protocols, will support a deeper understanding of how VR installations in cultural venues can foster meaningful and multisensory engagement with heritage content.

7. Conclusion

This study explores the potential of VR to enhance public engagement with cultural heritage through immersive gaming experiences. Using the MobiCave, a custom-built VR CAVE, we investigate how interactive and social VR games can enhance cultural experiences. By analyzing game mechanics, collaborative play, and spectator involvement, we aim to identify strategies for creating more inclusive and participatory forms of cultural exploration. After looking at three different VR games, we conclude that VR games can be highly interactive, accessible, and impactful regarding cultural experiences both involving individuals and groups of active or less active players. To create a cohesive design framework, we integrated the MDA and FIVE principles and ensured that game mechanics align with the MobiCave's physical constraints, and immersive elements. Player interactions should encourage collaboration and exploration, while the design must resonate emotionally through compelling narratives and striking visuals. Future studies could explore the long-term impact of VR games in this setup on knowledge retention and engagement with heritage sites. Expanding VR interactions, integrating advanced AI-driven narratives, and incorporating mixed and augmented reality could further enhance the blending of physical and virtual worlds. Finally, we aim to use projecting dynamic content onto the floor of the MobiCave to complement the unfolding story, along with experimenting with olfactory stimuli in specific scenarios, to create more multi-sensory gaming experiences.

ACKNOWLEDGMENTS

This research has been funded within the framework of the operational program "Peloponnese 2014–2020" (project code: 80578). We would like also to extend our gratitude to Elina Roinioti, Marios Ilias Ntetzonai and Yannis Aggelakos for their exceptional work in designing and developing the games featured in MobiCave.

References

- Shafer, D.M.; Carbonara, C.P.; Korpi, M.F. Factors affecting enjoyment of virtual reality games: A comparison involving consumer-grade virtual reality technology. *Games Health J.* **2019**, *8*, 15–23.
- Li, W.; Huang, X. The Interactive Design and User Experience of Virtual Museums: Case Study of the Virtual Palace Museum. In Proceedings of the International Conference on Human-Computer Interaction, Aragón, Spain, 7–9 September 2022; pp. 400–409.
- Vocaturo, E.; Zumpano, E.; Caroprese, L.; Pagliuso, S.M.; Lappano, D. Educational Games for Cultural Heritage. In Proceedings of the VIPERC@ IRCDL 2019, Pisa, Italy, 31 January–1 February 2019; pp. 95–106.
- Liarokapis, F.; Vidová, I.; Rizvić, S.; Demesticha, S.; Skarlatos, D. Underwater Search and Discovery: From Serious Games to Virtual Reality. In Proceedings of the International Conference on Human-Computer Interaction, Copenhagen, Denmark, 19–24 July 2020; Springer: Cham, Switzerland, 2020; pp. 178–197.
- Smith, M.; Walford, N.S.; Jimenez-Bescos, C. Using 3D modelling and game engine technologies for interactive exploration of cultural heritage: An evaluation of four game engines in relation to roman archaeological heritage. *Digit. Appl. Archaeol. Cult. Herit.* **2019**, *14*, e00113.
- Franczuk, J.; Boguszewska, K.; Parinello, S.; Dell'Amico, A.; Galasso, F.; Gleń, P. Direct use of point clouds in real-time interaction with the cultural heritage in pandemic and post-pandemic tourism on the case of Kłodzko Fortress. *Digit. Appl. Archaeol. Cult. Herit.* **2022**, *24*, e00217.
- Razuvalova, E.; Nizamutdinov, A. Virtual reconstruction of cultural and historical monuments of the Middle Volga. *Procedia Comput. Sci.* **2015**, *75*, 129–136.
- Sherman, W.R.; Craig, A.B. *Understanding Virtual Reality: Interface, Application, and design*; Morgan Kaufmann: Burlington, MS, USA, 2018
- Antoniou, A., Lepouras, G., Bampatzia, S., & Almpanoudi, H. (2013). An approach for serious game development for cultural heritage: Case study for an archaeological site and museum. Journal on Computing and Cultural Heritage (JOCCH), 6(4), 1-19.
- Han, L., & Cui, Y. (2021). The application of virtual reality technology in museum exhibition——Take the Han Dynasty Haihunhou Ruins Museum in Nanchang as an example. In *E3S Web of Conferences* (Vol. 236, p. 04045). EDP Sciences.
- Koutsabasis, P. (2020). Empirical evaluations of interactive systems in cultural heritage: A review. *Cognitive Analytics: Concepts, Methodologies, Tools, and Applications*, 1331-1355..
- Shih, Y. C. (2015). A virtual walk through London: Culture learning through a cultural immersion experience. *Computer Assisted Language Learning*, *28*(5), 407-428.
- Shehade, M., & Stylianou-Lambert, T. (2020). Virtual reality in museums: Exploring the experiences of museum professionals. *Applied sciences*, *10*(11), 4031.
- MIKOVEC, Z., SLAVIK, P., AND ZARA, J. 2009. Cultural heritage, user interfaces and serious games at CTU Prague. In Proceedings of the 2009 15th International Conference on Virtual Systems and Multimedia (VSMM'09). 211–216.
- APOSTELLIS, P. AND DARADOUMIS, T. 2010. Audience interactivity as leverage for effective learning in gaming environments for dome theaters. In Proceedings of the 5th European Conference on Technology Enhanced Learning Conference on Sustaining TEL: From Innovation to Learning and Practice (EC-TEL'10). 451–456.

- DE AMICIS, R., GIRARDI, G., ANDREOLLI, M., AND CONTI, G. 2009. Game based technology to enhance the learning of history and cultural heritage. In Proceedings of the International Conference on Advances in Computer Enterntainment Technology (ACE'09). 451.
- DE PAOLIS, L. T., ALOISIO, G., CELENTANO, M. G., OLIVA, L., AND VECCHIO, P. 2010. A game-based 3D simulation of Otranto in the Middle Ages. In Proceedings of the 2010 3rd International Conference on Advances in Computer-Human Interactions (ACHI'10). 130–133.
- DE PAOLIS, L. T., CELENTANO, M. G., OLIVA, L., VECCHIO, P., AND ALOISIO, G. 2011. MediaEvo project: The life in a medieval town. In Proceedings of the 10th WSEAS International Conference on Communications, Electrical & Computer Engineering, and 9th WSEA International Conference on Applied Electromagnetics, Wireless and Optical Communications (ACELAE'11). 22–27.
- Andreoli, R., Corolla, A., Faggiano, A., Malandrino, D., Pirozzi, D., Ranaldi, M., ... & Scarano, V. (2017). A framework to design, develop, and evaluate immersive and collaborative serious games in cultural heritage. Journal on Computing and Cultural Heritage (JOCCH), 11(1), 1-22.
- ANTONIOU, A., DIAKAKIS, D., LEPOURAS, G., AND VASSILAKIS, C. 2011. Towards a methodological framework for the cognitive behavioural evaluation of educational e-games. Int. J. Learn. Technol. 6, 3, 263–287.
- PANIAGUA MART´IN, F., PALACIOS, R. C., AND GARC´IA-CRESPO, A. 2009. MAS: Learning support software platform for people with disabilities. In Proceedings of the 1st ACM SIGMM International Workshop on Media Studies and Implementations That Help Improving Access to Disabled Users. 47–52.
- PAPASTERGIOU, M. 2009. Exploring the potential of computer and video games for health and physical education: A literature review. Comput. Edu. 53, 3, 603–622.
- FRANCO, J. F. AND DE DEUS LOPES, R. 2009. Three-dimensional digital environments and computer graphics influencing K-12 individuals' digital literacy development and interdisciplinary lifelong learning. In Proceedings of the ACM SIGGRAPH ASIA 2009 Educators Program (8 pages).
- DE AGUILERA, M. AND MENDIZ, A. 2003. Video games and education: Education in the face of a "parallel school." Computers in Entertainment, 1, 1, 1–10.
- Bellotti, F., Berta, R., De Gloria, A., D'ursi, A., & Fiore, V. (2013). A serious game model for cultural heritage. Journal on Computing and Cultural Heritage (JOCCH), 5(4), 1-27.
- Huizinga, J. (1949). Homo Ludens: A Study of the Play-Element of Culture. London: Routledge & Kegan Paul.
- Roussou, M. (2004). Learning by doing and learning through play: an exploration of interactivity in virtual environments for children. Computers in Entertainment (CIE), 2(1), 10-10.
- Lazzaro, N. (2009). Why we play: affect and the fun of games. Human-computer interaction: Designing for diverse users and domains, 155, 679-700.
- Glasberg, D. S., Nangle, B., Maatita, F., & Schauer, T. (1998). Games children play: An exercise illustrating agents of socialization. Teaching Sociology, 26(2), 130-139.
- Anderson, E. F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., & De Freitas, S. (2010). Developing serious games for cultural heritage: a state-of-the-art review. Virtual reality, 14, 255-275.
- Mortara, M., Catalano, C. E., Bellotti, F., Fiucci, G., Houry-Panchetti, M., & Petridis, P. (2014). Learning cultural heritage by serious games. Journal of Cultural Heritage, 15(3), 318-325.
- Malegiannaki, I., & Daradoumis, T. (2017). Analyzing the educational design, use and effect of spatial games for cultural heritage: A literature review. Computers & education, 108, 1-10.
- Vayanou, M., Katifori, A., Chrysanthi, A., & Antoniou, A. (2020, September). Cultural Heritage and Social Experiences in the Times of COVID 19. In *AVI²CH@ AVI*.

- Bonini, E. (2008). Building virtual cultural heritage environments: the embodied mind at the core of the learning processes. *International journal of digital culture and electronic tourism*, *1*(2-3), 113-125.
- Kenderdine, S. (2015). Embodiment, entanglement, and immersion in digital cultural heritage. *A new companion to digital humanities*, 22-41.
- Do, T. D., Benjamin, J., Protko, C. I., & McMahan, R. P. (2024). Cultural Reflections in Virtual Reality: The Effects of User Ethnicity in Avatar Matching Experiences on Sense of Embodiment. *IEEE transactions on visualization and computer graphics*.
- Drossis, G., Birliraki, C., & Stephanidis, C. (2018). Interaction with immersive cultural heritage environments using virtual reality technologies. In *HCI International 2018–Posters' Extended Abstracts: 20th International Conference, HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part III 20* (pp. 177-183). Springer International Publishing.
- Freeman, G., & Maloney, D. (2021). Body, avatar, and me: The presentation and perception of self in social virtual reality. *Proceedings of the ACM on human-computer interaction*, *4*(CSCW3), 1-27.
- Liu, Z., Yan, S., Lu, Y., & Zhao, Y. (2022, April). Generating Embodied Storytelling and Interactive Experience of China Intangible Cultural Heritage "Hua'er" in Virtual Reality. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts* (pp. 1-7).
- Theodoropoulos, A., & Antoniou, A. (2022). VR games in cultural heritage: A systematic review of the emerging fields of virtual reality and culture games. *Applied Sciences*, *12*(17), 8476.
- Theodoropoulos, A., Stavropoulou, D., Papadopoulos, P., Platis, N., & Lepouras, G. (2023, May). Developing an interactive VR CAVE for immersive shared gaming experiences. In *Virtual Worlds* (Vol. 2, No. 2, pp. 162-181). MDPI.
- Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *6*(6), 603-616.
- Theodoropoulos, A., Roinioti, E., Dejonai, M., Aggelakos, Y., & Lepouras, G. (2022, November). Turtle heroes: designing a serious game for a VR interactive tunnel. In *International Conference on Games and Learning Alliance* (pp. 3-10). Cham: Springer International Publishing.
- Hunicke, R., LeBlanc, M., & Zubek, R. (2004, July). MDA: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI* (Vol. 4, No. 1, p. 1722).
- Freyermuth, G. S. (2022). *Vegas, Disney, and the Metaverse*. Studies of Digital Media Culture, 14, 17.
- Ronchi, A. M. (2023). The evolution of immersive technologies over time. *Designing Immersion in Art and Culture*, 69.
- Cheng, M. S. M. (2022). *The role of immersive media in engaging Singapore's history & cultural heritage*. Nanyang Technological University.
- Zhao, X. (2023). *A virtual reality application: Creating an alternative immersive experience for Dunhuang Mogao Cave visitors*. Duke University.
- Campesan, C. (2024). *Virtual Reality in Venice at the Biennale and Film Festival*. Università Ca' Foscari Venezia.
- Tcha-Tokey, K., Christmann, O., Loup-Escande, E., Loup, G., & Richir, S. (2018). Towards a model of user experience in immersive virtual environments. *Advances in Human-Computer Interaction*, *2018*(1), 7827286.
- de Vasconcelos, G. N., Malard, M. L., Van Stralen, M. D. S., Campomori, M. J. L., de Abreu, S. C., Lobosco, T., ... & Lima, L. D. C. (2019). Do we still need CAVEs?. In *Architecture in the age of the 4th industrial revolution-proceedings of the 37th*

international conference on education and research in computer aided architectural design in europe. Universidade Federal de Minas Gerais.

- Combe, T. et al. (2023). *Perception in VR: Comparing CAVE and HMD Setups in Spatial Tasks*. ACM Transactions on Applied Perception.