# Integrating High-Fidelity 3D Documentation into Immersive Learning: A VR Serious Game for the Holy Aedicule

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**Abstract**

This paper details the development and initial evaluation of the EDICULA Digital Game, a virtual reality tool created to share inter-disciplinary knowledge from the rehabilitation of the Holy Aedicule in Jerusalem's Church of the Holy Sepulchre. The application uses comprehensive geometric data collected before, during, and after restoration, including high-resolution point clouds, textured 3D models, and orthophotos, to create an interactive virtual environment for cultural heritage education through edutainment. The paper describes the process of converting survey-grade 3D heritage data into a real-time immersive experience, focusing on game architecture, educational scenario design, implementation in Unity3D, and optimisation for balancing detail with performance. The application features modules such as virtual tours, a digital classroom, and quizzes. Preliminary feedback from EDICULA partners shows high user engagement, educational value, and positive responses to the immersive experience, though technical challenges remain in scene loading, hardware needs, and interface refinement. The study highlights the potential of serious games for cultural heritage dissemination and emphasises ongoing optimisation and user-focused evaluation.

## 1. Introduction

The rapid development of immersive technologies has opened new possibilities for the documentation, interpretation, and dissemination of cultural heritage. Among these technologies, Virtual Reality (VR) has attracted particular attention as a medium capable of combining spatial realism, user interaction, and narrative structure to create engaging and meaningful digital experiences. In the field of cultural heritage, VR is increasingly employed not only for visualisation and virtual access, but also for educational purposes, public engagement, and the communication of complex historical and conservation-related knowledge. At the same time, the widespread availability of high-resolution 3D survey data has enabled the creation of immersive applications based on geometrically accurate heritage documentation rather than hypothetical or simplified reconstructions. Previous work has already demonstrated the importance of rigorous recording and information management for heritage places, while more recent studies emphasise the educational value of serious games, gamification, and immersive virtual exhibitions in cultural heritage contexts (Letellier, 2007). A major challenge in this context is the transformation of survey-grade heritage data into real-time interactive environments without compromising either geometric fidelity or user accessibility (Zhong et al., 2021). Point clouds, dense meshes, orthophotos, and other reality-based products are extremely valuable for documentation, conservation, and scientific analysis, but they are often too demanding for direct use in immersive applications (Banfi, 2023). Their adaptation requires a careful balance between metric accuracy, visual realism, rendering performance, and pedagogical clarity. This issue becomes even more critical when the final objective is not merely visualisation, but the communication of interdisciplinary knowledge through an engaging and educational user experience. Recent work in immersive heritage applications and VR/HBIM integration has underlined the need for clearer methodological pipelines connecting documentation outputs with extended-reality environments, while optimisation studies have shown that substantial polygon reduction can be achieved with minimal visual degradation when carefully designed workflows are applied (Liu et al., 2025).

This study develops the EDICULA Digital Game, a VR serious game from the EDICULA Erasmus+ project. It leverages documentation from the Holy Aedicule's rehabilitation in Jerusalem, a sacred Christian site. The rehabilitation project conducted by NTUA (Georgopoulos et al., 2017) produced detailed geometric data, materials analysis, building phase identification, decay diagnosis, and ongoing monitoring. These findings provided the basis and content for the game's virtual environment and educational design (Moropoulou et al., 2017; Georgopoulos et al., 2017). The EDICULA project promotes transdisciplinary cooperation in cultural heritage education by integrating digital tech with conservation knowledge. The EDICULA Digital Game aims to transform documenting and rehabilitating a monument into an immersive educational application. Its goals are to give users a realistic virtual experience of the Holy Aedicule and its rehabilitation, and to communicate scientific, historical, and conservation knowledge through an engaging, interactive approach. This aligns with trends in digital heritage, where serious games and immersive apps are valued for linking research with non-experts, but require careful design to remain meaningful and educational. (Wang et al., 2024; Camuñas-García et al., 2024).

Unlike many heritage VR experiences that focus on virtual access or visual reconstruction, the EDICULA Digital Game is based on the detailed geometric documentation of a monument across multiple rehabilitation phases and is designed as a serious game for cultural heritage learning. It includes mini-games and educational modules, like virtual tours, a digital classroom, and quizzes, enabling users to explore, interact, and test knowledge. The project advances beyond static 3D views by offering a workflow to turn high-res reality-based data into an immersive educational environment. This approach

addresses reviews showing many heritage games lack a strong educational structure, clear learning mechanics, or meaningful links between content and interaction. (DaCosta et al., 2023).

From a technical perspective, the study also addresses a set of practical and methodological issues that are highly relevant to the fields of photogrammetry, 3D modelling, and interactive visualisation (Manfredi et al., 2025). These include the optimisation of detailed 3D models for real-time rendering, the organisation of semantic information within a game architecture, the implementation of user interaction in Unity3D, and the evaluation of usability and educational effectiveness through preliminary user feedback. Therefore, the contribution of this paper lies not only in the presentation of a VR application, but also in the documentation of the workflow, design decisions, and implementation challenges involved in bridging the gap between high-fidelity 3D survey data and immersive heritage dissemination. In this regard, the study aligns with current discussions on accessibility, scalability, and replicability in immersive cultural heritage applications, especially when complex documentation assets must be adapted for smooth real-time performance on conventional hardware (Zhao et al., 2025).

The paper is structured around three main objectives. The first is to present the heritage and educational context of the EDICULA project and the Holy Aedicule rehabilitation as the scientific basis of the application. The second is to describe the methodological and technical workflow followed for the development of the EDICULA Digital Game, including game design, architectural structuring of the virtual environment, Unity3D implementation, and 3D model optimisation. The third is to report and assess the preliminary results of the application’s evaluation, highlighting both its educational potential and the technical limitations identified by the users.

## 2. Background

### 2.1 The Holy Aedicule Rehabilitation and Documentation Basis

The Holy Aedicule, built in 1809 and located within the Church of the Holy Sepulchre in Jerusalem, is one of the most sacred and symbolically charged monuments of the Christian world. As the structure that encloses the Tomb of Christ, it carries exceptional religious, historical, and cultural significance, while also representing a highly complex architectural and conservation case. In 2015, the monument exhibited serious structural, material, and environmental deterioration, raising major concerns about its stability and long-term preservation. In response to these conditions, the National Technical University of Athens (NTUA) undertook the integrated study and rehabilitation of the Holy Aedicule through an interdisciplinary project that combined structural engineering, material science, architecture, archaeology, surveying, and heritage documentation.

The rehabilitation project followed a multi-phase scientific workflow. After the preparation of a comprehensive study and the approval of the three religious communities responsible for the monument, the NTUA interdisciplinary team proceeded with the full diagnostic investigation of the Holy Aedicule. This included the analysis of its geometry, deformation patterns, structural behaviour, building materials, environmental conditions, and historical evolution. Based on these investigations, a detailed diagnosis of the monument’s condition was produced, followed by a rehabilitation proposal that was approved in 2016 by the three main Christian communities and subsequently implemented under continuous scientific monitoring and documentation. The project has been widely recognised as a landmark example of interdisciplinary collaboration for the conservation of a monument of universal significance (Georgopoulos et al., 2017).

A fundamental component of this effort was the integrated documentation of the monument and of the different phases of the rehabilitation process. This documentation included historical, archaeological, architectural, and photographic archives, as well as metric and diagnostic data acquired before, during, and after the restoration works. Among these, the geometric documentation carried out by the Laboratory of Photogrammetry of the School of Rural, Surveying and Geoinformatics Engineering at NTUA played a particularly important role, since it provided the accurate spatial basis for diagnosis, monitoring, intervention planning, and future safeguarding.

The geometric documentation campaign aimed to define the size, form, and spatial configuration of the Holy Aedicule in three-dimensional space with high precision. To achieve this, a combination of image-based techniques and terrestrial laser scanning was employed in order to generate a complete and metrically reliable record of the monument. The documentation was not limited to a single phase of the project, but extended throughout the rehabilitation process, capturing the monument before intervention, during dismantling and restoration, and after completion of the conservation works. This phased documentation produced an exceptionally rich and coherent dataset, which constitutes one of the major scientific outcomes of the overall project.

The resulting metric products included dense point clouds, high-resolution 3D meshes, textured and non-textured models, orthoimages, sections, and stereo-video outputs, all of which served multiple purposes within the rehabilitation project (Fig. 1). On the one hand, these products supported architectural and structural analysis, geometric interpretation, and the assessment of construction details and deformations. On the other hand, they formed a lasting digital archive of the monument, preserving not only its geometry but also the successive states of its conservation and intervention. In this sense, the documentation was directly aligned with established principles in heritage recording and information management, according to which metric documentation constitutes a critical component of conservation planning and long-term safeguarding (Wright J., 2018).

Figure 1. The results of the geometric documentation: point cloud, 3D textured model, orthoimage (left to right).

Beyond their immediate role in the rehabilitation project, these 3D datasets proved highly reusable for subsequent digital applications. Earlier studies had already explored their potential for visualisation and measurement purposes, including the development of tools for extracting dimensions and sections

within virtual environments (Kontos et al., 2020; Papadopoulou et al., 2022). The work presented in this paper builds upon that documented basis but moves in a different direction: instead of using the 3D data only for analytical or visualisation purposes, it repurposes them as the foundation for an immersive serious game aimed at education, interpretation, and dissemination. In this way, the documentation of the Holy Aedicule does not remain confined to professional conservation practice but is extended into an interactive digital environment capable of communicating the monument’s significance and the complexity of its rehabilitation process to broader audiences.

### 2.2 Serious Games and Immersive Heritage Learning

In recent years, serious games and immersive environments have emerged as promising tools for the communication, interpretation, and teaching of cultural heritage. Unlike conventional digital visualisations, serious games are designed not only to entertain but also to serve a primary educational, training, or awareness-raising purpose. In the heritage domain, they offer the possibility of transforming complex scientific, historical, and conservation-related information into interactive experiences that can engage users more actively than traditional text-based or exhibition-based approaches (Kampa et al., 2016). This is particularly important in cases where monuments are physically difficult to access, are characterised by layered historical meanings, or involve rehabilitation processes that are not easily understood by non-specialist audiences.

The educational value of serious games lies in their capacity to support active learning, exploration, and experiential engagement. Through interactive tasks, spatial navigation, and narrative progression, users are encouraged not only to observe but also to construct knowledge by interacting with digital content. Such environments can support cognitive processes such as observation, comprehension, memory retention, and reflection, while also increasing motivation and attention through immersion and play. In this respect, serious games align well with the growing demand for more participatory and learner-centred approaches in higher education and heritage interpretation (Mortara et al., 2014).

Within cultural heritage studies, serious games have been used in a variety of contexts, including archaeological reconstructions, museum interpretation, historical storytelling, architectural exploration, and heritage awareness campaigns. Several studies have shown that game-based environments can improve user engagement and facilitate the communication of intangible or difficult-to-visualise aspects of heritage, especially when they integrate realistic spatial representation with interactive narrative mechanisms (Anderson et al., 2010; DaCosta et al., 2023). At the same time, immersive technologies such as VR have expanded these possibilities by enabling users to experience monuments and spaces at the human scale, navigate through them in real time, and interact with digital objects in a more embodied and intuitive manner.

Despite this growing body of work, several limitations remain evident in many heritage-related immersive applications. Firstly, numerous examples focus primarily on visualisation and virtual access, without establishing explicit learning objectives or educational structures. Secondly, many projects rely on generalised or hypothetical reconstructions rather than on high-fidelity, survey-based 3D data, which may limit their scientific reliability and interpretive transparency. Thirdly, the relationship between the immersive environment and the underlying interdisciplinary knowledge is often weakly articulated, resulting in applications that are visually impressive but pedagogically superficial. Finally, the technical challenge of converting large, high-resolution heritage datasets into real-time interactive environments is not always addressed in sufficient detail, even though it is fundamental for the practical development of such systems.

The EDICULA Digital Game is positioned within this field, but also seeks to respond to these limitations in a more structured way. Its innovation does not lie simply in the use of VR for heritage presentation, but in the integration of scientifically documented 3D data, interdisciplinary conservation knowledge, and serious game design principles into a single immersive educational workflow. The application is not based on a generic virtual reconstruction, but on the complete geometric documentation of a monument captured across the multiple phases of a real rehabilitation project. In addition, the game is not limited to free exploration; it incorporates different forms of educational interaction, including guided virtual tours, a thematic digital classroom, and a quiz-based assessment environment. This combination allows the user to engage with the monument both spatially and cognitively, moving from observation to comprehension and knowledge testing.

A further important aspect concerns the notion of edutainment, which has gained increasing relevance in discussions on digital didactics and informal learning environments depth (Antoniou et al., 2013). In the context of cultural heritage, edutainment refers to the design of experiences that combine educational content with engaging and enjoyable interaction, in order to increase user motivation and accessibility without reducing scientific depth. The EDICULA project adopts this logic by embedding transdisciplinary content within a playful but structured immersive experience. The objective is not to trivialise the monument or its rehabilitation, but to create an environment in which users are motivated to explore, learn, and retain information through interaction with realistic 3D representations and contextualised content.

From a design perspective, developing serious games for cultural heritage involves key parameters like target audience, cognitive skills, interaction level, learning objectives, storytelling, visual and spatial design, and technological access. These are vital in heritage contexts, where users range from experts and students to casual visitors with limited knowledge. The EDICULA Digital Game was designed as a single-player experience using traditional devices like a mouse and keyboard, to enhance accessibility, lower entry barriers, and reach a broader educational audience. The study views serious games not just as digital attractions or visualization tools, but as educational environments grounded in scientific and pedagogical methods.

## 3. Methodological framework

### 3.1 Overall Workflow

The development of the EDICULA Digital Game followed a structured workflow aimed at transforming reality-based documentation of the Holy Aedicule into an immersive and educational virtual environment. The process combined heritage documentation, content structuring, serious game design, technical implementation, and user evaluation within a unified methodological framework (Fig 2). The workflow consisted of five main stages. First, the available 3D survey products and related semantic documentation were identified and organised as the scientific basis of the application. Second, the educational

and interaction framework of the game was defined, including the target users, learning objectives, and the overall structure of the experience. Third, the high-resolution 3D assets were optimised for real-time rendering in order to ensure smooth interaction while preserving the essential geometric and visual characteristics of the monument. Fourth, the virtual environment and its interactive components were implemented in Unity3D as a set of interconnected scenes corresponding to the different mini-game modules. Finally, the application was subjected to a preliminary evaluation in order to assess its usability, educational effectiveness, and technical performance. This workflow was designed to ensure that the final application remained scientifically grounded while also being accessible, interactive, and suitable for educational use. The following subsections describe each of these stages in greater detail.

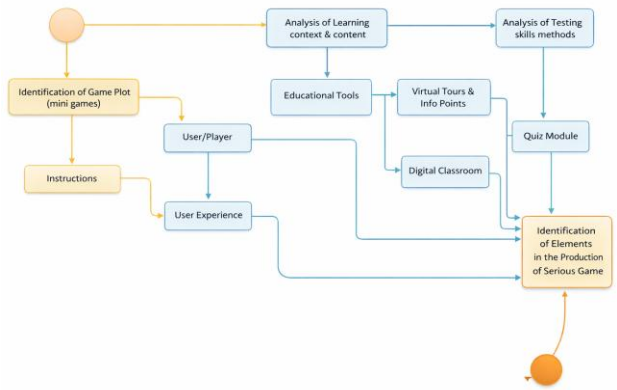


Figure 2. Phase of the analysis for the design of the EDICULA Digital Game.

### 3.2 Input Data and Heritage Content

The EDICULA Digital Game was developed based on the extensive documentation produced during the rehabilitation of the Holy Aedicule in the Church of the Holy Sepulchre in Jerusalem. The input data combined both metric documentation and heritage-related semantic content, allowing the creation of a virtual environment that was not only visually realistic but also educationally meaningful.

The primary input consisted of the high-resolution 3D geometric documentation products generated by the Laboratory of Photogrammetry of the National Technical University of Athens before, during, and after the rehabilitation works. These datasets included dense point clouds, textured and non-textured 3D meshes, orthophotos, and sections derived from the combination of methods including geodetic measurements, image-based modelling and terrestrial laser scanning. The use of multi-phase documentation was particularly important, as it allowed the virtual application to present the Holy Aedicule in different states and to communicate aspects of the rehabilitation process rather than only the final restored form.

In addition to the 3D survey products, a second category of input data included semantic and interpretive content related to the monument and its restoration. This material comprised historical information, descriptions of the rehabilitation procedures, images from the restoration process, and explanatory text concerning the monument’s architectural, cultural, and technical significance. These resources were selected and structured in order to support the educational objectives of the application and to provide users with accessible information during navigation and interaction.

### 3.3 Game Design Logic

The EDICULA Digital Game was structured as a modular single-player serious game composed of three complementary components: virtual tours, a digital classroom, and a quiz module. This structure was selected to support different modes of interaction with the heritage content, ranging from spatial exploration to focused learning and self-assessment.

The virtual tours form the core of the experience and allow the user to navigate through the documented 3D environment of the Holy Aedicule in different phases, including its state before rehabilitation, its condition after the restoration, and the interior environment associated with the Tomb of Christ, closed or opened. Their purpose is to encourage direct observation of the monument and to provide contextual information through interactive points of interest. The digital classroom complements this exploratory mode by presenting additional explanatory material related to the rehabilitation process in a more organised and didactic format. The quiz module acts as a simple knowledge-checking mechanism, reinforcing key information encountered during the previous stages of the experience.

The internal logic of the game was designed to remain intentionally simple. Rather than relying on complex gameplay mechanics, the application emphasises free exploration, interaction with information points, and progressive familiarisation with the monument and its conservation history. This decision was made to keep the focus on the heritage content itself and to ensure that the user’s attention remains on the monument, the rehabilitation methods, and the associated knowledge rather than on game difficulty or task-solving complexity. A further design principle was the clear separation of functions between the game modules (Table 1). Each module was assigned a distinct role within the experience: exploration in the tours, explanation in the classroom, and reinforcement in the quiz. This segmentation helped organise the content and avoid overloading a single environment with too many simultaneous tasks or information layers. Overall, the game design logic was based on the combination of exploration, interpretation, and repetition, allowing the user to approach the Holy Aedicule and its rehabilitation process through successive and complementary levels of engagement.

| | | | **EDICULA GAME** |
|---|---|---|---|
| **Game Characteristics** | Cognitive Skill | Observation | ✓ |
| | | Reflection | |
| | | Action | |
| | Learning objectives | Knowledge | ✓ |
| | | Comprehension | ✓ |
| | | Application | |
| | | Analysis | |
| | | Synthesis | |
| | | Evaluation | |
| | Degree of complexity | Mini | ✓ |
| | | Complex | |
| | Number of players | Single | ✓ |
| | | Multiplayer | |
| | Theme | Strategy | |
| | | Action | |
| | | Adventure | |
| | | Shoot’m up | |
| | | Board | |
| | | Role | |
| | | Knowledge | ✓ |

| | | | |
|---|---|---|---|
| | | Observingness | ✓ |
| | Mode | Interactive game | |
| | Audience | All users | |
| | | Specific target group | ✓ |
| | Game concept | EDICULA Digital Game | |
| | Game description | Consisting of multiple mini-games, including virtual tours with info points, a digital classroom with further information about rehabilitation methods and a quiz game. | |
| | Scope | Education through entertainment in an interactive, contemporary and fun way | |
| | Mechanics | The rules that govern and guide the user’s actions simply concern the movement and interaction during the virtual tours, as well as the interaction in the digital class, while during the quiz game, the user simply has to pick an answer for each question. | |
| | User Interaction | 1st person | |
| | Technology | Online | |
| | | Desktop | ✓ |
| | | Mobile | |
| **Player Characteristics** | The players/users are described above. | | |
| **Organization Characteristics** | Level of museumness | High levels of museumness (Holy Aedicule of Jerusalem) | |
| | Budget | Erasmus+ Programme EU Project / IKY | |
| | Demands on personnel | No demands of in situ personnel | |

Table 1. Summary of EDICULA Game, using the descriptive model.

### 3.4 Technical Implementation in Unity3D

The EDICULA Digital Game was implemented in Unity3D (version 2017.2.0f3), selected after comparison with other game engines due to its flexibility in scene management, support for interactive 3D environments, and suitability for integrating complex heritage assets into a desktop application.

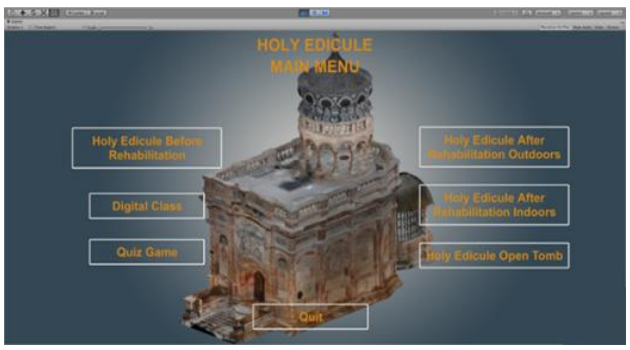


Figure 3. EDICULA Digital Game: Main Menu Interface.

The application was developed as a single executable composed of multiple scenes, each corresponding to a distinct module of the game. A main menu scene was created as the entry point, allowing the user to select between the available virtual tours, the digital classroom, and the quiz module (Fig. 3). Each menu option was linked to its corresponding scene through dedicated scripts controlling scene loading and transitions. To improve user feedback during scene changes, an intermediate loading screen was introduced. The virtual tour scenes contained the optimised 3D models of the Holy Aedicule and, where required, of the surrounding Rotunda (Fig. 4). These objects were imported into Unity as textured meshes and configured with colliders to prevent the user from crossing solid geometry during navigation. The environment was further enriched with static and dynamic lighting in order to enhance depth perception and visual realism. User movement was implemented through a first-person controller, while a camera object defined the user’s viewpoint within the scene. An avatar downloaded from Sketchfab was used for player visualisation during development and testing. Interaction within the tour scenes was based on 3D information points placed at selected locations. Each information point was linked to a script that triggered the display of a panel with explanatory text when the user chose to do so. The same panel structure was reused across the different scenes, ensuring consistency in the presentation of information. A dedicated escape function allowed the user to close the panel or return to the main menu at any moment.

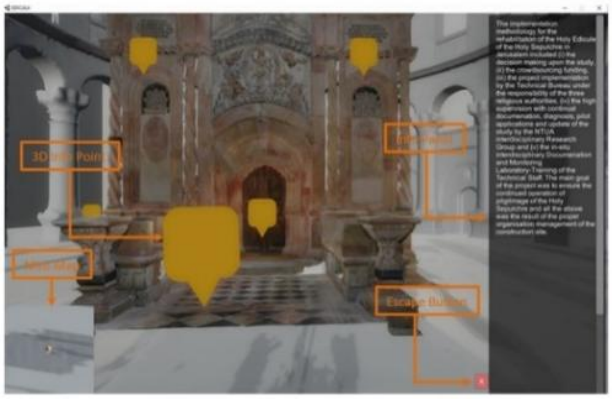

Figure 4. EDICULA Digital Game: Main Menu Interface.

The digital classroom was implemented as a separate 3D scene with a simpler spatial configuration. It included 2D and 3D educational objects, such as panels, desks, and boards, as well as additional information points connected to explanatory content (Fig. 5). The interaction logic from virtual tours was maintained, letting users access text by interacting with scene objects. The digital classroom supports focused learning by providing a clearer interpretive layer beyond the monument. It serves as a space between exploration and assessment, allowing users to revisit and better understand conservation content introduced indirectly during tours. In this sense, the module contributes to the application's pedagogical coherence by providing a more focused, explanatory form of interaction.

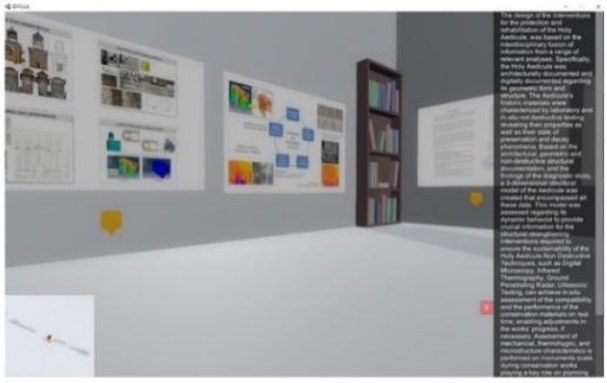

Figure 5. EDICULA Digital Game: Main Menu Interface.

The quiz module was implemented using a 2D user interface rather than a full 3D environment. Each question was managed as a separate state controlled through Unity’s scene

management and custom scripts. The user was asked to respond through simple True/False buttons, while visual transitions and answer feedback were handled through the Unity Animator. Question order was randomised in order to reduce predictability and encourage attention to the displayed content (Fig. 6). The quiz module was designed as a simple assessment component intended to reinforce the knowledge acquired in the previous modules. The design of the quiz intentionally remains uncomplicated, so that the focus stays on content recall rather than on gameplay complexity. Immediate feedback is provided after each response, helping the user identify correct and incorrect answers while maintaining the interactive rhythm of the application. In combination with the tours and the classroom, the quiz completes the overall learning cycle by introducing an element of repetition and self-assessment.

At the project level, the Unity environment was organised through a structured set of asset folders containing materials, textures, scripts, audio files, UI components, and imported 3D models. This facilitated content management and the separation of front-end and back-end components during development. Overall, the implementation in Unity3D provided the necessary framework for integrating the optimised heritage models, interactive logic, educational content, and user interface elements into a coherent immersive application.

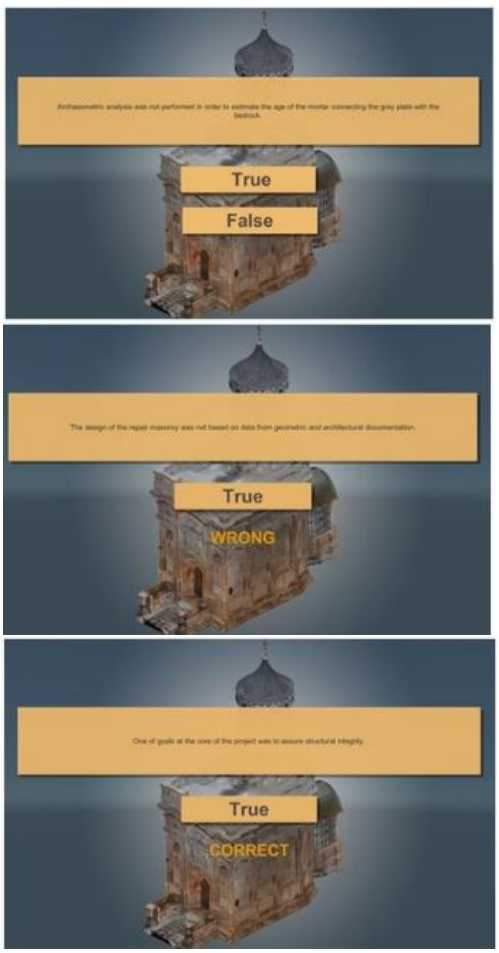

Figure 6. EDICULA Quiz Game: The true and false answers.

### 3.5 Optimisation of High-Fidelity Models for Real-time Rendering

One of the main technical challenges in the development of the EDICULA Digital Game was the integration of high-resolution survey-based 3D models into a real-time interactive environment. The original models of the Holy Aedicule were produced for documentation and analysis purposes and therefore contained a level of geometric and textural detail that was unsuitable for direct use in a game engine. If imported without processing, these datasets would have resulted in excessive memory consumption, long loading times, and reduced rendering performance, negatively affecting the usability of the application.

To address this issue, an optimisation workflow was applied to reduce the geometric complexity of the models while preserving their essential visual and architectural characteristics (Arige et al., 2021). The main strategy adopted was mesh decimation, with particular emphasis on edge-collapse simplification methods. Through this process, the number of vertices and triangles was progressively reduced by collapsing less-significant edges and merging adjacent polygons, while attempting to maintain the monument's overall form and perceptual quality. The simplification process was guided by the relative importance of geometric features, so that areas with a stronger contribution to the silhouette, curvature, or recognisable architectural detail were preserved with a higher level of fidelity. The purpose of this optimisation was not simply to reduce file size, but to achieve a workable balance between scientific credibility and interactive performance. Since the application was intended for educational use on standard desktop hardware, the models had to remain sufficiently detailed to support realistic immersion, while being lightweight enough for stable rendering and navigation. This was particularly important in a virtual environment where the user explores the monument at close range and where visual artefacts caused by over-simplification would immediately affect the perception of realism.

In addition to mesh reduction, the optimisation process involved managing textures and scene complexity. Textured models were preserved where visual realism was essential to the user experience, while the overall scene structure was kept as simple as possible to avoid unnecessary computational load. These decisions were closely related to the architectural and educational role of the environment: the objective was to retain the monument’s recognisable character and material appearance without overloading the system with excessive geometric detail irrelevant to the intended interaction. The importance of this stage became evident during testing, where some of the technical limitations reported by users, particularly scene loading speed and hardware performance, were directly linked to the computational demands of the high-resolution assets. The optimisation of the Holy Aedicule models was therefore a crucial step in making the EDICULA Digital Game functional as a real-time application. More broadly, it highlighted the general challenge of adapting documentation-grade cultural heritage datasets to interactive immersive environments, where performance constraints require selective simplification without undermining the authenticity of the virtual representation.

This optimisation stage can thus be understood as a key methodological bridge between heritage documentation and serious game implementation, ensuring that the scientific value of the original 3D survey could be translated into an accessible and responsive immersive experience.

## 4. Evaluation

The preliminary evaluation of the EDICULA Digital Game was carried out through questionnaires distributed among the

EDICULA project partners and associated users. The purpose of this evaluation was to collect feedback on the functionality, educational effectiveness, and overall user experience of the application, as well as to identify technical limitations and possible areas for improvement. A total of twenty participants with different backgrounds, including students, researchers, professors, engineers, and technicians, took part in the evaluation (Fig. 7).

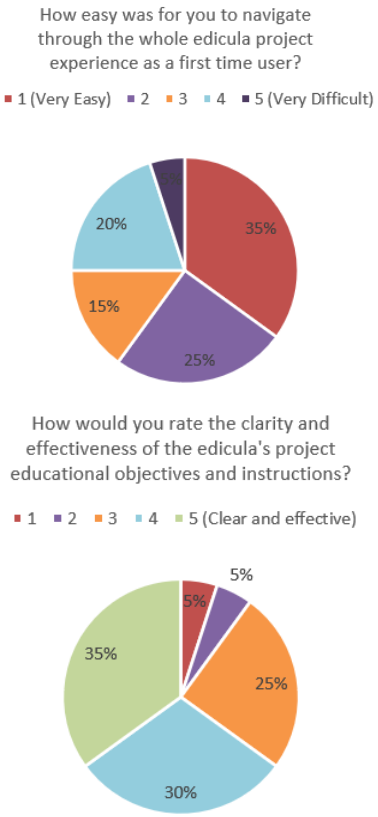


Figure 7. Survey results provide useful insight into the effectiveness of the project.

The overall reception of the EDICULA Digital Game was largely positive. The majority of participants, approximately 85%, rated their overall experience as very good or excellent. Most users found the project engaging from an educational perspective, while the interactive virtual environment and the realistic 3D models were repeatedly identified as the most appealing aspects of the experience. A similarly positive trend was recorded regarding willingness to reuse or recommend the application: 80% of the participants stated that they would probably or very likely use the game again, while 95% indicated that they would recommend it to others. The responses also suggest that the structure and content of the application were generally clear. Most participants reported that they were able to find the information they were looking for with relative ease, and a significant proportion indicated that the available instructions were sufficient and did not require substantial additional explanation. The user-friendly character of the application was also reflected in the navigation feedback, as 60% of users considered the first-time navigation of the environment easy or very easy. Furthermore, 65% rated the educational objectives and instructions of the game as clear and effective.

At the same time, the evaluation revealed several technical limitations. A notable proportion of participants reported occasional or frequent technical difficulties, mainly associated with scene loading times and the computational demands of the application. This was likely related to the complexity of the high-resolution 3D content and the hardware requirements needed to support real-time rendering in higher visual quality. Users also pointed out that the transitions between scenes could be improved and that the appearance of certain user interface elements, especially in the quiz module, could be refined.

Overall, the evaluation confirms that the EDICULA Digital Game is effective in attracting user interest and in communicating heritage content in an immersive and engaging way. At the same time, it underlines the need for continued optimisation and iterative refinement, particularly in relation to performance and interface design. These findings are important not only for the improvement of the current application but also for the design of future serious games based on high-fidelity cultural heritage documentation.

## 5. Discussion and Conclusion

The development of the EDICULA Digital Game demonstrates the potential of serious games and immersive environments as tools for the dissemination of complex cultural heritage knowledge. By combining accurate 3D documentation, educational content, and interactive design, the application extends the value of the Holy Aedicule rehabilitation project beyond professional conservation practice and into the domain of public engagement and digital learning.

The study shows high-resolution metric documentation can be repurposed into an immersive application supporting interpretation and education. The game uses scientifically documented representations of the monument at different rehabilitation phases, providing authenticity and documentary grounding that enhance its educational role and set it apart from generic heritage visualisations. However, integrating detailed heritage data into real-time environments needs optimisation and creates technical compromises affecting performance and usability. User feedback confirms appreciation for realism and interactivity but highlights computational demands as a significant issue. Successful VR heritage games depend on both quality documentation and careful adaptation to system constraints. Educationally, modular design supports various engagement levels through tours, explanatory spaces, and quizzes, allowing users to shift from free observation to structured learning, confirming the value of combining exploratory and didactic elements.

In conclusion, the EDICULA Digital Game represents a first but significant step toward the transformation of scientific heritage documentation into interactive educational experiences. The study shows that serious games can serve as meaningful tools for cultural heritage interpretation, especially when they are grounded in accurate documentation and supported by thoughtful educational design. Future work should focus on improving technical performance, extending the testing to broader user groups, and exploring additional forms of accessibility and dissemination. More broadly, the project suggests that immersive serious games can play an important role in bridging the gap between heritage science, education, and public communication.

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