Embracing Cultural Heritage Through Virtual Reality: Development, Usability and Enjoyment Evaluation of a VR Environment for the Church of Panagia Aggeloktisti

Louis Nisiotis[1](✉), Markos Souropetsis[2], and Eleni A. Kyza[2]

[1] School of Sciences, University of Central Lancashire, Pyla, Cyprus
LNisiotis@uclan.ac.uk

[2] Department of Communication and Internet Studies, Cyprus University of Technology, Limassol, Cyprus
{Markos.Souropetsis,Eleni.Kyza}@cut.ac.cy

Abstract. The importance of preservation, accessibility and dissemination of Cultural Heritage is universally acknowledged, and the latest technological advancements in visualisation technologies such as Virtual Reality, and Serious VR Games in particular, have been increasingly utilised for innovation and application to support these efforts with great success. This paper presents the development and evaluation of a VR environment focusing on disseminating information on the Byzantine art of Panagia Aggeloktisti church in Cyprus, through an immersive learning scenario requiring users to complete challenges to progress while learning important historical information about the church. The paper presents information on the VR environment development, providing details on the process of capturing, processing and digitising in 3D models the exterior and several artefacts of the church. Two versions of the environment have been developed, featuring Gamified and non-Gamified components. The study presented in this paper compares and evaluates these versions through analysing users perceptions towards usability/playability, enjoyment and visual aesthetics of the environment. A comparative experimental study was conducted and the results revealed that the users' experience was positively perceived regardless of interacting with the gamified elements of the environment or not during their VR experience. The results suggest that the VR environment was perceived usable/playable, enjoyable and with appealing graphics, and is at a stage to be used for public access and further experimentation. The paper also highlights the need for developing and extensively evaluating the efficacy of VR environments to provide immersive, engaging and enjoyable gamified and gaming experiences to embrace cultural heritage.

Keywords: Virtual Reality · Serious Games · Game Based Learning · Digital Cultural Heritage · Computer Graphics

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1 Introduction

Cultural heritage and our ancestral connections influence and define our lives, our identities and social behaviours. Preserving our cultural ties and ensuring accessibility, availability, and dissemination of history and cultural beliefs is of out-most importance to protect our legacy and progress. Recent technological advancements in hardware, software, and networking capabilities have fostered the digital transformation of the cultural heritage domain, providing opportunities to protect and disseminate open access heritage with significant societal, technological and industrial impact. Extended Reality (XR - the umbrella term encapsulating Augmented, Virtual and Mixed Reality technologies) is one of the emerging technologies that recently attracted considerable research and industrial attention in innovation and application in the field of cultural heritage. Virtual Reality (VR) in particular has been extensively used in cultural heritage, leveraging its capabilities to support high fidelity graphics, visualisations, simulations, and opportunities for developing interactive story telling, fostering the development of interactive experiences that increase presence and immersion to visitors [35]. VR enable the creation of realistic representations of historical locations, buildings, artefacts, events, and phenomena within immersive digital spaces, and a particular type of VR experiences which has been successfully used in cultural heritage is through serious game applications, and recently through VR gaming [28].

This paper presents the development details and evaluation of a VR environment focusing on educating users about the UNESCO protected byzantine art of Panagia Aggeloktisti church in Cyprus, through an immersive gamified learning scenario requiring users to complete a series of learning tasks within a VR world. The paper presents details on the environment design, including the process of capturing, processing and digitising 3D models of the exterior and several artefacts of the church, and the development of gamified components and tasks. The paper also presents the results of an initial evaluation of the environment, focusing on the users' perceptions towards usability/playability, enjoyment, and the visual aesthetics of a Gamified and a non-Gamified version of the VR environment. The aim of this study was to ensure that the current development stage of the environment is usable, enjoyable and visually pleasing regardless of the gamified elements, so to proceed with further empirical evaluations to assess its educational efficacy and relevant technical topics in the future, and for public use.

2 Background and Context

2.1 Digital Cultural Heritage

Cultural heritage and our historical past are closely connected with our lives, beliefs, values, identities and behaviours. Museums, heritage organisations, research institutions and other cultural heritage stakeholders make significant efforts in preserving, safeguarding and disseminating heritage. The use of digital technologies offer tools to support digitisation for storage, reconstruction and representation of tangible and intangible cultural heritage [22]. A fusion of several multi-modal interactive technologies (augmented and virtual reality, mobile phones, tablet devices, sensors and robots among others) are converged with the latest advancements in artificial intelligence, cyber-physical systems, complex computing, computer graphics, and sophisticated software to support the needs of cultural heritage and to enhance the visitors experience through the concept of Digital Cultural Heritage (DCH) [12,15,17,22]. DCH focuses on the digital transformation of historical artefacts, including locations, buildings, traditions, practices, phenomena, cultures and social experiences among a plethora of other tangible and intangible characteristics and attributes of significant historical and cultural importance, supporting transferability, accessibility, and preservability of heritage [7,12,23,24]. To achieve this, the research and application areas in DCH require advanced data capture and processing mechanisms, high fidelity visualization tools and rendering techniques, specialised hardware and advanced technologies. Such sophisticated requirements are now feasible to be developed and applied at scale in DCH, as a result of exponential technological improvements and significant decrease in complexity, costs of ownership and operation of digital technologies. The use of XR is one of the technologies that has been extensively utilised in DCH over the past decade, and its applicability and effectiveness have been studied and established as a successful technological method of providing attractive, engaging and immersive experiences to the users/visitors [2,6,14,17,18,25]. XR offer opportunities to create virtual versions of heritage, enabling users to access and experience famous heritage sites that can be geographically dispersed, inaccessible, or may no longer exist [17,25]. Applications such as Virtual Museums are increasingly developed, enabling navigation in high fidelity immersive spaces, observing and interacting with exhibits, and even communicating with other visitors, formulating new types of immersive, interactive and personalized experiences to the visitors and enhancing the appreciation and understanding of cultural heritage [15,16]. This is developing the concept of 'cultural presence', referring to the feeling of being in the presence of a cultural belief system that visitors develop when visiting a museum or cultural heritage site [4,23]. Further to digital capturing, 3D reconstruction and visualisation capabilities, XR also contributes to the development of interactive story-telling experiences [35] that can enhance the users' feeling of presence and involvement in the immersive experience [21,32]. Cultural heritage institutions, museums and other relevant stakeholders have been early adopters of XR technology to support and enhance the experience of their visitors with great success over the years [1]. Experimentation with VR technology in particular, has led to the emergence of immersive and engaging interactive applications [5] and projects, such as open access heritage though virtual museums and virtual exhibitions, projects focusing on storytelling, visualisation, the promotion and education of cultural heritage, and recently through applications for entertainment purposes.

2.2 Serious Games in Digital Cultural Heritage

The use of Serious Games with the intentions to complete learning objectives and support education, offer opportunities for innovative and engaging game-based learning approaches [27] and have been the focus of extensive research for innovation and application in DCH. Serious games are digital games designed for non-entertainment purposes (i.e., education, training, management, engineering etc.) [34], where the users develop their skills and knowledge by completing tasks and obtaining rewards [8]. Serious games span across a range of genres including puzzles, mini-games, simulations of events, virtual tours, action, adventure and role playing games among others, in single or multiplayer modes [13]. When games are utilised as learning tools, they can increase motivation, support the process of knowledge acquisition and improve learning outcomes, and gamified learning approaches are found to also improve students' attitude, engagement, and performance [27,33]. There is wide range of successful applications in the form of gamification and game-based learning (see comprehensive review in [27]). Translating traditional learning activities into gamified scenarios is a common practice that has been found to increase students motivation and contributing to their cognitive development [26]. Some of the most commonly used elements in gamified applications are reward-based achievements such as points, badges, and leaderboards. The most commonly used elements in game-based learning applications are graphics, points, and levels [27]. In the context of DCH, game-based learning and gamified educational approaches have been drawing significant research attention [11], and have been widely used with great success over the recent years to support documentation, representation and dissemination of DCH [9]. A common serious game design approach is through narrative story telling design and historic scene/setting reproduction [11], and their efficacy and impact in the DCH context has been the focus of extensive research for the past 20 years. However, despite the wide range of research works in this domain, the recent interest in innovation and application of VR in DCH has revealed new and open technological, societal and industrial challenges requiring in-depth exploration to ascertain the affordances and limitations of VR and serious VR games in this domain [3,28].

2.3 VR Gaming in Digital Cultural Heritage

An exponential increase in the use of VR for gaming has been recorded as a result of the significant improvements in hardware and computer graphics, and is considered one of the most interesting technological advancements in the gaming scene [19]. A recent study conducted by [28] identifies a number of VR game genres implemented in DCH, and categorises them in serious games, puzzles, story telling, quests, action, beat-them-up, and multiplayer games. Video games provide new and entertaining ways of experiencing and disseminating heritage, with several examples of serious and entertainment games developed by museums, heritage organisations, research institutions and even entertainment game studios [5]. The literature suggests that there are a plethora of elements that contribute to the enjoyment and satisfaction of video games, such as the usability of the game, its aesthetics and others, and these have been the focus of extensive ongoing research [20]. Successful games are the ones that manage to entertain players and provide them with enjoyable and challenging tasks [19]. Game designers and developers need to ensure that the games are enjoyable to play and also marketable to reach their target audiences [20]. To aid designers, developers and researchers, a plethora of data collection instruments and heuristics have been developed over the years, measuring important areas of the players' gaming experience from multiple perspectives (see overview list in [20]). Understanding the relevant important factors such as usability, enjoyment, immersion, creativity, personal gratification, social connection, and the visual aspect of the game can help game developers to understand their target audience, cater for their playing needs and attract new players [10]. Several methods such as usability testing, heuristics evaluation and play-testing are commonly used to assess video games, helping developers to understand the players' behaviour, attitudes and preferences [20].

2.4 Project Description

The project discussed in this paper presents details on the development and evaluation of a VR environment to support the efforts of promoting and educating people about the Byzantine art of the Church of Panagia Aggeloktisti located in the village of Kiti in Larnaka, Cyprus. In particular, the usability/playability, enjoyment and the visual aspect of the VR environment were evaluated, in preparation for its public use and future experiments. The environment will be used to conduct a series of empirical studies in the future, looking into its efficacy to support DCH education, and other technical considerations.

Panagia Aggeloktisti is an early Christian-Byzantine architecture church renowned for its beautiful decorations spanning across different historical periods. The church is known for its well-preserved 6th-century mosaic depicting the Virgin Mary holding baby Jesus in her arms, and with Archangels Michael and Gabriel on either side. This mosaic is located over the sanctuary apse in a half dome wall structure, is the only survived wall mosaic in Cyprus to date, and is one of the finest and most significant examples of early Christian art. The church also features well-preserved wall paintings from the 11th, 13th and 19th centuries with significant cultural and religious importance. The name "Panagia" means "Virgin Mary" and "Aggeloktisti" translates to "built by angels" in Greek language, according to the local tradition on how the church was constructed. The church is included on UNESCO's Tentative List, highlighting its cultural significance and potential for future world heritage status [29].

To support the efforts of promoting the art history and heritage of the church, the VR environment presented in this paper has been developed, to be used as a vehicle for future experimentation and investigation of topics in the DCH, computer graphics and VR research domains. In preparation of research protocols, the development team has deemed necessary to initially evaluate important usability components of the environment, to determine the extent to which it is at a state which extensive educational research can take place, and to also be used publicly. A comparative research methodology has been devised, and an experiment has been conducted and explained in the sections below.

3 Research Methodology

This study aims to ascertain the extent to which the usability/playability, enjoyment and visual appeal of the VR environment are affected by the implementation of Gamified and non-Gamified elements during an interactive game-based learning activity in VR. Two versions of the VR environment have been developed, the one without gamified elements such as points, time for completion, badges and rewards. The study hypothesizes that the overall playing experience of the users would be positively perceived regardless of the implementation of gamified elements as part of the experience. This would serve as an indicator that both version of the VR environment have reached a development stage where they are usable, enjoyable and visually appealing, to be used for further empirical investigation in the future.

3.1 VR Environment Description

In the VR environment, users immerse and participate in a series of learning activities designed to educate them about the Byzantine art and significance of the church of Panagia Aggeloktisti. This VR environment is designed to have a semi-realistic look and feel influenced by the design and feeling of the interior of the church. Key artefacts of the church such as the wall mosaic and specific paintings have been digitized and featured within the environment (more details in Sect. 3.2).

To connect to the environment and experience the VR world, the users launch the application from the VR headset directly. The environment features an inquiry-based learning approach where the users assume the role of historians attempting to figure out the dating of the mosaic through a collection of evidence. Once the users connects to the environment, a Non-Playing Character (NPC) who is a dedicated learning companion to the user, approaches and provides details on the purpose of the environment and its missions in audio format captioned by text. The gamified activity requires the user to investigate three areas in the church and complete a set of questions before reaching a final area/stage. The user follows the NPC which is responsible for sharing educational and historical information, instructions, and general advice on how to complete each stage to the user throughout the experience. Each area features a different set of educational materials in various multimedia formats, focusing on the historical significance of the mosaic, and general information about the church. After reviewing all materials in each area, the user must answer a question to get access to the next area. The final area features a question that covers all the learning outcomes of the previous areas.

3.2 VR Environment Design and Implementation Details

For the design of the environment, a team of undergraduate students studying Computer Games Development at the University of Central Lancashire, Cyprus (UCLan Cyprus), and the authors of this paper have visited the church multiple times to capture and digitise its exterior and specific key artefacts in display inside the church, including the famous mosaic. Data was captured through drones equipped with high-definition cameras and through high-quality digital single-lens reflex cameras (DSLR). A large volume of photographic data was captured to ensure that enough data will be processed, which was reviewed to ensure that only the best of quality photographs covering the required angles and meet a particular quality threshold would be used, through the process of photogrammetry. The collected data was processed through 3DF Zephyr (www.3dflow.net) photogrammetry software that uses a range of complex algorithms to process the photographic data of the church, the mosaic, and the other objects, converted them into detailed 3D models (Figs. 1, 2, and 3), to later import them in the VR environment (Fig. 4).

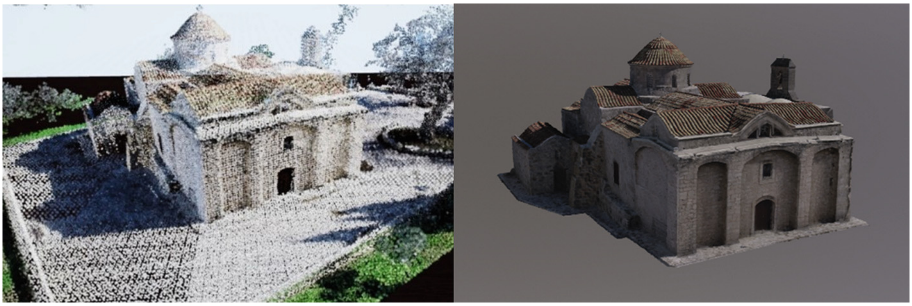

Fig. 1. Point cloud data (left) and 3D generated mesh (right) of the Aggeloktisti church exterior.

The results of the generated 3D models produced meshes with high polygon counts, visual artefacts and issues with textures and shapes. The generated models were processed further using a chain of Computer Aided Design (CAD) software to enhance and optimise their performance by reducing their geometry in ways that keep the original shape and texture quality of the objects intact, but make them efficient for further use in CAD and game engine software. Initially, we have used the Agisoft De-Lighter (www.agisoft.com) software to remove shadows from the textures of the generated models, due to weather and lightning condition changes occurred during the data capture stage. The process of mesh retopology was utilised (Fig. 3) to convert high polygon 3D assets into reduced polygon count models using Instant Meshes software (www.github.com/wjakob/instant-meshes). UV unwrapping and texture baking process took place using Blender (www.blender.com) to use high detail and quality textures on the newly

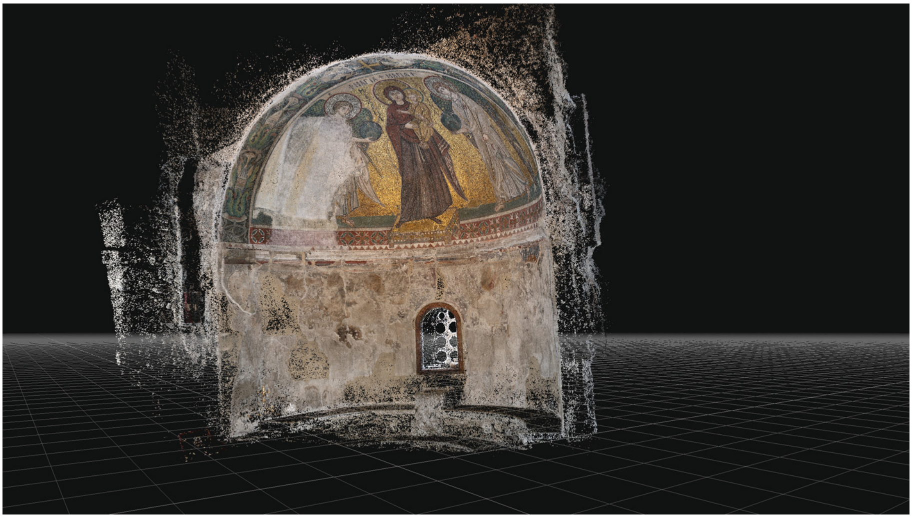

Fig. 2. Example of the generated dense point cloud data of the mosaic.

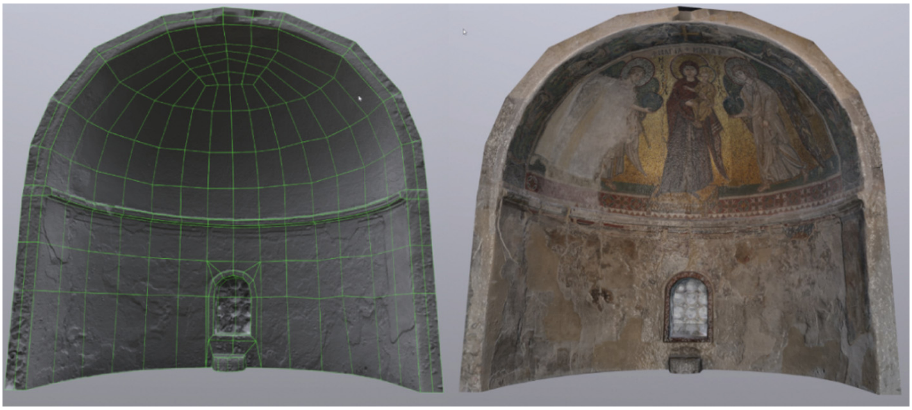

Fig. 3. Example of mesh retopology and applying high quality texture to the mosaic.

decimated 3D models. The optimised 3D models were then imported into Unreal Engine 4, which was the game engine used to develop the VR environment. This is a widely used game engine developed by Epic Games (www.epicgames.com) which provides advanced rendering engine, programming environment, tools and capabilities for developing high quality games and not only in multiple platforms. The manual process described above, was necessary to ensure that the 3D models would have been optimized enough in terms of size and polygon count to be imported in VR. This helps to improve the loading times and rendering costs of the VR scene, and ensuring high and consistent frame rate counts during the VR experience. To further contribute to this and ensure that the VR environ-

Fig. 4. In-world view of the mosaic.

ment offers a usable and consistent user experience, we have employed a number of optimization techniques to improve graphics rendering and memory management, which are common issues affecting the VR gaming experience. We have used Unreal's forward shading renderer that provides faster rendering passes and supports better performance in VR, and enabled the 4x Multi Sample Anti-Aliasing (MSAA) as suggested by the game engine's best practices guidance [30] to improve the visuals of the VR scene. For the educational aspect of the environment, several learning materials in image format were used, and we have applied texture processing techniques such as varying the level of detail based on distance from the viewer (mip-maps) and texture filtering (triliniear smoothing filtering) to remove visual artefacts. Additional techniques to optimize the VR environment have been implemented using general advise provided by the game engine development team [31] and from the experience of the development team, such as techniques for reducing draw calls, memory management, spatial partitioning and others. For the design of the environment, we have also used 3D models available for public download and reuse for non commercial purposes.

3.3 Environment Functionalities and Mechanics

The environment was developed to target the Meta Quest 2 standalone device, which is one of the worlds' leading consumer ready VR devices. Meta Quest 2 is an all-in-one headset device that can operate either being wired to a computer or completely untethered, and features a hand tracking system through two wireless controllers. The controllers are rendered in the VR environment as the users hands, and the user is using them to interact with the NPC, the learning materials, and the environment during the experience.

In the VR experience, the user must attempt all quiz questions and visit all areas in order to complete the gamified activities. The system features a badge based rewards system, which the user obtains by successfully answering quiz questions. Points are also allocated for each correct question. A feedback system is implemented indicating to users if their answer is correct or not. In either case, the user can progress to the next level/area in the environment. A timer to complete the activities is also provided. The basic gameplay mechanic focus on enabling the user to complete in-world quizzes by interacting with them through their wireless controllers. The user interacts with objects via a blue highlight line (raycast) emitted from the left controller/virtual hand and allow hovering and pressing buttons of the possible answers of each quiz. On the right hand controller, the user can see information about their progress, time available to complete the environment and achieved badges. The user's locomotion in the environment is also facilitated through the wireless controller, and the user rotates around in VR by rotating in the real world. When the NPC is telling a story or giving direct instructions to the user, the user's navigation is temporarily disabled, and the user is only able to rotate around. This was implemented to ensure that the users would pay attention to the NPC when sharing instructions and key information, and to guide the storyline.

To develop the behaviour of the NPC, several tools and scripts have been implemented to enable the NPC to interact with the user, and the VR world (Figs. 5 and 6). The NPC's behaviour is mostly controlled by the behaviour trees and blackboard AI tools provided by Unreal Engine, and with scripted finite state machines AI. Navigation was facilitated through Unreal's NavMesh pathfinding AI functionality, allowing the NPC to navigate in the VR world, as well as through specific scripted actions of reaching goals via waypoints to guide the user throughout the gamified experience. A dialogue tree functional-

Fig. 5. Gameplay example of the user interacting with the NPC.

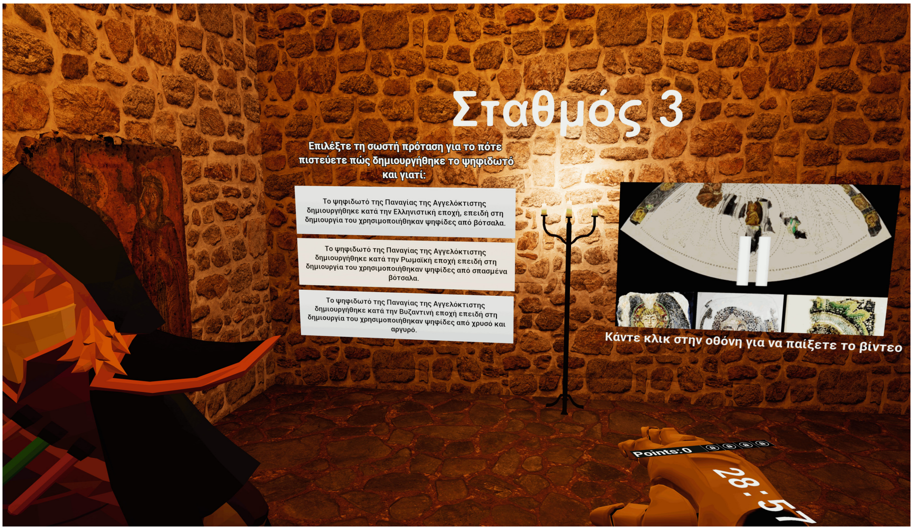

Fig. 6. Gameplay example of the user interacting with quiz and video content.

ity was implemented on the NPC to facilitate communication and interaction with the user. The NPC communicates with the user through pre-recorded audio recordings, which are also captioned to aid the users' understanding. By using the raycasting functionality, the user can interact with the NPC at any time to repeat the last issued instructions.

Two versions of the environment have been developed: 1) a Gamified and a 2) non-Gamified. In the Gamified version of the environment, for each completed area activity, the user is awarded a completion badge and points for each correct answer. Nevertheless, users' progress to the next area during the experience regardless of providing correct or wrong answers. The gamified experience has a countdown timer of 30 min to complete all areas. In the non-Gamified version, the rewards-based functionality and timer have been removed. The user attempts the same quiz questions, and proceeds to the next stage regardless of a correct or wrong answer. In both versions, the status of the answer to quiz questions is highlighted green or red and accompanied by "correct" or "wrong" sound effects accordingly.

3.4 Data Collection Instruments

To collect data for this study, we have used and translated into Greek language the Game User Experience Satisfaction Scale (GUESS) questionnaire developed and validated by [20]. GUESS is a psychometrically validated questionnaire used to evaluate computer games, consisting of 55 questions and organized in 9 factors/subscales namely: including Usability/Playability, Narrative, Play Engrossment, Enjoyment, Creative Freedom, Personal Gratification, Social Connectivity, Audio Aesthetics, and Visual Aesthetics. The items are rated on a seven-point Likert scale range (1 - Strongly Disagree to 7 - Strongly Agree) and scored by averaging, and also aggregating the results of each subscale, and in total.

For the needs of the study presented in this paper, the factors of Usability/Playability, Enjoyment, and Visual Aesthetics have been adapted, translated and used to directly assess the user experience of the specific factors of the environment. The Usability/Playability factors investigate the ease of which the environment is experienced through having clear goals and objectives in the users mind, and that minimal cognitive distractions from the user interface and controls of the environment have been perceived. Enjoyment factor relates to users perceptions around pleasure because of playing the gamified activities. Visual Aesthetics concern the graphical elements of the environment and their attractiveness. The overall score of each subscale would be considered, together with the overall composite score of all scales. The score to be interpreted should be in a range of 11 to 77 points for Usability/Playability, 5 to 35 points for Enjoyability, and 3 to 21 points for the Visual Aesthetics factor. The total aggregated score of the combined factors will be ranging from 19 to 133.

3.5 Sample and Experimental Procedures

This study was conducted over a period of five weeks and involved the overall participation of 50 undergraduate students from various departments studying at the Cyprus University of Technology. Participants were assigned into two groups, playing the Gamified or non-Gamified version of the VR environment respectively. The Gamified version was played by 12 Male and 13 Female users between 20 and 26 years old (M = 22), and the non-Gamified by 7 Male, and 18 Female users between 19 and 23 years old (M = 21). The questionnaire was used to measure the users' perceptions of the above mentioned factors through the Gamified and non-Gamified version of the VR environment, and was administered online after the participants exposure with the VR experience. At the end of the experience, their previous experience with VR was qualitatively queried, and have been categorised by the authors of this study into a Likert scale ranging from 1 (No previous Experience with VR) to 5 (Experienced VR User). Participants for both the Gamified (M = 1.64, SD = .5) and non-Gamified (M = 1.26, SD = .45) groups had very little experience with VR. In particular, 36% had no previous experience and 64% has very little experience with VR in the Gamified group, with 73% and 26% respectively for the non-Gamified group.

4 Results and Discussion

Before conducting any statistical analyses on the results, the degree of normality of the data distribution for both measurements was tested through Kolmogorov and Smirnov's test for normality. The normality test result for all scales but the non-Gamified Enjoyment scale, have passed the test and fulfilled the normality assumptions. The non-Gamified Enjoyment scale revealed a value ($p = .002$) that violates the test's threshold ($p < .05$). Visual inspection of the data indicated that the distribution of data was positively skewed, therefore the results must be considered with caution. For all the data analyses employed, parametric tests have been used.

To ensure the validity and reliability of the results reported and interpreted in this paper, a reliability test was conducted on all the scales used in the data collection using the Cronbach's Alpha coefficient. Both the Gamified and non-Gamified scales have been tested and passed the reliability test (Table 1), denoting high internal consistency between the items comprising the scales. The reliability test result confirms the already validated reliability as reported by the original authors of the GUESS scales [20], as well as verifies that translating the scales into Greek language did not invalidate the reliability and validity of the instrument.

Table 1. Reliability results for the Gamified and non-Gamified versions of the VR environment.

	Cronbach's Alpha		
	Gamified (N25)	Non-Gamified (N25)	N of Items
Usability/Playability	.85	.87	11
Enjoyment	.88	.94	5
Visual Aesthetics	.82	.71	3

The data analysis began by investigating the descriptive statistics for both the Gamified and non-Gamified versions of the environment. The average and aggregated results are shown in Table 2 and Table 3 respectively. The descriptive statistics for each individual item comprising the scales are reported in Table 4.

The results for the Usability/Playability factor of the Gamified ($M = 5.9$, $SD = .7$) and non-Gamified ($M = 5.6$, $SD = .73$) version were very positively rated. These results suggest that both versions of the environment could be played with clear goals and objectives in the user's mind, and that there were minimal cognitive interference and distractions from the user interface (UI) and the controls of the environment that could hinder the playing experience.

Table 2. Descriptive statistics of the average values for the Gamified and non-Gamified Versions of the VR environment.

	Gamified (N25)				Non-Gamified (N25)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Usability/Playability	5.9	.7	4.18	7	5.6	.73	4.4	6.8
Enjoyment	5.6	1.4	2.20	7	6.2	1	3.2	7
Visual Aesthetics	5.7	1.3	2.33	7	6.2	.8	4.3	7

The results for Enjoyment also revealed high values for the Gamified (M = 5.6, SD = 1.4), and non-Gamified (M = 6.2, SD = .1) version, suggesting that the users perceived high amount of pleasure as a result of playing the gamified activities. Furthermore, the visual aspect, the design and the graphics for both versions of the environment and their attractiveness have also been positively perceived by users (Gamified: M = 5.7, SD = 1.3, non-Gamified: M = 6.2, SD = .8).

The aggregated average results for the Gamified (M = 109.7, SD = 16.9) and non-Gamified (M = 111.2, SD = 13.4) versions were quite high against the maximum achievable score of 133, denoting highly positive experience (Table 3).

Table 3. Descriptive Statistics of the aggregated values for the Gamified and non-Gamified versions of the VR environment.

	Gamified (N25)				Non-Gamified (N25)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Usability/ Playability	64.8	8	46	77	61.5	8	48	75
Enjoyment	27.8	7.1	11	35	31.1	5.1	16	35
Visual Aesthetics	17.1	3.8	7	21	18.5	2.4	13	21
Aggregated Result	109.7	16.9	64	132	111.2	13.4	85	131

Interestingly, the non-Gamified version of the environment was perceived more positively and with less data dispersion than the Gamified version in terms of Enjoyment, and for the Visual Aesthetics of the environment. To investigate the extent to which the differences between the results for the two groups/ versions of the environment were statistically significant, a one-way-ANOVA test was employed using the groups that played the Gamified and non-Gamified version of the VR environment as the dependent variable, and the factors under study as the independent variables. Assumptions for homogeneity of variances were met since the population variances for each group were the same (N = 25 in both groups). The test revealed that the results for Usability/Playability (F(1, 48) = [2.116], p = 0.152), Enjoyment (F(1, 48) = [3.512], p = 0.067), and Visual Aesthetics (F(1, 48) = [2.498], p = 0.121) were not statistically significant.

The results for the individual items comprising each scale were also investigated, to have an in-depth look and evaluation of the user responses from both groups (Table 4). Users found the gamified activities easy to learn how to play, easy to navigate around the UI elements, controls and menus, providing them with the necessary and clear information on how to complete the goals within the environment. However, the lack of gamified elements seemed to have hindered the users' understanding on achieving their objectives in the non-Gamified version of the environment (M = 4.76, SD = 1.59). The same group also perceived the awareness of the next goal after completing a task in the environment relatively low compared to the other items (M = 4.28, SD = 1.4). This may indicate that more structured user feedback to user completed actions on the non-Gamified environment, and more visual clarity on the next task could be implemented.

Clear visual ques and hints such as arrows, signposts, or a task list, to aid the users understanding of what should follow next can be considered for implementation in future iterations of the environment design to support this finding.

Table 4. Descriptive Statistics of All Items Comprising the Factors

Item	Gamified		Non-Gamified	
	Mean	SD	Mean	SD
Playability/Usability				
I think it is easy to learn how to use the environment	6.44	.58	6.00	.86
I find the controls of the environment to be straightforward	6.12	.97	5.52	1.08
I always know how to achieve my goals/objectives in the environment	5.64	1.1	4.76	1.59
I find the environment's interface to be easy to navigate	5.96	.98	5.80	.96
I do not need to go through a lengthy tutorial or read a manual to use the environment	5.88	1.51	5.84	1.14
I find the environment's menus to be user friendly	6.20	.96	6.20	.82
I feel the environment trains me well in all of the controls	5.80	1.12	5.76	1.2
I always know my next goal when I finish an event in the environment	5.40	1.38	4.28	1.4
I feel the environment provides me the necessary information to accomplish a goal within the environment	6.16	.89	5.88	.88
I think the information provided in the environment (e.g., onscreen messages, help) is clear	5.80	1.55	6.24	.83
I feel very confident while interacting with the environment	5.40	1.15	5.24	1.23
Enjoyment				
I think the environment is fun	5.56	1.68	6.44	.92
I enjoy interacting with the environment	5.80	1.55	6.20	1.15
I feel bored while interacting with the environment.*(reversed)	5.16	2.0	6.20	1.12
I am likely to recommend this environment to others	5.84	1.6	6.16	1.11
If given the chance, I want to reuse this environment again	5.48	1.76	6.12	1.42
Visual Aesthetics				
I enjoy the environment's graphics	5.84	1.25	6.04	1.31
I think the graphics of the environment fit the mood or style of the experience	5.60	1.66	6.24	.88
I think the environment is visually appealing	5.64	1.52	6.24	.83

Looking at the environment enjoyability results, the users have enjoyed and found it fun, but some users on the Gamified version of the environment were a little bored during the experience (M = 5.16, SD = 2). Nevertheless, users indicated that they are very likely to recommend this environment to others, and that they would like to play the gamified activities and the experience again if they had the chance. The graphics of the environment were perceived as enjoyable, relevant to the mood of the environment, and visually appealing.

An ANOVA test was also performed on each individual item comprising each scale as well, without revealing any statistically significant differences between the two groups. These results indicate that the users for both the Gamified and non-Gamified versions have positively perceived the environment's aesthetics, and have enjoyed the experience equally positively. The results were further investigated to identify potential gender differences within and between the two groups, without revealing statistically significant differences. The previous experience of users with VR was also investigated for potential correlations with the measured factors and the items comprising the scales, without revealing any relationships, suggesting that their previous experience did not influence their evaluation perceptions of the environment. Overall, the analysed results indicate that the users' experience was positively perceived regardless of experiencing the gamified elements of the environment or not during the educational experience.

5 Conclusions and Future Work

While the efficacy and applicability of VR in cultural heritage has been established, the field of serious VR gaming needs further studying, and it is important to evaluate the affordances and limitations of such approach to support DCH. New and existing research and application challenges need to be investigated and addressed to support the needs for preservation, reconstruction and dissemination in DCH and to also support and enhance the user experience through immersive interactive ways. Data capture and digitisation tools, optimisation and rendering techniques, interaction methods, NPC behaviour, AI, balance and gameplay, VR hardware and software, are only some of the many areas of ongoing research taking place at academic and industrial levels. Developing and extensively evaluating VR environments, serious games, and VR applications utilising gamified and gaming approaches from multiple perspectives is necessary to innovate and develop novel ways of supporting DCH. The resource intensive and complex computing requirements of VR drive research and innovation, constantly pushing the technological boundaries to the limits, and being responsible for some of the latest revolutionary achievements in the fields of hardware technology, computer graphics, high performance processing, artificial intelligence, user interface and user experience among other software and hardware advancements. Embracing cultural heritage through VR can offer opportunities for engaging the younger generations of visitors who are exposed and used to rich multimedia tools and technologies such as XR, video games and fast networking speeds, promoting heritage and intercultural understanding in fun and innovative ways.

The project presented in this paper describes the development and evaluation of a VR environment designed to support learning about the church of Panagia Aggeloktisti in Cyprus. The paper provides details on the design of the environment and the process of capturing, digitising and optimising 3D models to be used in the environment scene, together with details on the core environment mechanics and gamified elements of the environment. The study presented in this paper was set out to evaluate the users' experience focusing on usability/playabity, enjoyment, and the visual aesthetics of the Gamified and a non-Gamified version of the VR environment. A comparative study was conducted, where users experienced an immersive gamified learning scenario requiring them to complete a series of learning tasks within the VR world. The results of this study indicated that both versions of the environment have been perceived usable and playable, without any major issues hindering the ease in which the environment could be experienced and played. The environment features clear goals and objectives, with minimal cognitive interference or distractions from the environment UI hindering the users' experience. Both versions of the VR environment have been perceived as enjoyable, with high degree of pleasure and delight reported by the users, featuring attractive and visually appealing graphical elements. A key finding that should be considered for future development is the implementation of a comprehensive tutorial level to help the users familiarise with the use of the environment and its functionalities to ease the learning curve. Providing clear guidance and visual ques to help users identify the tasks and challenges within the environment is also deemed necessary based on the results of this study, and should be considered for the future iterations of the environment design.

The purpose of this comparative study was to try out the environment with real users, and evaluate specific aspects of their experience to ensure that the current stage of the environment development is usable, enjoyable and visually pleasing to proceed with further empirical evaluations in the future. Future studies are under preparation including evaluations on the educational efficacy of the VR environment, and technical evaluations. Factors such as presence, engagement and motivation during the VR experience will be assessed, together with engagement and user experience evaluations, as well as investigating issues pertaining VR sickness. Furthermore, additional gaming elements, levels, functionalities and challenges will be implemented to increase re-playability of the gamified activities of the environment.

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