Designing the Future of Museum Exhibition: A User Acceptance Study of Immersive VR Museum

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Abstract. The COVID-19 pandemic has forced museums to rethink their approach to exhibitions and visitor engagement, with many turning to digital technologies to offer alternative experiences. This paper presents a design and development process for an immersive Virtual Reality Museum application aimed at springboard museum experience to be more attractive, informative, engaging, and safe. The application showcases the evolution of telecommunication devices used in Malaysia in the 1960s within a futuristic museum environment. The study aims to investigate the acceptance and usability of the immersive VR Museum from the perspective of young adults in Malaysia. Specifically: to what extent do young adults in Malaysia accept and use immersive VR Museum? To evaluate the immersive VR Museum, a pilot study was conducted with 30 participants aged 18–24 who voluntarily participated in the evaluation activities and provided feedback using the System Usability Scale. Results show that the immersive VR Museum was well-received, with positive feedback on usability and learnability. The study contributes to the field of museum exhibition design by providing a new approach for museums to enhance the user experience through the adoption of immersive VR technology. The proposed VR Museum not only allows visitors to remotely explore artefacts but also offers an interactive, educational, and immersive experience that traditional museums cannot provide. The research offers insights into the potential of immersive VR museums to engage and educate young audiences and guides future developments in the field.

Keywords: Museum Exhibitions, Immersive Virtual Reality, User Acceptance, Young Adults, Malaysia.

1 Introduction

Museums are buildings or structures that house physical collections of artefacts or exhibits that help to strengthen history, preserve culture, and promote social development. These establishments offer informal learning environments where individuals can explore various subjects such as art, history, science, and culture through tangible exhibits and artefacts [1]. Nevertheless, conventional display methods involving transparent

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glass windows, labels, and text descriptions may no longer captivate modern audiences, resulting in waning visitor interest. The COVID-19 pandemic has exacerbated this issue by forcing museums to temporarily close, creating significant revenue losses [2], and compelling institutions to adopt new strategies to attract visitors and ensure their safety. One emerging approach is the digitization of museums, facilitated by advances in multimedia and information technology. This innovation has expanded information exchange opportunities beyond physical museum boundaries and enabled institutions to disseminate knowledge more effectively. For instance, the Louvre digital museum in France has employed digital spaces such as web portals to host video recordings and photo series of artefacts, thereby broadening visitor access to the museum experience [3]. Although numerous museums have started experimenting with virtual alternatives, challenges still exist in providing immersive and satisfactory user experiences. Consequently, researchers are actively exploring and implementing novel exhibition methods to meet the growing demand for engaging museum visits.

Virtual Reality (VR) is a promising technology with the potential to revolutionize museum exhibit presentations. VR has been widely adopted across various industries, including the military [4], medicine [5], aviation training [6], education [7], etc. Utilizing specialized hardware, such as Head-Mounted-Device (HMD) that encompasses multimedia, computer graphics, sound, human-computer interaction, etc., enables VR applications to provide immersive and vivid sensory environments that enhance users' perception and sense of presence. The immersive experience can mimic any real-world environment, such as a museum, and enables visitors to interact with and appreciate 3D artefacts from all angles, while simultaneously safeguarding the artefacts from potential damage. Thus, VR represents an ideal technology for digitizing museums and presenting exhibits to visitors. Although immersive VR technology holds immense promise for delivering a highly engaging and interactive museum experience, limited research has been conducted on the design, development, and usability of immersive VR museums. Hence, further exploration is crucial to evaluating the feasibility of immersive VR museums as alternatives to traditional physical museums and other virtual museum categories, as well as their effectiveness and appeal among younger generations.

Given such a backdrop, the objective of this research is to develop an immersive VR Museum and investigate its usability and learnability among young adults in Malaysia. Usability is defined as quality attribute that assesses how the system interface is easy to use [8] while learnability is defined as capability of a software artifact to enable the user to learn how to use it [9]. The immersive VR Museum would not only enable remote artefact exploration but also deliver interactive, educational, and immersive experiences unattainable by traditional museums. The findings of this research will contribute to the field of virtual museum exhibition design and guide future developments in the field. The remainder of this paper is structured as follows: Section II reviews relevant literature on virtual museum exhibitions, Section III details the design and development of the immersive VR Museum, Section IV presents user evaluation methodology, and Section V discusses the findings. Lastly, Section VI concludes the paper and outlines future research directions.

2 Related Work

Virtual museums have surfaced as a complement to or substitution for the traditional means of experiencing historical and cultural artefacts. This section provides an overview of the various forms of existing virtual museums and the manifold approaches to their implementation, from websites and panoramic photographs to immersive VR and AR experiences. Each approach has its own set of benefits and drawbacks, which will also be discussed.

Though virtual museums have been part of the digital landscape for years, their popularity has soared in recent times. This surge can be attributed to major technological leaps and the global COVID-19 pandemic. The concept of a "virtual museum" refers to an interactive electronic museum, but not necessarily in a 3D digital environment, and shares the same objectives as its brick-and-mortar physical museum [10]. These objectives encompass the preservation, interpretation, and dissemination of historical and cultural artefacts, as well as providing captivating, educational experiences for visitors. Among the various forms, website-based virtual museums are perhaps the most prevalent. Essentially, this approach involves crafting a website filled with images and exhibit details from a museum's collection. Often peppered with interactive features like quizzes, games, and videos to engage visitors This approach is relatively simple and inexpensive for museums to implement, and it has the potential to reach a large audience. The experience, however, is limited to two-dimensional images, text descriptions, and videos. The Louvre sought to enhance visitors' experiences by combining web technology with a series of 360-degree elongated photos, offering panoramic, uninterrupted views [3]. Although these virtual tours are equipped with navigation buttons, images, videos, and links to more information, visitors are unable to interact directly with the artefacts.

To further intensify the immersive qualities of website-based virtual museums, researchers have turned to web-based VR content [11]. This method involves creating a website that hosts VR content, that can be accessed through a web browser. Despite the seemingly boundless potential, viewing the VR experience on a flat computer screen can be underwhelming. As visitors cannot directly interact with artefacts, researchers have sought to enhance website-based virtual museums by adopting AR and immersive VR technologies to create a more profound, holistic experience. AR technology has piqued the interest of researchers in the realm of virtual museums, particularly when augmented with web-based technology [12]. By scanning a 2D image of an artefact on a museum's website, visitors using an AR-enabled app on their smartphone or tablet can conjure a 3D digital model. This allows for a dynamic visual experience, with visitors able to view the model from various angles. Immersive VR technology has emerged as a pivotal player in the progression of virtual museums, providing visitors with a profound and comprehensive experience [13]. Through the utilization of VR controllers, visitors can fully engage with virtual artifacts and seamlessly navigate the virtual museum environment.

3 Design and Development of VR Museum

In this section, the intricacies of the design and development process underlying the immersive VR Museum, with particular emphasis on the meticulous selection of the Head-Mounted Display (HMD), content creation, and user interface components are discussed. The HMD choice assumes paramount significance in delivering a captivating and immersive experience to visitors. After careful consideration, the Meta Quest 2 platform was deemed the optimal candidate for the development and deployment of the VR Museum, owing to its cost-effectiveness and widespread accessibility. This wireless HMD bestows six degrees of freedom tracking, empowering visitors to explore exhibits naturally and intuitively, thereby heightening engagement and overall satisfaction [14]. For seamless interaction with virtual exhibits and environment, the Meta Quest 2 HMD is paired with Meta Touch controllers, replete with user-friendly buttons, triggers, and haptic feedback, fostering an intuitive and precise tracking experience, thereby enriching the overall museum experience for visitors.

The immersive VR museum application development pipeline includes several stages, starting with concept design, asset creation, coding, testing, and deployment of the VR Museum. For the asset development of the VR Museum, Maya, Substance Painter, and Unity3D were utilized. Maya was chosen as the primary modelling tool for creating museum exhibits, as it has the capabilities and features for researchers to generate complex and visually appealing 3D digital exhibits [15]. Maya was also employed to create a lifelike VR environment, including the design of information panels and furnishings that were strategically placed throughout the VR Museum. Fig. 1 depicts the VR Museum's floor plan, consisting of a main hall that is connected to two distinct exhibition halls, each showcasing unique exhibits consisting of both phone and non-phone types of telecommunication devices used in Malaysia in the 1960s. Substance Painter was used to create materials and textures for 3D models, and preview changes in real-time [16]. The combined use of Maya and Substance Painter enabled the creation of highly detailed and realistic 3D digital telecommunication devices, as shown in Fig. 2. Besides, digital characters were also modelled using Maya and added to the VR Museum to humanize the environment and enhance the user's sense of presence.

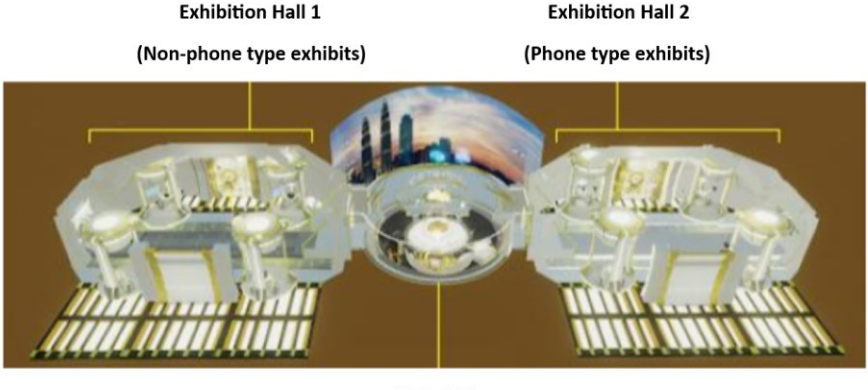

Fig. 1. VR Museum Floor Plan: A 3D Map of Exhibits

Once all the exhibits and digital characters were modelled and textured, they were imported into Unity3D for further development and coding. Unity3D was utilized to develop the VR Museum due to its versatility as a game engine and comprehensive toolset for creating interactive and engaging VR experiences [17]. The developed 3D exhibits, digital characters, and VR environment provided an ideal starting point for constructing a cohesive museum experience in Unity3D. The VR Museum was designed to offer a first-person perspective, in which a visitor can explore the environment as if it is physically present. A visitor, upon wearing a Meta Quest 2, will spawn at the main hall as shown in Fig. 3 and can navigate the VR Museum through teleportation functions. The use of teleportation in VR is a common method of moving around in virtual spaces and can help alleviate cybersickness.

The VR Museum's User Interface (UI) was designed to be intuitive and straightforward, with a clear and concise pathfinding guide to help visitors navigate the VR Museum with ease. Besides, background music and sound effects were carefully selected to enhance the overall ambiance of the VR Museum. The sound effects were designed to correspond with specific interactive elements of the exhibits, therefore, enhancing visitors' sense of engagement and interactivity. The background music was added to complement the theme of each exhibit hall, heightening the sense of immersion and transportive quality of the overall VR Museum experience. To further engage visitors, custom scripts were developed to handle the logic of interactive components, allowing for a more dynamic and engaging visitor experience. For example, scripts were coded to allow visitors to use their virtual hands to interact with exhibits, such as typing on a traditional typewriter or changing channels on an analogue TV, as shown in Fig. 4. Visitors can also use a "laser beam" controlled through a Quest controller to select menus and objects.

Fig. 2. Rendered 3D Telecommunication Devices for VR Museum

Fig. 3. VR Museum's main hall in first person view

Typing on Vintage Typewriter Exhibit Changing Channel on Old TV Exhibit

Fig. 4. Nostalgic Experience in VR Museum

4 User Evaluation

To gain feedback on the usability and learnability of the newly developed immersive VR Museum, a pilot evaluation was conducted using a quantitative approach via the System Usability Scale (SUS), developed by Brooke [18]. Comprising a comprehensive questionnaire of ten items, rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), this widely adopted instrument has been extensively leveraged to assess the usability of diverse products and user interfaces, including VR applications [19, 20], among other domains. The SUS provides researchers with the advantage of a swift and user-friendly instrument that can be effectively utilized with a small sample size to gather feedback from users. Importantly, the scores obtained from the SUS are normalized to a range from 0 (the worst) to 100 (the best), to provide a quantitative measure of the user's perceived usability [21]. This normalization process allows for direct comparisons between different systems evaluated using the SUS.

This study sought to answer the following research question: How do young adults interact with the immersive VR Museum, and what can be done to improve its design and implementation? The study drew a voluntary sample of 30 Malaysians ranging in age from 18 to 24, with a mix of genders and varying levels of VR experience. The inclusion of Malaysia is not intended to focus on specific contextual factors within the

country. Instead, Malaysia is chosen as the sample in our study, contributing to the overall diversity and representativeness of our data, without seeking to address Malaysia-specific issues or make claims about the unique characteristics of the Malaysian context. Participants received no monetary or other compensation for their contributions. The evaluation took place at a VR research lab, as depicted in Fig. 5. Each participant was given a briefing on the purpose of the evaluation, the functionality of the VR Museum, and the testing procedures. Participants were then asked to sign a consent form via Google Forms before proceeding with the evaluation. A tutorial on how to use the Meta Quest 2 HMD was given to each participant before the evaluation process began. Participants were then given the opportunity to use the VR Museum within the context of a fully operational demonstration environment. The evaluation process lasted approximately 25 minutes for each participant. Participants were not given specific tasks or scenarios to complete while testing the VR Museum. Following the evaluation, participants were asked to complete a Google Form consisting of a 10-item SUS questionnaire. The evaluation concluded with a Q&A session with the participants to obtain additional feedback.

Fig. 5. Participant Evaluating the VR Museum

5 Discussion

The SUS questionnaire data was analyzed to determine the VR Museum's learnability and usability. Fig. 6 presents an encompassing perspective of each participant's SUS score, with a mean SUS score of 76.5, signifying a good level of usability for the immersive VR Museum. The elevated mean SUS score, along with the median SUS score of 75, further ascertains that the VR Museum was straightforward to utilize and learn from. Nevertheless, a standard deviation (SD) of the SUS score of 16.32 reveals variability in the participants' experiences. While many participants deem the VR Museum to be usable, some encountered challenges. A low minimum SUS score of 50 exemplifies that a minority of participants may have struggled to operate the VR Museum, whereas a maximum SUS score of 100 signifies that some participants rapidly mastered

the VR Museum. This variability could be attributed to the disparate levels of familiarity with immersive VR devices among participants, with some being novices, while others possessing prior experience with VR technology.

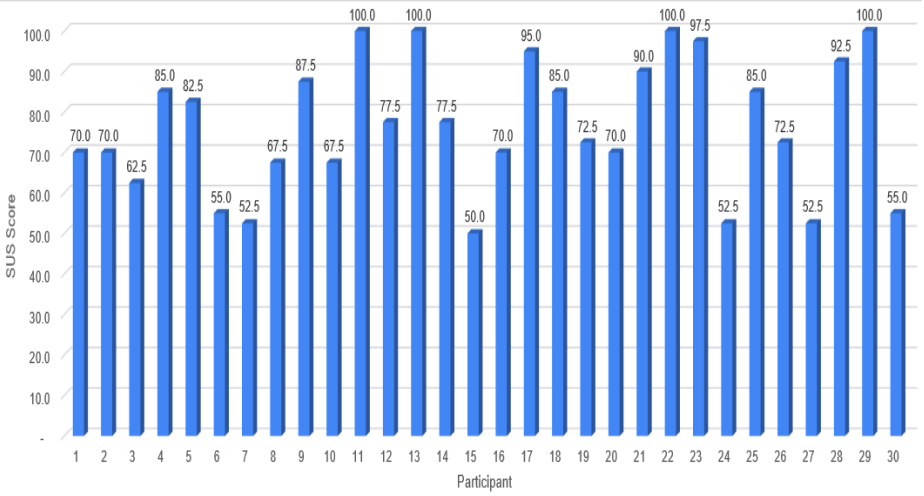

Fig. 6. Reported SUS score per participant.

A synopsis of individual responses in the form of mean, median, min, max, and SD from the participants for each of the SUS questions is provided in Table 1. The results illustrate a positive usability and learnability of the VR Museum. Specifically, Q3 (easy to use) and Q5 (well-integrated functions) achieved high mean scores of 4.33 and 4.27, respectively, denoting the efficacious design and development of the VR Museum in establishing a user-friendly experience. These scores imply that the participants perceived the VR Museum as intuitive and valued the seamless integration of various functions within the application. Regarding learnability, the participants' findings assert that the VR Museum is easy to learn, as corroborated by the mean score of 4.27 for Q7 (most people would learn to use it very quickly). In a similar vein, Q10 (needed to learn a lot of things) received a lower mean score of 2.00, suggesting that the participants did not confront substantial difficulties or a steep learning curve. This finding suggests that the VR Museum's design enables users to promptly grasp its functionalities and traverse the experience effortlessly. Furthermore, the participants manifested a positive predilection towards the acceptance of the VR Museum. This sentiment is evinced through the results from Q1 (would like to use the VR museum frequently) and Q9 (felt confident using it), which attained mean scores of 3.50 and 3.93, respectively. The captivating and immersive nature of the VR Museum may have positively swayed the participants' acceptance of the application.

Table 1. User Evaluation Results: System Usability Scale (SUS) Question Analysis

SUS Question		Mean	Median	Min	Max	SD
Q1	I think that I would like to use this Virtual Museum frequently.	3.50	4.00	1.00	5.00	1.22
Q2	I found this Virtual Museum unnecessarily complex.	2.23	2.00	1.00	5.00	1.22
Q3	I thought this Virtual Museum was easy to use.	4.33	5.00	2.00	5.00	0.88
Q4	I think that I would need assistance to be able to use this Virtual Museum.	2.10	2.00	1.00	5.00	1.30
Q5	I found the various functions in this Virtual Museum were well integrated.	4.27	4.00	2.00	5.00	0.78
Q6	I thought there was too much inconsistency in this Virtual Museum.	1.73	2.00	1.00	4.00	0.83
Q7	I would imagine that most people would learn to use this Virtual Museum very quickly.	4.27	4.00	2.00	5.00	0.78
Q8	I found this Virtual Museum very cumbersome/awkward to use.	1.63	1.50	1.00	3.00	0.72
Q9	I felt very confident using this Virtual Museum.	3.93	4.00	1.00	5.00	1.08
Q10	I needed to learn a lot of things before I could get going with this Virtual Museum.	2.00	2.00	1.00	5.00	1.20

6 Conclusion

This research work extends the boundaries of immersive VR technology capabilities to transcend the conventional landscape of museums by developing a new immersive VR Museum. Numerous existing implementations of virtual museums have largely focused on 360-degree panoramic views [3], web-based VR [11], and AR [12]. However, research on adopting immersive VR for virtual museums has been significantly neglected. The primary contribution of this research is the new VR Museum, which integrates immersive VR technology with historical 3D exhibits, coupled with informative and interactive storytelling, to offer a unique and transformative museum experience that both captivates and educates visitors. An experiment and user evaluation survey showed that the VR Museum is expected to gain acceptance from young adults as the participants perceived positive usability and learnability of the VR Museum. The findings of the study also reveal that the immersive VR Museum, with its first-person viewpoint and interactive exploration, indicates the significant potential of VR technology as a powerful tool for captivating and enlightening museum visitors. In practice, our research work contributes to the design principles of virtual museum exhibitions and

guides future developments in the field. The proposed system has a research limitation that should be noted. Since the current evaluation is based on young adults' feedback, in our future research, more user evaluations will be conducted with users in the real world, such as museum caretakers, tourists, and families. As VR technology continues to advance, it is anticipated that even greater possibilities will emerge for crafting immersive and impactful museum experiences, ushering in a new era of digital museums. Therefore, an immersive vintage environment, allowing visitors to experience the telecommunication devices prevalent in Malaysia during the 1960s, is suggested for future work. This will engage and enlighten visitors through museum encounters that bridge the past and present, thus fostering a deeper understanding of the cultural, societal, and technological aspects of that era.

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