

Cultural Heritage in The Digital Age: Evaluating User Experience in Virtual Reality Cultural Heritage Learning Application

Mohamad Shahfik Afendi bin Abdul Ghani*, Sudirman bin Kiffli*, Tenh Hock Kuan*, Syadiah Nor binti Wan Shamsuddin**, Normala binti Rahim**

*Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan, 16300 Bachok, Kelantan, Malaysia.

**Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia.

afendi.ag@umk.edu.my, sudirman.k@umk.edu.my*, kuan.th@umk.edu.my, syadiah@unisza.edu.my, normalarahim@unisza.edu.my

Abstract— The Fourth Industrial Revolution (IR4.0) has transformed various sectors, including cultural heritage preservation, education, and tourism, through advanced technologies like virtual reality (VR). This study explores the intersection of technology and cultural heritage learning, highlighting the crucial role of user experience (UX) in VR applications. While VR holds significant potential for cultural heritage learning, existing research often emphasizes utility and usability over UX. To address this gap, the study evaluates the UX of VR applications designed for cultural heritage, specifically focusing on the Istana Jahar historical site. The objectives include assessing dimensions such as effectiveness, efficiency, attractiveness, satisfaction, emotion, engagement, attention, and perception. The research employs quantitative methods using the Design Science Research Methodology (DSRM) to guide the development and evaluation of the VR application. A cluster random sampling technique was used to recruit 113 students from Universiti Malaysia Kelantan (UMK), ensuring a representative sample with relevant educational backgrounds. Participants interacted with the VR application and completed a survey based on the developed conceptual framework. Findings indicate high mean scores across UX dimensions: Effectiveness (4.487), Efficiency (4.363), Attractiveness (4.528), Satisfaction (4.363), Emotion (4.401), Engagement (4.385), Attention (4.366), and Perception (4.416). These results demonstrate that the elements within the conceptual framework effectively enhance the UX in cultural heritage learning applications.

Keywords— Cultural Heritage Learning, User Experience (UX), UX Evaluation, Virtual Museum, and Virtual Reality

I. INTRODUCTION

The Fourth Industrial Revolution (IR4.0) has ushered in a transformative era marked by the integration of advanced technologies across diverse sectors, including cultural heritage preservation, education, and tourism [1]. This industrial paradigm shift has significantly reshaped the style and approach to cultural heritage learning (CHL) [2], [3]. Within this transformation, virtual reality (VR) has emerged as a powerful tool, and the role of user experience (UX) has become crucial in enhancing the intersection of technology and cultural heritage learning [4]. Moreover, virtual

environments have transcended traditional boundaries, offering immersive platforms for users to explore, learn, and connect with cultural heritage in unprecedented ways [5].

However, despite VR's potential in cultural heritage learning, researchers have often prioritized the utility and usability of VR applications, frequently overlooking the essential aspect of UX [6]. This oversight is significant, as a comprehensive consideration of UX is necessary to ensure the development of high-quality applications that effectively engage users [7]. Consequently, there is a pressing need for virtual environment applications that integrate cultural heritage learning with UX design, thereby enhancing user engagement and contributing to the education, preservation, and dissemination of cultural knowledge.

Furthermore, previous studies have predominantly explored the technical aspects of VR applications, focusing on usability and functionality [8]. Nonetheless, these studies often neglect the UX perspective within the context of cultural heritage learning, leaving a gap in understanding how to optimize these experiences for users in this specific domain. Addressing this gap is essential to improving the effectiveness of VR applications in cultural heritage settings [9].

Therefore, this study aims to evaluate the UX of VR applications designed for cultural heritage settings, with a specific focus on the Istana Jahar historical site. The research objectives include understanding various dimensions of UX, such as effectiveness, efficiency, attractiveness, satisfaction, emotion, engagement, attention, and perception, when interacting with VR reconstructions of Istana Jahar (Kelantanese Royal Palace).

Regarding the scope, this study is limited to VR applications that reconstruct Istana Jahar virtually and does not cover other types of VR applications or cultural heritage contexts. By concentrating on this specific site, the research intends to provide detailed insights into UX, which can inform the development of similar applications for other cultural heritage sites.

This paper is organized into three sections: the first section is a literature review that examines the current state of research on cultural heritage learning using virtual technology,

identifies gaps in existing studies, and suggests future research directions. The second section outlines the research methodology, detailing the evaluation of UX in VR applications focused on cultural heritage learning. The third section presents an analysis of UX evaluations and conducts a series of experiments to validate the performance of the proposed UXCHEL framework.

II. RELATED WORKS

This section aims to understand existing literature by identifying similarities, differences, and contradictions in previous research on cultural heritage learning and UX elements relevant to virtual museum design. The goal is to enhance the effectiveness of cultural heritage learning and ensure a positive emotional impact on users. Additionally, this section seeks to provide an overview of research trends, patterns, and gaps. Various fields of study were critically evaluated and synthesized, including UX in virtual museums, past UX frameworks, learning theories, and features of existing virtual museums.

A. User Experience in Virtual Museums

Firstly, the literature review focuses on UX in virtual museums by analyzing and synthesizing existing UX metrics and evaluation instruments. The evolution of UX in technological product design began in the early 20th century and gained prominence in the 1980s and 1990s. Defined by various scholars, including Alben, Norman, and ISO, UX extends beyond usability to encompass individual perceptions and emotions during product interactions. Notably, the definition of UX became intentionally broad after 2010 to acknowledge its multifaceted nature.

Furthermore, UX metrics are crucial for digital product success, encompassing measures of usability, satisfaction, and emotional response. These evaluation methods contribute to understanding user interactions and satisfaction. UX evaluation instruments like AttrakDiff [10], UEQ [11], meCUE [12], SUS [13], mDES [14], and UES [15] vary in dimensions and focus, highlighting the importance of selecting tools that align with the specific goals of the evaluation.

However, despite their strengths, none of these instruments fully aligns with the proposed UX framework for a cultural heritage learning application. Therefore, a new UX instrument is deemed necessary, integrating elements from existing tools while adhering to the principles of the proposed framework.

B. Past User Experience Frameworks

Moving on to the second topic of the literature review, this section involved the analysis of twelve past UX frameworks sourced from established scholars in UX, such as The Hassenzahl UX Model [16], The Simplified Model of UX [17], The Integrates UX Factors [18], The UX Model of RECMA [19], The CUE Model [20], The GeSToUX [21], The VAH Framework [22], The HUXSIM Framework [23], The EUX Framework [24], The UXIVE Framework [25], The 2PHT UX Modeling [26], and The NPE Framework [27]. The

findings revealed a lack of standardization among these frameworks, with each incorporating distinct and non-standardized UX factors. This comparative analysis scrutinizes the twelve UX frameworks to identify patterns and differences in their design principles, integration of learning theory, use for UX evaluation, and applicability across various domains. The frameworks examined span a range of authors and terminologies, each offering a structured approach to understanding and enhancing UX, as illustrated in Table I.

TABLE I. COMPARATIVE ANALYSIS OF TWELVE DISTINCT UX FRAMEWORKS.

Frameworks Name	UX Factors	Learning Theory	UX Evaluation	Domain
The Hassenzahl UX Model	Yes	No	Yes	General
The Simplified Model of UX	Yes	No	Yes	General
The Integrates UX Factors	Yes	No	Yes	General
The UX Model of RECMA	Yes	No	Yes	General
The CUE Model	Yes	No	Yes	General
The GeSToUX	Yes	No	Yes	Cultural Heritage, Storytelling and Natural User Interface
The VAH Framework	Yes	No	Yes	Cultural Heritage
The HUXSIM Framework	No	No	Yes	Cultural Heritage
The EUX Framework	Yes	No	Yes	General
The UXIVE Framework	Yes	No	Yes	Edutainment
The 2PHT UX Modeling	Yes	No	Yes	General
The NPE Framework	Yes	No	Yes	General

Most of the frameworks, including the Hassenzahl UX Model, CUE Model, and EUX Framework, have a general-purpose orientation. These frameworks position themselves as versatile tools applicable across a range of domains. However, the specific methodologies and UX components for evaluation may vary across different domains, which warrants further investigation into the comparative efficacy of these approaches. Additionally, none of the examined frameworks explicitly incorporate learning theories. This omission raises questions about how well these frameworks address cognitive and behavioral aspects in shaping UX. Future developments in UX frameworks could benefit from integrating learning

theories to enhance the understanding of user learning and better address user emotions.

C. Learning Theories

The third topic in the literature review addresses learning theories. Notably, none of the examined frameworks explicitly incorporate learning theories, raising questions about how cognitive and behavioral aspects are considered in shaping UX. To address this gap, this research proposes integrating three learning theories—Experiential Learning Theory (ELT)[28], Discovery Learning (DL) [29], and Motivational Learning Theory (MLT) [30]—to influence user learning behavior based on application features and enhance cultural heritage learning.

Additionally, the research explores these three prominent learning theories—experiential, discovery, and motivational learning—in the context of cultural heritage learning (CHL). It meticulously examines the attributes of each theory to identify key elements that can be integrated into the framework components, particularly the virtual environment. This approach establishes a meaningful connection between the learning theories and the features of the virtual application component, as illustrated in Figure 1.

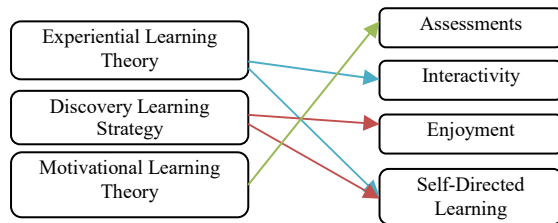


Figure 1. Derived virtual application features from learning theories.

Experiential learning emphasizes the importance of self-directed learning and enjoyment in cultural learning contexts. In contrast, Discovery learning also highlights self-directed learning and enjoyment as key factors. Meanwhile, Motivational learning stresses the need to incorporate assessment features within virtual applications to foster emotional engagement and improve user attention. Collectively, these insights provide a foundation for developing prototype features inspired by the unique attributes of each learning theory.

D. Existing Virtual Museums

The fourth topic of the literature review examines existing virtual museums, such as The Louvre Museum Virtual Tour, The Vatican Museum Virtual Tour, VR Geguti Palace, The British Museum, and the National Museum of Natural History. This study reveals a variety of features aimed at enhancing interactivity, social presence, and personalization. Consequently, the proposed solution incorporates assessment, interactivity, self-directed learning, and enjoyment as potential features for virtual museums. These elements could significantly improve UX, elicit positive emotions, and support effective learning.

In summary, the analysis of UX factors through past UX frameworks and literature review leads to the proposal of a

new UX framework that integrates UX factors, product features, and relevant learning theories. This integration is expected to enhance engagement and attention while offering a positive UX in virtual environments specifically designed for cultural heritage content. Notably, the proposed User Experience for Cultural Heritage Learning (UXCHEL) framework, as illustrated in Figure 2, is distinct from existing ones because it combines UX factors and CHL in a manner tailored specifically for cultural heritage, unlike the more general-purpose frameworks currently available.

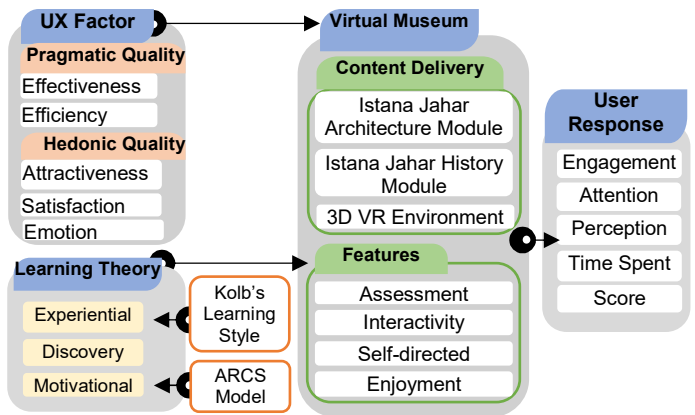


Figure 2. User Experience for Cultural Heritage Learning (UXCHEL) Framework.

III. METHODOLOGY

This study will employ quantitative methods using the Design Science Research Methodology (DSRM) proposed by Holopainen [31] as a guiding model to evaluate UX using a developed VR application of Istana Jahar. This methodology is regarded as the most reliable, commonly used, and extensively referenced approach in the field of innovation and development in information systems. The methodology includes prototype development, questionnaire design, and the evaluation procedure, all aligned with the proposed UXCHEL framework.

E. Prototype Development

The VR Istana Jahar application was developed using Unity 3D software and deployed on Oculus Quest 2 headsets. The development process followed a structured prototyping methodology adapted from Aman [32], encompassing several essential stages: Planning, Analysis, Design, Prototype, and Implementation.

Initially, during the Planning stage, critical issues related to cultural heritage learning were identified, establishing the foundation for the application's development. Data was collected, including architectural records, photographs, and videos of Istana Jahar, to create digital content for the application. In the Analysis stage, constraints such as budget, time, technology, resources, and any legal or regulatory requirements were identified. Understanding the end-users and their interactions with the system was essential. Creating user personas and scenarios helped represent different user types, ensuring the prototype met their needs and expectations. This

thorough analysis laid a solid foundation for the development process. Moving to the Design stage, storyboards were created to outline the interface, visual design elements, and UX components as proposed in the UXCHEL framework. This stage aimed to enhance overall UX and learning performance. Poly 3D modeling techniques were then used to reconstruct the Istana Jahar site in a virtual environment. Textures and animations were applied to enhance realism and interactivity.

The Prototyping stage involved integrating cultural heritage content and multimedia elements into the prototype to create a compelling and immersive learning experience. The 3D models were incorporated into the Unity 3D platform, ensuring compatibility with Oculus Quest 2 for an immersive experience as shown in Figure 3.



Figure 3. Screenshot of VR Istana Jahar application using Unity 3D software.



Figure 4. Participants interact with the prototype.

Finally, in the Implementation stage, features were implemented using Unity 3D software to deliver an effective virtual museum environment that meets educational purposes while engaging users with cultural heritage content. This systematic approach ensures that the virtual museum application not only meets technical standards but also effectively serves its educational and experiential purposes for diverse user groups.

F. Instrument Development (Questionnaire)

The developed instrument was designed to measure and evaluate the proposed UX elements and cultural heritage learning elements outlined in the UXCHEL framework. This framework served as a guideline for developing the virtual environment application. Consequently, the evaluation instrument needed to encompass attributes such as effectiveness, efficiency, attractiveness, satisfaction,

engagement, attention, emotion, and perception. To achieve this, established questionnaires—including AttrakDiff, the User Experience Questionnaire (UEQ), mCUE, the System Usability Scale (SUS), the Modified Differential Emotion Scale (mDES), and the User Engagement Scale (UES)—were incorporated into the instrument.

Once the instrument was developed, face and content validity were assessed with the help of five experts. Following this, reliability testing was conducted through a pilot test with 35 respondents. The Cronbach's alpha scores for each component were all greater than 0.80, indicating that the Q-UCHEL items were reliable and suitable for measuring UX in the context of cultural heritage learning through virtual museum technology.

G. Procedure of Evaluation

The recruitment of respondents from a population of 13,584 Universiti Malaysia Kelantan (UMK) students utilized a cluster random sampling technique. Specifically, the sampling frame consisted of 348 students enrolled in cultural heritage studies and heritage conservation, forming distinct clusters within the population. These fields were chosen due to the students' educational background, which likely provided them with knowledge and interest in cultural heritage and Istana Jahar. From this sampling frame, 113 participants were randomly selected, ensuring that each student in the cluster had an equal chance of being chosen for the research. Additionally, Bullen [33] suggests that using 100 participants, or ten percent of the population (if the respondents do not exceed 1,000 per population group), is sufficient for evaluating or validating product development tests. This guideline supports the adequacy of our sample size for this study. The 113 selected participants, aged between 20 and 40 years, were intended to evaluate the UX of a prototype developed according to the proposed UXCHEL framework. The evaluation process involved a survey method with the developed questionnaire. Participants interacted with the prototype as shown in Figure 4 before completing the questionnaires, thereby providing informed feedback on their UX.

IV. RESULT AND DISCUSSION

This section presents the key results derived from the experiment conducted in the authentic learning environment of cultural heritage, specifically centered around the Istana Jahar Museum in Kelantan. Initially, participants were tasked with physically visiting the Istana Jahar Museum. Following this visit, they were given the opportunity to engage with the Istana Jahar Virtual Museum Prototype, designed to facilitate their learning about Kelantan Royal Customs and the impressive architecture of Istana Jahar. This process allowed participants to compare their experiences between using the Istana Jahar Virtual Museum Prototype and physically visiting the museum.

H. UX Factors components

The main component evaluated in this research was the UX factors, represented by the hedonic quality and pragmatic

quality of the application. The elements of effectiveness, efficiency, attractiveness, and satisfaction were assessed and analyzed to understand the reliability of the UX factors within the UXCHEL framework.

Table II presents the analysis of the mean scores and Likert scale points, ranging from strongly disagree to strongly agree, for the components and elements in this research. The mean score for the effectiveness element was 4.487 (SD: 0.589), with 57.52% of respondents strongly agreeing, 33.63% agreeing, and 8.85% being neutral. The mean score for efficiency was 4.363 (SD: 0.621), with 49.56% of respondents strongly agreeing, 37.17% agreeing, and 13.27% being neutral. Consequently, the mean score for pragmatic quality was 4.425 (SD: 0.567).

In contrast, the mean score for the attractiveness element was 4.528 (SD: 0.595), with 61.06% of respondents strongly agreeing, 30.09% agreeing, and 8.85% being neutral. The mean score for the satisfaction element was 4.363 (SD: 0.624), with 48.67% of respondents strongly agreeing, 38.94% agreeing, and 12.39% somewhat agreeing. Additionally, the mean score for the emotion element was 4.401 (SD: 0.598), with 50.44% of respondents strongly agreeing, 38.94% agreeing, and 10.62% somewhat agreeing, with none disagreeing or strongly disagreeing. Therefore, the mean score for hedonic quality was 4.431 (SD: 0.558).

TABLE II. MEAN SCORE FOR UX FACTOR COMPONENT.

Elements	Mean (Std. Dev)		Frequency and Per cent				
			Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
			1.00- 1.80	1.81- 2.60	1.00- 1.80	1.00- 1.80	1.00- 1.80
Pragmatic Quality							
Effective- ness	4.487 (0.589)	N %	0 0.00	0 0.00	10 8.85	38 33.63	65 57.52
Efficien- cy	4.363 (0.621)	N %	0 0.00	0 0.00	15 13.27	42 37.17	56 49.56
Pragmatic	4.425 (0.567)						
Hedonic Quality							
Attractive -ness	4.528 (0.595)	N %	0 0.00	0 0.00	10 8.85	34 30.09	69 61.06
Satisfac- tion	4.363 (0.624)	N %	0 0.00	0 0.00	14 12.39	44 38.94	55 48.67
Emotion	4.401 (0.598)	N %	0 0.00	0 0.00	12 10.62	44 38.94	57 50.44
Hedonic	4.431 (0.558)						

Thus, the elements of effectiveness and efficiency within pragmatic quality, as well as the elements of attractiveness, satisfaction, and emotion within hedonic quality, were deemed reliable for use in the framework developed for the virtual museum focused on cultural heritage learning.

I. User Response Component

One of the primary focuses of this research was the evaluation of the User Response component as the main

output. The elements of Engagement, Attention, and Perception were assessed and analyzed to determine the reliability of the User Response component within the UXCHEL framework. Table III provides an analysis of mean scores and Likert scale points, ranging from strongly disagree to strongly agree, for the User Response component in this study. The mean score for the Engagement element was 4.385 (SD: 0.616), with 49.56% of respondents strongly agreeing, 38.94% agreeing, 11.50% remaining neutral, and none disagreeing or strongly disagreeing. The mean score for the Attention element was 4.366 (SD: 0.619), with 44.25% of respondents strongly agreeing, 41.59% agreeing, 14.16% remaining neutral, and none disagreeing or strongly disagreeing. Furthermore, the Perception element proved to be significant in developing a virtual museum integrated with cultural heritage learning. According to Table 3, the mean score for the Perception element was 4.416 (SD: 0.598), with 50.44% of respondents strongly agreeing, 40.71% agreeing, 8.85% somewhat agreeing, and none disagreeing or strongly disagreeing. Consequently, the mean score for the User Response component was 4.389 (SD: 0.545). These findings indicate that the proposed Engagement, Attention, and Perception elements in the UXCHEL framework for developing a virtual museum focused on cultural heritage learning are essential and reliable for application.

TABLE III. MEAN SCORE FOR USER RESPONSE COMPONENT.

Elements	Mean (Std. Dev)		Frequency and Per cent				
			Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
			1.00- 1.80	1.81- 2.60	1.00- 1.80	1.00- 1.80	1.00- 1.80
User Response Component							
Engage- ment	4.385 (0.616)	N %	0 0.00	0 0.00	13 11.50	44 38.94	56 49.56
Attention	4.366 (0.619)	N %	0 0.00	0 0.00	16 14.16	47 41.59	50 44.25
Percept- ion	4.416 (0.598)	N %	0 0.00	0 0.00	10 8.85	46 40.71	57 50.44
User Response	4.389 (0.545)						

J. Virtual Museum Features Components

The Virtual Museum Features played a fundamental role in this research, enhancing the functionality of the tested prototype. By incorporating learning theories, the research aimed to integrate features such as assessment, interactivity, self-directed learning, and enjoyment within the application to facilitate effective cultural heritage learning and promote a positive UX. Table IV provides an analysis of mean scores and Likert scale points, ranging from strongly disagree to strongly agree, for the elements and components in this research. The mean score for the assessment element was 4.395 (SD: 0.593), with 50.44% of respondents strongly agreeing, 38.94% agreeing, and 10.62% remaining neutral. Similarly, the mean score for interactivity was 4.336 (SD: 0.600), with 47.79% of respondents strongly agreeing, 38.05%

agreeing, and 14.16% remaining neutral. The mean score for the self-directed learning element was 4.469 (SD: 0.573), with 55.75% of respondents strongly agreeing, 35.40% agreeing, and 8.85% remaining neutral. Additionally, the mean score for the enjoyment element was 4.528 (SD: 0.595), with 61.06% of respondents strongly agreeing, 30.09% agreeing, and 8.85% remaining neutral. Consequently, the mean score for the feature component was 4.425 (SD: 0.546).

TABLE IV. MEAN SCORE FOR VIRTUAL MUSEUM FEATURES COMPONENT.

Elements	Mean (Std. Dev)		Frequency and Per cent				
			Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
			1.00- 1.80	1.81- 2.60	1.00- 1.80	1.00- 1.80	1.00- 1.80
Features Component							
Assess- ment	4.395 (0.593)	N %	0 0.00	0 0.00	12 10.62	44 38.94	57 50.44
Interact- ivity	4.336 (0.600)	N %	0 0.00	0 0.00	16 14.16	43 38.05	54 47.79
Self- Directed Learning	4.469 (0.573)	N %	0 0.00	0 0.00	10 8.85	40 35.40	63 55.75
Enjoy- ment	4.528 (0.595)	N %	0 0.00	0 0.00	10 8.85	34 30.09	69 61.06
Features	4.425 (0.546)						

Therefore, based on the analyzed mean scores, the proposed elements in the prototype features—such as assessment, interactivity, self-directed learning, and enjoyment—should be utilized in the UXCHEL framework to rigorously enhance cultural heritage learning in virtual museums. The analysis revealed a remarkable minimum mean score of 4.336 out of 5 among the 113 respondents, indicating strong agreement on the suitability of the UXCHEL framework components for developing applications related to cultural heritage. A detailed analysis of UX parameters showed high mean scores across various dimensions: Effectiveness (Mean = 4.487, SD = 0.589), Efficiency (Mean = 4.363, SD = 0.621), Attractiveness (Mean = 4.528, SD = 0.595), Satisfaction (Mean = 4.363, SD = 0.624), Emotion (Mean = 4.401, SD = 0.598), Engagement (Mean = 4.385, SD = 0.616), Attention (Mean = 4.366, SD = 0.619), and Perception (Mean = 4.416, SD = 0.598). These components collectively contributed to a positive evaluation, as reflected in the high overall UX mean score for the prototype.

V. CONCLUSION AND FUTURE STUDY

The proposed UXCHEL framework has been demonstrated to effectively optimize UX and learning performance. The development and deployment of the Virtual Museum: Istana Jahar application provided empirical evidence supporting this claim. User feedback collected through the developed UX instrument indicated that the application successfully met users' requirements and expectations,

resulting in positive UX. Respondents reported improvements in learning performance and understanding of cultural heritage, particularly related to Istana Jahar and royal Kelantan content. High mean scores for UX factors (Effectiveness, Efficiency, Attractiveness, Satisfaction, and Emotion) and user response (Engagement, Attention, and Perception) affirmed that the framework's elements significantly contributed to a comprehensive UX and enhanced learning outcomes.

In conclusion, the VR Istana Jahar application was highly appreciated by all respondents, who expressed excitement and satisfaction with the implementation of the UXCHEL framework in the prototype development. The respondents found the design to be excellent and attractive, resulting in overall satisfaction with its features, design, and content. This study demonstrates that the elements within the UXCHEL framework effectively enhance UX and are well-suited for cultural heritage learning.

Building on these positive findings, future study should focus on ensuring that virtual heritage environments are accessible and usable for all users, including those with disabilities. It is crucial for future research to identify and overcome barriers to accessibility, such as challenges in navigation, interaction, and comprehension. Researchers should explore the application of universal design principles to create inclusive virtual environments that cater to a diverse user base. This includes examining the use of assistive technologies, alternative input methods, and customizable interface options to accommodate different needs. By prioritizing usability and accessibility, future studies can contribute to creating more inclusive and equitable virtual learning experiences.

ACKNOWLEDGMENT

This research was funded by the Ministry of Higher Education, Malaysia, through the Fundamental Research Grants Scheme (FRGS) [grant numbers: FRGS/1/2022/WAB01/UMK/03/1]. The project, titled "Modeling a Framework of User Experience Assessment for Malaysian Cultural Heritage Using Virtual Museum Technology," falls within the research domain of Natural and Cultural Heritage.

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Dr. Mohamad Shahfik Afendi Bin Abdul Ghani is a Multimedia Lecturer at Universiti Malaysia Kelantan (UMK), with an MSc. in Advanced Multimedia Design and 3D Technologies from Brunel University London. Since 2014, he has been a key contributor to academia, specializing in 3D Technologies, CGI, Stereoscopic, Anaglyph Film, and Virtual Reality Heritage. He is actively engaged in research and publications, particularly in the fields of Human-Computer Interaction (HCI), cultural heritage, and digital technology. His PhD focuses on User Experience (UX) and Virtual Reality in Cultural Heritage Learning, where his research continues to push the boundaries of how digital technologies can enhance the preservation and education of cultural heritage. He can be contacted at email: afendi.ag@umk.edu.my



Sudirman bin Kiffli earned his Master's degree (MA) in Literature from the School of Humanities, Universiti Sains Malaysia. He began his career in higher education in Malaysia in 2014. Currently, he is a lecturer at the Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan. Actively engaged in teaching and learning, as well as research related to literature, he specializes in Modern Literature. His research focuses on the application of contemporary technology to revitalize the field of literature, which is often perceived as fading over time, by bringing it to life across various digital mediums in line with current technological advancements. Corresponding author can be contacted via email at sudirman.k@umk.edu.my.



Tenh Hock Kuan. He is a lecturer in multimedia at the Department of Creative Technology, Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan (UMK). He holds a Bachelor's degree in Multimedia with Honors and a master's degree in information technology, both from Universiti Utara Malaysia. Since beginning his academic career in 2014, He has pursued research interests in multimedia applications, digital storytelling, human-computer interaction, and digital heritage. His latest research focuses on the use of augmented reality in heritage preservation. He also teaches a wide range of multimedia courses, sharing his expertise with students in the faculty. He can be contacted at email: kuan.th@umk.edu.my



Associate Professor Ts. Dr. Syadiah Nor binti Wan Shamsuddin. She has a comprehensive academic background, beginning with a Diploma in Information Technology from UniSZA, earned in 1997. She then pursued a Bachelor's degree in information technology from Universiti Kebangsaan Malaysia, which she completed in 1999. Her pursuit of advanced knowledge led her to the University of Bradford, UK, where she obtained her Ph.D. in 2012. Her research interests

include virtual reality, the metaverse, user interaction, and e-learning. Her work focuses on developing and enhancing virtual learning environments and understanding how technology affects human interaction and educational processes. In addition to her role as a senior lecturer, she is an active member of the Metaverse Special Interest Group (SIG) and the Advanced Multimedia Research Group. She can be contacted at syadiah@unisza.edu.my.



Dr. Normala Binti Rahim received the Diploma and Bachelor's in photography and creative Imaging from the Universiti Teknologi MARA (UiTM), in 2006 and 2008, respectively. She awarded the master's and PhD degree in Information Technology from the Universiti Kebangsaan Malaysia, in 2012 and 2020, respectively. She is currently a senior lecturer at Faculty of Informatics & Computing, Universiti Sultan Zainal Abidin (UniSZA). She is also a member of Metaverse

Special Interest Group, Cluster of Smart Technology and System, UniSZA. Her research interests include human-computer interaction that includes the Metaverse, user interaction design, usability & user experience, virtual and augmented reality, e-learning, and multimedia application. She can be contacted at email: normalarahim@unisza.edu.my