

## USERS EXPERIENCE PERSPECTIVE IN EXPLORING AN ANCIENT MANUSCRIPT USING AUGMENTED REALITY APPLICATION

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**ABSTRACT.** *Augmented Reality (AR) has begun to play an important role in the preservation of cultural heritage. It has been used to make artefacts and cultural heritage environments accessible to the general public by utilizing the real world as a substrate and augmenting it with computer-generated information. This paper presents the use of digital technology, in particular augmented reality, in a mobile application for exploring an ancient manuscript in the cultural heritage gallery. This study measures what effect the use of AR in mobile applications has on the Visitor Experience (VX). Terengganu Cultural Heritage Mobile Application (TCHMA) is an AR mobile application that has been developed to portray rare and ancient Quran manuscripts in the cultural heritage gallery, taking account of all essential criteria for each artefact's unique characteristics. A study with 31 participants was conducted to investigate visitor experience using the Museum Experience Scale (MES). The results showed a positive experience score on all MES components, with the component of engagement having the highest score, followed by knowledge and learning. The findings indicate that the TCHMA as an AR artefact, incorporates all four components and succeeds in creating an engaging experience for visitors. This study provides insight into the role of AR in depicting artefacts and the visitor's experience in interacting with them.*

**Keywords:** Augmented reality, Mobile application, User experience, Visitor experience, Cultural heritage

1. **Introduction.** Cultural Heritage (CH) is defined as “the treasure of physical artefacts and intangible elements of a group or society inherited from previous generations, preserved in the present, and bestowed for the benefit of future generations” [1]. Paintings, sculptures, coins, and manuscripts are examples of tangible cultural heritage that

can be touched and moved, whereas intangible cultural heritage includes aspects such as oral traditions and expressions, music, social practices, and rituals [1,2]. Creating a virtual environment to coexist with the real world is regarded as the most dynamic and interactive method of integrating a culture's environment, artefacts, and knowledge. Augmented Reality (AR) has become one of the most popular methods for re-enacting past cultural elements such as artefacts, manuscripts, and monuments and connecting them with their original spaces [3]. These advancements of digital technologies are becoming more common and play an important part in the development, sharing of information, and enhancement of Cultural Heritage (CH).

The integration of technology in cultural heritage exhibitions "lies in the blending, not the separation, between the virtual and real worlds" [4,5]. AR technologies have the potential to capture the attention of visitors and encourage them to interact more actively with artefacts [4,6]. When it comes to cultural galleries, the use of AR, in particular, has the potential to improve and enhance visitor experiences [6,7]. The use of mobile AR applications, particularly, is becoming more ubiquitous in cultural heritage exhibitions, and the use of them is fundamentally altering the museum experience [8].

The journey to explore artefacts beyond the physical object and into the virtual environment will be exciting, enthralling, and inspiring [9]. This happens due to the fragility of historical artefacts; museum visitors or cultural heritage galleries are frequently prevented from directly touching and exploring the artefacts. However, with the help of technology, visitors can feel engaged with the cultural heritage artefact collection and improve their digital experience while visiting [10].

An AR application can contribute to the preservation of historical objects by educating visitors about the significance of preserving cultural heritage through the exploration of ancient manuscripts. AR provides a unique opportunity to satisfy visitors curiosity about the past and provide insight into the lives of people from different time periods [11]. Moreover, exploring an ancient manuscript with augmented reality combines the thrill of using cutting-edge technology with educational content, making it an attractive option for visitors who are frequently anxious to try out innovative technology for the first time.

Terengganu Ancient Quran manuscripts are valuable cultural artefacts, especially for the local people of Terengganu. Since the illumination and ornamentation of these Quran manuscripts is similar to the design of silver art and wood carvings that adorn ancient houses, mosques, and palaces on the East Coast, particularly in Terengganu, it demonstrates the need to recognize and preserve local wisdom for future generations [12].

In this article, we will look at how an AR mobile application was developed and can be used to preserve the Terengganu ancient Quran manuscript, as well as contributing factors that can enhance the user experience when exploring an ancient manuscript with technology. The Terengganu Quran manuscripts, which are said to be between 100 and 200 years old, are also known as the most beautiful Quran manuscripts in Southeast Asia due to their elaborate and intricate carvings. Unfortunately, due to their fragile condition and deterioration, these Quran manuscripts cannot be displayed to the public and were carefully placed at the Terengganu State Museum Board (LMNT).

This ancient manuscript has been transformed into 3D visual objects using AR technologies and displayed on portable devices such as mobile phones and tablets to create augmented spaces. Through the layering of content, applications, and technical infrastructure over real-world locations, 3D visual objects of Quran manuscripts and digital information can increasingly coexist, interact, and complement each other [13]. In other words, AR visually connects the physical and digital worlds. Even without the presence of physical objects, it provides the user with a composite view that combines the visitor's actual scene and computer-generated virtual scenes [14].

Today, various technologies have been integrated into cultural heritage exhibitions.

- i) The exhibition of cultural heritage has become more useful for knowledge transmission, particularly for accessing artifacts information;
- ii) A well-designed AR application can better attract people, and easily direct the user's attention to cultural objects;
- iii) The primary focus should be on drawing attention to cultural objects rather than simply highlighting the technological medium [15].

The following section will provide an overview of the use of augmented reality in cultural heritage, a definition of user experience, factors that contribute to the engagement and enhancement of visitors' experiences using digital technology, and a system design for the Terengganu Cultural Heritage Mobile Application (TCHMA). This paper will also present development and methodology-related data in the following section before moving on to results and discussion. Finally, in the final section, the study's conclusion is presented.

## 2. Literature Review.

**2.1. Augmented reality and cultural heritage.** Augmented Reality (AR) is a technology that can transform an existing environment into a digital context. AR is defined as a system that i) combines the physical and virtual worlds, ii) allows for real-time interaction, and iii) enables 3D virtual objects to coexist in the same space as the real world [1,16,17]. It enables the real-time combination of digital and physical information via various technological formats such as tablets or smartphones to create this new reality, which has had an impact on the number of AR applications developed [18,19].

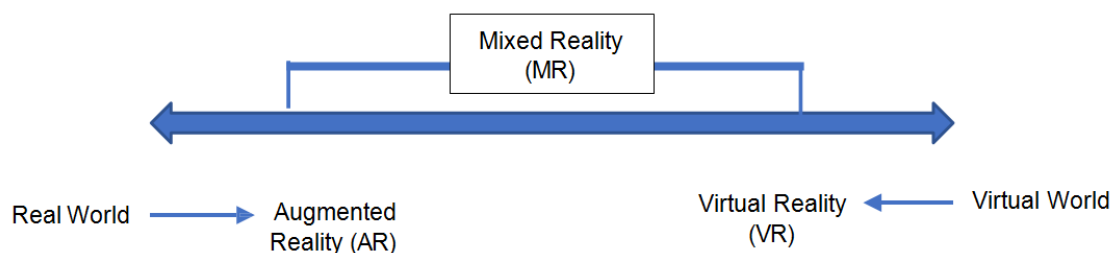


FIGURE 1. The Milgram and Kishino reality-virtual continuum [20]

In the past few decades, there has been a lot of growth in the use of digital technologies like Augmented Reality (AR) and Virtual Reality (VR) in cultural heritage with the goal of giving visitors digital and immersive experiences [21]. Technological advancements have played a pivotal role in the preservation and display of historical artefacts [8]. Location-aware audio guides, web based and mobile applications, games, interactive multi-touch displays, virtual/augmented reality systems, 3D virtual worlds, and other types of installations, including kinesthetic control, are all used in CH [7]. Methods such as 3D scanning, digital archive repositories and photogrammetry have been adopted as ways to preserve heritage, particularly for physical artefacts and historical sites [13].

AR applications in cultural heritage are mostly used to improve digitization, documentation, digital preservation and exploration of artefacts and cultural sites [7]. AR applications that are frequently used in cultural heritage can be classified into three categories: marker-based, marker-less, and hybrid tracking approaches [22]. AR systems can be either indoor or outdoor. Indoor AR employs marker-based tracking and does not require GPS.

Meanwhile, outdoor AR, is heavily reliant on marker-less and hybrid tracking [22,23]. On the other hand, a well-designed AR application, can better promote and direct the

user's attention to cultural objects instead of just drawing attention to the technological itself [15]. When it comes to cultural heritage exhibitions, such as museums and galleries, there are four forms of augmented reality [15]:

- **Outdoor guides and explorers:** There were environments created to be experienced outside of museums (for example, archaeological sites);
- **Interpretive mediation:** This is a form of augmented reality that allows access to digital information about the observed work;
- **New media art and sculpture:** This is where artists use augmented reality to create art;
- **Virtual exhibition:** Augmented Reality (AR) is used to create virtual exhibitions in which virtual objects are blended with the physical world as seen through the mobile device.

Because of this AR form, there are new and exciting ways for visitors to connect with and interact with the cultural objects.

AR as a digital tool for preservation cultural heritage, is more essential because of multiple factors, like deteriorating materials, natural phenomena like hurricanes, earthquakes, tsunamis and a few other natural disasters, as well as wars [7,24]. The main reasons for preserving CH, and artefacts particularly are i) to create a 3D digital replica, ii) to create and compile a list of databases containing information about the shape, size, texture and appearance of a physical object or artefact, and iii) to design and develop new types of applications based on the digital media collection with the goal to enhance user experience when interacting with the objects or artefacts [7]. According to the finding of the survey [22], augmented reality is preferable for enhancing exhibitions and, in particular:

- **Education** which aims the visitors enabling to learn about the history;
- **Exhibit enhancement** at physical museums, cultural heritage galleries and heritage sites;
- **Exploration** will assist visitors in terms of visualizing and exploring previous historical events;
- **Reconstruction** allows visitors to visualize and interact with restored historical views of CH;
- **Virtual museums** allow the visitor to experience and learn about cultural heritage (tangible and intangible).

It has been discovered [25] that visitors who explore the collections in a digital context might have a better sense of control over the experience, and even express more emotions towards the digital representations than they do towards the real objects [26].

The TCHMA project is particularly focused on using AR in the context of ancient manuscripts, specifically the Quran. The project intends to use AR technology to improve preservation, exploration and enhance the digital experience for visitors by bringing the ancient manuscripts to life. Visitors can interact with the digital representation of the ancient manuscripts, by zooming in on details, flipping through pages, and exploring the intricate carving details, calligraphy, and artistic elements while maintaining the authenticity of the original manuscripts. This AR application can provide visitors with an immersive experience as if they were holding the ancient manuscripts in their hands, compared to viewing them through a display glass with a static object in an exhibition.

**2.2. Terengganu ancient Quran manuscript.** Heritage and culture are essential components of any country. They represent the people's values and traditions in that country. Terengganu is well known for its unique traditions and historical heritage. The Quran manuscript is one of Terengganu's most valuable historical artefacts. Manuscripts are old

documents that were written by hand before the Quran and books were printed [27]. The Terengganu Quran manuscripts, said to be between 100 and 200 years old, are known to be the most beautiful in Southeast Asia because of their elaborate and intricate carvings. Terengganu is known for producing beautiful and luxurious Quranic manuscripts in the 19th century. This beautiful manuscript is a great example of the state's rich and thriving Islamic art, and it is well known throughout the Malay world [28].

The production of lavish and beautiful manuscripts at that time was certainly supported by the Terengganu Palace, as the efforts to produce them would require high-quality expertise and materials [12]. The findings show that Terengganu Quran manuscripts have become collections in several museums and archives in Malaysia, Indonesia, Thailand, and Singapore. This diaspora occurs because the Terengganu Quran manuscript was known for its beauty and was in high demand in the 19th century by sultanates in Southeast Asia, who used the manuscript for coronation and study purposes [29].

The illuminated al-Quran manuscripts from Terengganu are some of the most beautiful pieces of Islamic art from Southeast Asia. The decoration on his frame and the fact that his calligraphy is very fine, beautiful, and delicate show how precise and beautiful his work is. In the Malay world, the neatness and quality of the volume generated make it highly valuable. However, there is still a lack of awareness and knowledge about the preservation of ancient Quran manuscripts. Aside from that, experts are intrigued by the range of embellishments illustrated in this al-Quran manuscript. There are not many Malay manuscripts with ornaments like the al-Quran manuscripts. This Quran manuscript also shows the expertise of previous scholars, who not only excelled in Arabic calligraphy but were also experts in rasm, fawasil, and dabt al-Quran [41].

The manuscripts are on display at the Terengganu State Museum Board (LMNT), but visitors are not allowed to touch them due to concerns that doing so would damage them. The Terengganu State Museum Board (LMNT) is where the majority of this valuable heritage will be preserved. According to records, the LMNT has eight Terengganu Quran collections that are not on display, despite the fact that they are a heritage that should be appreciated by the local community, as well as visitors to the museum. To solve this issue, 3D Augmented Reality (AR) technology was used to show the public this valuable manuscript while keeping and protecting it from deterioration.



FIGURE 2. Terengganu Quran manuscript in LMNT collections

**2.3. Visitor's experience.** Technology can be used to create experiences that are interesting and engaging on their own, which not only draw people in but also satisfy their own interests [4]. At the moment, many digital applications have been developed and are available in the museum to help visitors learn more about the collections and engage with the artefact's objects. Museums have transitioned from a collection-centric to a user-centric paradigm in terms of human involvement and participant interaction by leveraging digital tools to improve information exchange [46]. The use of digital technology would enhance



FIGURE 3. The condition of the back cover on Terengganu Quran manuscript

the visitor experience and evoke the visitors' engagement, resulting in their interest in the artefacts [30]. Visitors can enhance and transform their experience beyond the physical objects on display [31,32]. Most museums believe that visitors will have a better time if they can get information that goes far beyond what is on display panels and in exhibits [10].

Emerging technologies in cultural spaces should not be regarded as a replacement for curated tours, but rather as additional ways to connect and engage visitors with artefacts (objects), collections, and exhibits [43]. Historical artefacts help us connect with our ancestors by providing a strong link to the past and how other cultures lived [8]. Cultural heritage digitization offers a new way of displaying work and objects that capture visitors and enhance their experience, as well as improving scenography and exhibitions, making the museum or gallery more accessible to a wider audience [44,45]. The utilization of digital technology such as the AR application can ignite visitors' interest in history, artefacts, and historic sites.

People go to museum or art gallery exhibitions so that they can see the actual artefacts. On the other hand, the museum's artefacts are either enclosed in glass cases or presented on picture posters [9]. Many genuine artefacts have been discovered broken and damaged, and there are some artefacts that, when displayed, visitors are unable to see and appreciate the design or pattern clearly. Visitors can have novel experiences with real space and virtual things merged by employing immersive reality technology as a supporting tool in museum or gallery displays [46]. Visitors can enhance their experience by exploring, observing artefacts from various perspectives, peeking inside, or receiving a complete visual of damaged artefacts by using the AR application. AR applications are designed to allow visitors to reconstruct historical artefacts without physically interfering with the artefacts themselves [47]. Interacting with the virtual artefacts object in real space will provide visitors a new experience that they never encountered before.

**3. Development of TCHMA.** This section discusses the development of the Terengganu Cultural Heritage Mobile Application (TCHMA) as a medium for displaying 3D augmented reality visualizations of ancient manuscripts in order to provide visitors with information. AR applications seek to facilitate interaction between the real and virtual worlds through the use of marker-based AR systems on desks and in rooms that enable visualization [47].

**3.1. System design.** The Terengganu Cultural Heritage Mobile Application (TCHMA) is being developed in order to conserve this exquisite ancient manuscript in excellent

condition while also displaying it to the public. It is anticipated that this interactive approach will give visitors an engaging experience that will help them appreciate cultural treasures through the AR application that has been created [6]. TCHMA is created through a five-stage process, starting with camera capture, image processing, interaction handling, simulation information management, and rendering, as seen in Figure 4.

Camera	Digital image processing	Engineering analysis and simulation	Rendering
<b>Digital Single-Lens Reflex (DSLR) camera</b> <ul style="list-style-type: none"> <li>Capture image using high resolution</li> </ul>	<ul style="list-style-type: none"> <li>Use computer to process the image stream captured by DSLR camera</li> </ul>	<b>Analysis and simulation module</b> Pre-processing, processing, post-processing	<b>Visual rendering using Vuforia.</b> <ul style="list-style-type: none"> <li>Visual presentation of simulation data.</li> </ul>
		Link to commercial software	
Main workflow of AR-based engineering analysis and simulation system			
Display		Tracking process	Human-computer interaction
Hand-held display (HHD) <ul style="list-style-type: none"> <li>Taking AR outdoor</li> <li>Light-weighted</li> </ul>		<b>Sensor based tracking</b> <ul style="list-style-type: none"> <li>Fast and robust</li> <li>Each type has different limitation</li> </ul>	<b>3D input device</b> Track the position and orientation of the interaction device. (e.g.: Marker stylus)
	<b>AR Environment Setup</b>		
<b>Large share of market</b>	<ul style="list-style-type: none"> <li>Real workspace and world coordinate system</li> <li>Human computer interaction functions</li> <li>Real and virtual components</li> </ul>	<ul style="list-style-type: none"> <li>Large share of market of IMU embedded device</li> </ul>	<b>Hand based device</b> <ul style="list-style-type: none"> <li>Tangible user interface</li> <li>Bare-hand interface</li> </ul>

FIGURE 4. The five-stage development of TCHMA

As for the design of the user interface, the menu screen will show a welcome screen first, and then it will show each design of manuscript based on AR marker. Users can augment, view, and flip pages of the manuscript on the screen, and users can also enlarge or reduce the 3D view of the manuscript. Apart from that, users can also see a pop-up menu of information about the manuscript. At the bottom of the manuscript design, there is a box of information about the uniqueness and privilege of the manuscript design, in which users can scroll up and down to read information about the manuscripts as shown in Figure 5.

The user experience in using this AR application compared to the exhibition of manuscripts without the help of technology is that, users have the opportunity to explore the



FIGURE 5. Screenshots show the TCHMA in use.

uniqueness and beauty of this manuscript with the process of enlarging and zooming into the screen to look at the view of the 3D image more closely. Users can also experience the manuscripts from various angles using AR technology. Visitors or users will not be able to explore the beauty of these ancient manuscripts without the help and support of technology. This is because these ancient manuscripts are very valuable and tangible artefacts that are fragile and are usually only exhibited in closed glass cases or through poster images.

**3.2. System implementation.** A user study was conducted to measure what effect the use of AR in mobile applications has on the visitor's experience when exploring digital ancient manuscripts. The data collection was carried out at the Cultural Heritage Digital Gallery (CHDG) at the Sultan Mahmud Islamic Centre, University Malaysia Terengganu. A call for study participation was sent through fliers put up outside the university's mosque and the gallery, and through email to selected university members with an interest in the gallery.

The digital manuscripts were exhibited in the central corridor of the entrance floor of the Sultan Mahmud Islamic Centre, University Malaysia Terengganu. Figure 6 depicts the setup. Six rectangular tables were used to display AR markers for the visitors' activities



FIGURE 6. Six rectangular tables were used to display AR markers.



as they entered the area. Posters with an AR marker, in particular, were used to cover the table. Participants will choose a tablet or iPad to augment, read, and view the 3D manuscripts (see Figure 5). At the end of their visit, people who used AR applications at this ancient manuscript exhibition were asked to fill out a survey to rate how engaged, knowledgeable, meaningful, and emotional they felt.

#### 4. Evaluation of TCHMA.

**Museum Experience Scale (MES).** The Museum Experience Scale (MES) by Othman et al. [42] is an instrument used to measure visitors' museum experiences. MES had been referred to and used as an evaluation instrument in a number of studies related to cultural heritage that used different types of technologies; AR [33,34], and VR [35].

There are four components to MES; i) engagement, ii) knowledge/learning, iii) meaningful experience, and iv) emotional connection, with each component consisting of five criteria. The engagement component refers to how involved the visitor was with the exhibitions and displays. The criteria measure how enjoyable, engaging, interesting, and inspiring the visit was for the visitor. The knowledge/learning component is about the information that the exhibits give, including the graphics, how clear the information is, and how well the visitor understands it. Meanwhile, the meaningful experience component consists of a scale that focuses on how the visitor reflects, thinks, makes sense, wants to know more, and feels satisfied with what they just experienced. The fourth component is an emotional connection. It looks at how the visitors reminisce about the past, the sense of being, the sense of overwhelming, wanting, and their connectivity with the exhibits.

The questionnaire was divided into four sections: demographics, computer experience, information about gallery visitors, and gallery visitor experience. Quantitative approaches were used in the design of this study. A survey was conducted using the Museum Experience Scale (MES). A questionnaire consisting of 20 items measuring the main 4 constructs of the study was calculated using a 5-point scale ranging from strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5.

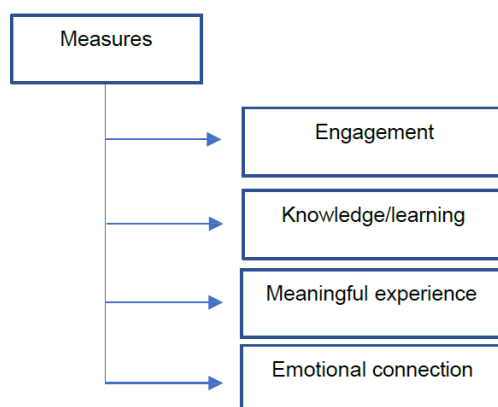


FIGURE 7. Museum Experience Scale (MES) by M. K. Othman et al.

This study involved 31 visitors who volunteered to participate in the study during their visit to the gallery. During the course of this study, ten mobile devices were used, including three Apple iPad Pro 11 (First Generation) units and seven Samsung Tab S5e units. The Apple iPad Pro 11 or the Samsung Tab S5e were given to participants at random.

There is a procedure participants must follow prior to beginning their exploration of the ancient digital manuscript at the gallery. Upon the arrival of the participants, there were briefing sessions to explain an instruction. They were informed that their tour would

be recorded for study purposes. The experimenter will explain the purpose of the study during the briefing. The participants were then provided with a consent form. The participants were then instructed to read and complete the consent form, and they were informed that they could withdraw from the study at any time. Participants were informed that they could spend as much time as they wanted exploring the gallery and digital ancient Quran manuscript, as well as asking questions. Participants were asked to complete a questionnaire after the visit. The researcher thanked the participants for their involvement in the study and gave them each a souvenir.



FIGURE 8. Participants who visit the digital gallery

## 5. Results and Discussion.

**5.1. Demographics of the visitors.** Profiles of 31 visitors who volunteered to participate in this study explained briefly in this section using descriptive analysis. This section intends to report the demographic profile of participants in terms of gender, race, religion, age, state, education, visitor's computer experience and their knowledge about augmented reality. This section also includes questions about how much time the participant spends at the Cultural Heritage Digital Gallery (CHDG), whether they come alone or with a friend, i.e., the dynamic form of the visitors, the type of mobile technology they use and carry during their visit, the reason for their visit, whether this is their first visit to the CHDG, and how much they enjoyed their visit.

Among the 31 respondents, 51.6% were female ( $n = 16$ ), and 48.4% were male ( $n = 15$ ). The age range of participants in this study mostly ranged from 41 to 60 years old, with a total percentage of 38.6%. Despite that, 35.5% of the respondents were 21 to 40 years old, 19.4% were no larger than 20 years old, and 6.5% were larger than 60 years. With regard to education, participants who obtained their first degree and diploma (graduate level) contributed a total of 45.2%. Besides that, participants who finished their school level accounted for only 48.3%, while the lowest percentage were participants who finished their highest education level (postgraduate level), which accounted for only 6.5%. In terms of computer literacy, over half of participants (58.1%) have more than 10 years of experience. Meanwhile, 22.5% for 6 to 10 years' experience and 19.4% for 1 to 5 years of computer experience according to the table, 96.8% of the participants were visiting CHDG for the first time, while 3.2% had previously visited the gallery.

For categories of race and religion, Malay and Islam constituted the huge majority of the respondents, with 96.8%. Indians and Hindus, in turn, accounted for 3.2% of the total participants in this study. The majority of participants are from Terengganu with a percentage of 61.3%, followed by Negeri Sembilan with 13%, Kelantan with 9.7%, and Pahang, Selangor, Pulau Pinang, Johor, and Perak with 3.2%, respectively. These two

TABLE 1. Participant's demographic information

Categories	Percentage %
Gender	
Male (n = 15)	48.4%
Female (n = 16)	51.6%
Age	
≤ 20 years	19.4%
21-40 years	35.5%
41-60 years	38.6%
> 60 years	6.5%
Education	
School level	48.3%
1st degree	45.2%
Postgraduate	6.5%
Computer literacy	
1-5 years	19.4%
6-10 years	22.5%
> 10 years	58.1%
Frequency visit	
1st time visit	96.8%
> 1st time visit	3.2%

questions were taken into consideration because the artefacts are associated with a specific religion and faith, and because they are located on the east coast of Malaysia.

Next, the surveyed data was also analyzed to identify the time spent at the CHDG. Approximately 51.6% of participants spend less than an hour, 25.8% spend less than 30 minutes and 22.6% spend more than an hour. According to the survey data, the majority of participants, 74.2%, visit the CHDG with others, while only 25.8% visit the gallery on their own. 32.3% of those who visit the gallery come in pairs, while 41.9% come in groups of three or four. Overall, it can be said that almost all participants brought their mobile phones when visiting CHDG, which was 96.8%, with only 3.2% not bringing a device during the visit. Besides using mobile phones, other mobile technologies were also brought and used during participants' visits to CHDG. There were 32.3% of participants who brought and used an iPad or tablet. Furthermore, 29% of participants brought and used a camera, 22.7% brought a video camera, and 6.4% brought a laptop. Only, 3.2% of participants did not bring any mobile technology, while only 6.4% brought and used only mobile phones. In accordance with the data, 64.5% of participants come to the CHDG with the intention of visiting the gallery, 25.8% come to find information, and 9.7% come to pass the time. In the survey, more than half of the participants (51.6%) were unfamiliar with augmented reality technologies, while 48.4% were familiar with them.

**5.2. Reliability test.** Cronbach's alpha model was used to test the reliability of the instrument. There was little change in the translation of the question items during the research. The questionnaire contained items relating to four components: engagement, knowledge/learning, meaningful experience, and emotional connection. From Table 2, it is clear that the Cronbach's alpha for all the instruments valued ranged between 0.765 and 0.910, which is considered fairly high and reliable [38].

TABLE 2. Cronbach's alpha model

	Cronbach's alpha	Number of items
Engagement	0.910	5
Knowledge/learning	0.838	5
Meaningful experience	0.804	5
Emotional connection	0.765	5
Total item		20

## 6. Discussion.

6.1. **Engagement (E).** According to the results shown in Table 3, engagement (E) has the highest mean score ( $M = 4.86$ ,  $SD = 0.255$ ). According to the survey results, 87.1% of participants strongly agree that they “enjoy visiting the exhibits”. Furthermore, 77.4% of participants strongly agree that “they felt engaged with the exhibition”. Moreover, 83.9% of participants strongly agree that they “learned something new from the exhibition”, 96.8% of participants strongly agree that “the exhibition held their attention” and 87.1% participant strongly agree that their “visit to the exhibition was inspiring”.

TABLE 3. Mean and Std. Dev. for each component

Components	Mean	Std. Dev.
Engagement (E)	4.86	0.255
Knowledge/learning (KL)	4.78	0.336
Meaningful experience (ME)	4.60	0.444
Emotional connection (EC)	4.54	0.472

6.2. **Knowledge/learning (KL).** Knowledge and learning have the second highest mean score ( $M = 4.78$ ,  $SD = 0.336$ ), as shown in Table 3. This is primarily due to the information that visitors can obtain from the TCHMA, as well as how well the visitor understands the virtual objects on display. According to the survey questionnaire, 87.1% of the participants strongly agree that the “information provided for the exhibition is very clear”. Meanwhile, 71% strongly agree that they “understand most of what they saw during their visit to the exhibition”. Furthermore, 77.4% of participants strongly agree that “the visit can enrich their knowledge and understanding of a particular exhibition” and “love the graphics associated with the exhibition to display the information” 80.6% strongly agree “they discovered new information from exhibition”.

6.3. **Meaningful experience (ME).** The meaningful experience is represented by the mean score in Table 3 ( $M = 4.60$ ,  $SD = 0.444$ ). A meaningful experience could denote an impactful experience that went beyond the acquisition of information [34]. “The importance of this exhibition” is strongly agreed upon by 67.7% of participants. Meanwhile, 74.2% of those who saw the exhibition are “still interested in learning more about the exhibition's topic”. Only 48.4% of participants strongly agree that “they only thought about the exhibition during their visit”. While 61.3% of participants strongly agree that “visiting exhibitions like this makes them feel very satisfied”. 77.4% of respondents strongly agree that “visiting the exhibition provided them with an entirely new experience”.

6.4. **Emotional connection (EC).** Finally, emotional connection has the lowest mean score ( $M = 4.54$ ,  $SD = 0.472$ ) in Table 3. According to the findings of [34] and [35], visitors were more likely to be engaged when they were emotionally attached to the exhibits, especially if the objects or artefacts reminisced about the past or were indirectly connected with them. 51.6% of participants strongly agree that the “exhibition allows them to reminisce on their past” and that they are “immersed in the exhibition’s world”. Meanwhile, 77.4% of participants strongly agree that “the aesthetic aspect of the exhibition overwhelmed them”. “They feel connected to the exhibition”, said 58.1% of participants. Meanwhile, 71% of participants strongly agree that “attending an exhibition like this provides them with valuable experience”.

TABLE 4. Descriptive statistics for individual items

Item	Measurement	Mean (Standard Deviation)
<b>Engagement</b>		
1	I enjoyed visiting the exhibits.	4.87 (.341)
2	I felt engaged with the exhibition.	4.77 (.425)
3	I learned something new from the exhibition.	4.84 (.374)
4	The exhibition held my attention.	4.97 (.180)
5	My visit to the exhibition was inspiring.	4.87 (.341)
<b>Knowledge/learning</b>		
1	The information provided about the exhibits was clear.	4.87 (.428)
2	I could make sense of the most of what I saw and did at the exhibition.	4.68 (.475)
3	My visit enriched my knowledge and understanding about specific exhibits.	4.77 (.425)
4	I discovered new information from the exhibits.	4.81 (.402)
5	I like graphics associated with the exhibition.	4.77 (.425)
<b>Meaningful experience</b>		
1	During my visit I was able to reflect on the significance of the exhibits and their meaning.	4.65 (.551)
2	After visiting the exhibition, I was still interested to know more about the topic of the exhibition.	4.71 (.529)
3	During my visit, I put a lot of effort into thinking about the exhibition.	4.29 (.824)
4	Visiting this exhibition makes me feel satisfying.	4.58 (.564)
5	Visiting this exhibition gives me a new experience about visiting exhibition.	4.77 (.425)
<b>Emotional experience</b>		
1	The exhibition enabled me to reminisce about my past.	4.26 (.965)
2	My sense of being in the exhibition was stronger than my sense of being in the real world (reversed relation).	4.39 (.715)
3	I was overwhelmed with the aesthetic/beauty aspect of the exhibits.	4.77 (.425)
4	I feel connected with the exhibits.	4.55 (.568)
5	Visiting this exhibition makes me have a valuable experience.	4.71 (.461)

**7. Conclusion.** This paper has presented the use of digital technology, in particular, augmented reality, in mobile applications for exploring an ancient manuscript in the cultural heritage gallery. This study measures what effect the use of AR in mobile application has on the visitor experience. Terengganu Cultural Heritage Mobile Application (TCHMA) is an AR mobile application that has been developed to portray rare and ancient Quran manuscripts in the cultural heritage gallery, taking into account all essential criteria for each artefact's unique characteristics. A population sample of 31 visitors of different types, i.e., individuals, pairs, or groups of three or more, who visited the gallery indicated that half of the visitors had experience with AR applications before. An adapted MES instrument with 20 questions was used to investigate visitors' experiences between the technology and the artefact.

In conclusion, the usage of AR as a digital preservation tool for cultural heritage has proven to be an effective tool for the visitors to visualize and experience rare and ancient artefacts. In addition, the study also revealed that the use of TCHMA as an AR artefact managed to establish engagement with the visitors. One of the lessons that can be learned from this study is when dealing with emotional connection, it is pertinent to consider the nature of the artefact itself. If the artefact is so rare and ancient that it almost has no connection with the current generation, to consider reminiscing as one of the criteria for emotional connection is challenging. Perhaps one of the ways to overcome this is by supporting the content of AR with some interactive storytelling to trigger some emotional connection [47].

Due to the very strict operational procedures during the pandemic, the limitation of the study was the number of participants involved, which could better reflect the population. Further studies may consider the qualitative data and findings to further understand the engagement of the visitors and the artefact. Overall, the findings of this study could help cultural heritage institutions that serve as informal education settings find ways to deliver information to visitors through appropriate mediums, benefiting both visitors and the institution.

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