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Evaluation of Augmented Reality Application Development for Cultural Artefact Education

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ABSTRACT This paper presents the evaluation of Augmented Reality Application development for the educational purpose of Palembang cultural artefacts in Sultan Mahmud Badaruddin II (SMB II) Museum. The method applied in this study effectively developed an AR application to visualize the 3D object of SMB II Museum collections and created new digital 3D objects of Palembang cultural artefact which no longer exist. The digitization of the collection is an innovation that provides new culture learning experiences utilizing AR technology and also contributes to the preservation of Palembang cultural artefacts. Users can interact directly with these artefacts virtually which cannot be performed in the real environment but AR enabling it. In term of effectiveness and efficiency, some testing scenarios were performed. The results showed that the application could run its functionality as designed with time responsiveness for detecting marker was 0.599 seconds on average. App usability was also evaluated using the SUS method. The SUS survey score of 78.3 showed that the developed AR of the SMB II museum was acceptable by two variations of the millennial user. The augmented reality (AR) application is proposed as a medium to support the services of SMB II museum for education that effective improving users knowledge by 28.5% after using the App. The use of AR in the SMB II Museum leads to an enhanced interactive learning experience that promotes cultural heritage preservation in Palembang Indonesia.

KEYWORDS Augmented Reality; Application Development; Cultural Artefact; Education; Virtual Museum.

I. INTRODUCTION

THE Augmented Reality innovation has provided a new platform to view virtual and real objects simultaneously in a real environment. AR technology is an interactive system that put virtual objects into the real environment. It blends virtual and real information in such a mobile device or other that gives a better visualization of the real-world object with 2D images or 3D objects. This feature indicates that AR could enhance the learning experience [1] that transform traditional learning into virtual learning environment and able to enriched print media [2] for interactive learning. Previous researches have proved that visualization provided a better way in learning for memorization because through an image, students are able to obtain a lot of ideas then common way such as reading or listening [3], and many other to enhance learning experience [4, 5]. The rapid development of AR technology enables novel learning model, especially for heritage education.

SMB II Museum has been playing an important role in Palembang heritage preservation. It has mission not only to store, collect, display the cultural heritage artefact but also to educate the visitor regarding the preservation of cultural heritage. In past few years, the number of SMB II Museum

visitors is slightly increasing and comes from many countries. However, the traditional management of museum can stay still as it is in the past just to keep it's ancient it needs to improve its performance by adding a creative element such as information technology application. Fast development in the field of mobile device that is simplified interfaces and simple to use adds significant values to the Museum for service quality improvement.

Our previous study has made a web-based application implemented in the SMB II Museum as media of documentation system for digital inventory provided resistance and more efficiency for museum operation. It has made the information about Palembang cultural artefact stored in SMB II museum and also historical building can be accessed easily anywhere and anytime [6]. However, the application has not been effectively used as a medium for cultural artefacts education due to limitations in visualizing objects in 2D form and not based on mobile applications. The promising solution to overcome this problem is AR technology that has proven can assist the educator more and deliver educational benefits. AR delivered many advantages included real-world extension and contextual visualization [7].

Therefore, in this study augmented reality technology that has expanded use in education for learning enhancement was developed for Palembang cultural artefact education. The proposed AR technology has SMB II museum collections as cultural artefact learning objects. The approach proposed in this study has created new 3D virtual cultural artefacts of Palembang which cannot be produced or used anymore. Students will get a new experience in museum learning by utilizing AR technology at the SMB II museum. It enables the user to interact directly with these historical objects virtually impossible in a real environment. Previous studies, web and desktop-based applications that contain information about the SMB II museum collection, have been developed apps but have weakness because only display 2D images that do not allow users to interact with objects and less attract visitors to use them, especially in learning. The application visitor statistics showed these facts. The AR application for SMB II proposed in this study for Palembang culture education increases user knowledge without visiting the museum. By using it, museum visitors can interact with the application for better learning experiences in cultural artefacts education [8–10].

II. MATERIALS AND METHODS

In this section, we described augmented reality technology for education and presented the proposed method for AR development in the SMB II museum for cultural heritage education

A. MUSEUM AND CULTURAL ARTEFACT

A museum is a non-profit institution that delivers service for purposes of education and enjoyment. It stores and conserves material evidence of people and their environment [11]. Some museums aim to preserve cultural heritage and served as important sources of learning for students and researchers. In museum, various relics of history are available to be studied. Interaction with objects can give unforgettable experiences. But some objects cannot be accessed directly to prevent damage to the ancient cultural artefact. Visiting the museum is seem such a boring activity for monotone collections and exhibition. The museum sector is a promising part to contribute significantly to the tourism industry. A museum needs to transform by adding a new value that can get visitor attention such as implementing information technology that can deliver more interactive and promising attractive experiences for visitors [12]. They will see, come, and then learn in the museum that will make museum achieve its goals for education and entertainment.

The wide use of information technologies has created a virtual museum as part of the modern museum. The modern museum should be able to deliver its activities in such a way so it can be synchronized with user needs and behaviours for the attention of potential visitors [13]. Information technology implementation in many daily life activities is emerging technology need to be blended with museum task. It can blend modern and traditional culture into new interesting view. The visitor will be able to interact with the collections of museum through virtual access to fragile objects of cultural artefact ancient collections [14]. Enabling social interaction around cultural heritage installations creates attractive and pleasant visitor experiences. The transformation will improve museum competitiveness to attract visitors and affect its income for preserving museum collections.

B. SMB II MUSEUM COLLECTIONS

Palembang is well known as the capital of the Srivijaya Kingdom and Palembang Darussalam Sultanate. It is the capital of the South Sumatra province in Indonesia. The two kingdoms left many cultural artefacts based on living habits and customs as well as beliefs that existed in the past, some of which persisted until now. Cultural artefacts stored in SMB II Museums in Palembang belong to the society that appeared since the era of Srivijaya are about to vanish, and only a few are still available and stored in the museum. A new method needs to be implemented to preserve the valuable cultural heritage that some are no longer available [6]. The SMB II Museum collections are categorized as Cloths, Tools and Art. A sample of cultural artefacts in the SMB II Museum is showed in the following Figure 1. The SMB II Museum has more than 600 collections consisting of clothing, art, and equipment. 20 sample were taken in this study to reconstruct the cultural artefacts into 3D virtual objects for SMB II AR applications.

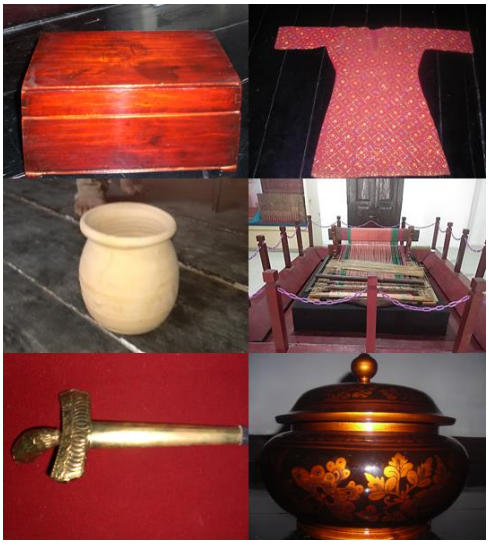


Figure 1. Cultural Artefacts in SMB II Museum

C. AR IN EDUCATION

Augmented Reality (AR) has expanded use in education as part of technology enhanced learning. It aims to improve student academic understanding. Augmented reality provides contextual visualization of virtual information in the extended informative real environment. AR enhanced real environment information by blending virtual object and real environment. AR can deliver contextual, compelling, immersive experiences [15]. AR blends the real and virtual world. It becomes an alternative new technology in education process provides conceptually enriching real educational contributing to improved students motivation [16] and to enable the student to decide on their learning.

There were many studies in AR area showing AR as rising technology that effectively enhanced student learning experience and understanding than traditional way. AR provides a way for student searching and learning building systems in many fields such as architecture, civil, also mechanical engineering [7]. Meanwhile [8] has discussed some AR for a different level of education used for various subjects at school for student [8, 9]. For cultural heritage education, a modern museum is a must to attract visitor especially millennial generation because has many interesting options to be seen influenced by the wide development of internet technology [10]. Historical fact presented in museum can generate a historic sense of an event or objects that may have occurred years ago and bring it to life for visitors. Student can learn and feel the past situation based on the museum collection through AR better than just a video. AR could project cultural artefact into a real-world context and improved learning experience. Santos et.al [7] stated that augmented reality has an interface that provided another way to access the information delivered to user interactively and joyfully for a better learning experience. AR technology as an alternative learning tool is enabling engagement improvement between students or visitors and cultural artefacts.

D. AR DEVELOPMENT METHODOLOGY

AR is a visualization media that allows the interaction of real-world environment with virtual representations of digital interface. Meanwhile, Museum has a role as an environment where the cultural heritage of the past is stored and displayed. The modern museum has blended with information technology to improve its competitiveness to attract visitors. Implementation of internet technology enables museum to create multi ways in offering their services. Digital transformation should be considered as a strategy to reach museum goals. A modern museum transformation will impact museum operational process. It will improve museum competitiveness to attract visitors to come which will impact its income for preserving museum collections. For that reason, SMB II Museum needs the AR application (AR app) to improve its performance and promote the museum.

The application was developed using an effective multimedia system development methodology to construct a learning environment [17]. The development methodology in this study consists of six phases shown in Fig. 2.

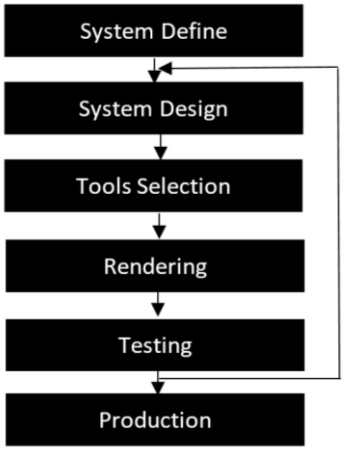


Figure 2. Multimedia Development Methodology for SMB II Museum AR app

1) System Define

It is important to understand precisely the application requirement. In this phase, it should consider the user and their expectation, goal of AR apps, timeline, different kind of media format needed such as text, graphics, audio, or video, and any other relevant characteristics of AR application. A well define detail of the application will help the developer to create a successful AR for SMB II Museum. For this reason, an interview was conducted with the head of the SMB II museum aim for knowing the situation and condition of the SMB II museum so that the requirements of the AR app be formulated. It was decided that AR applications based on Android devices should be developed because these devices are mostly used by the public.

2) System Design

The design phase involves the development of the conceptual model for the AR app involves the museum and culture education theory, the medium and AR technology to be used in the application. The output design determines the content of information delivered to user. The results of the requirement analysis at the initial stage modelled using UML diagrams. Figure 3 shows usecase diagram for modelling SMB II AR Application.

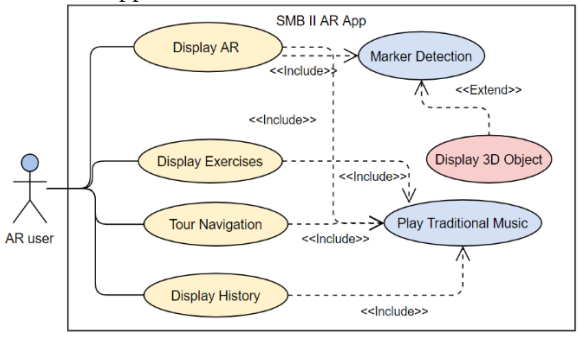


Figure 3. Proposed Usecase Diagram

SMB II AR application design consists of four functionalities or usecases, namely: Display AR, Display Exercises, Tour Navigation, and Display History. The Display AR use case manage augmented reality process includes marker detection and display 3D object when the detected marker matches the 3D object database. The application will play the traditional music Gending Srivijaya while the application was running. This music is part of Palembang's culture always played for welcoming guests. For learning features, this application also has the functionality of exercise, learning museum history, and museum tour navigation to show the virtual environment of the museum exhibition. The user outside the museum can visit the museum virtually through these features of the AR app.

3) Tools Selection

AR application contained multimedia requires many types of software tools for working with digital images, audio, and video editing software and many others to develop interactive content. The marker of the 3D object was designed using Adobe Photoshop. 3D Blender software used for reconstructing cultural artefacts into 3D virtual object to be augmented in real environment through the developed AR app. Vuforia and Unity 3D environment tools were used for the AR application development in this study.

4) Rendering

AR combines real environment with virtual environment. 3D virtual objects added to the real environment that acquired through a camera device blended into AR. The object reconstruction process is an important stage and affects the success of AR implementation. The constructed 3D objects would make the visitors feel as if they see the real object and can bring visitors to immerse in the situation [14]. If the design does not match or does not resemble the original, it will affect students' understanding and learning about cultural artefacts. Good multimedia will give a better ability to interpret [18]. The process of reconstructing artefacts in a new 3D virtual object completed in the Blender development environment tool.

3D objects are also equipped with 2D markers used to complement virtual objects augmented to the real environment of the camera capture so that the blended results will be displayed by the AR app. 3D objects that have been designed will not appear without the corresponding markers designed at previous.

When the content is ready, it is required to put them all together so that a prototype of AR can be tested for evaluating its performance. The assets consist of Gending Srivijaya's, a musical sound that usually welcomes guests in Palembang culture, images of 3D objects, and narrative text combined in the Unity environment so that the SMB II AR application is ready to run its functionality on Android-based mobile devices.

5) Testing

The AR application then goes through testing stages including functionality testing and usability testing by users, museum visitors or the public. Testing aims to evaluate the functionality of the AR application if it fulfils user requirements.

The application response time to the AR marker also measured to determine the efficiency of the application. High running time for responding will be an obstacle for visitors to use the application because it can take up time so it is not interested in using the application. Placement of the camera position against the marker for lighting conditions in the museum also measured for evaluating its impact on the effectiveness of the AR markers detection. At the end of the testing phase, System Usability Scale testing was performed to evaluate its usability and has museum visitors as respondents.

Usability is the reason why people use the product or service. When the product, SMB II AR Apps, is not usable for user then the product fails. Rubin and Chisnell [19] have concluded that a system is usable for user during interaction with its GUI when it has delivered services with no hesitation, no doubt, or confusion what to do with the system. This intangible satisfaction measured using a method called System Usability Scale method [20].

System Usability Scale (SUS) method use a questionnaire instrument consisted of 10 (ten) items alternating five positive statements and five negative statements that number in odd and even ID for each statements item (Figure 4). The aim of constructing positive and negative statements for the SUS instruments was to minimize biases of respondent results in order to get a good validation score of system usability based on user view that gave impact on system implementation [21]. Positive and negative statements have a different approach to apply. For the positive statement, score 1 was subtracted from the Likert score result for each respondent, meanwhile, for negative

statements, the maximum score of 5 was subtracted by the response result (Equation 1). Based on the result of processed score of each item of those SUS statements, the SUS score acquired by multiplying the total calculation of each item scores by 2.5 that produced a score between 0-100. To get the overall score of system usability, the mean of SUS score of valid respondent's result was calculated and represented as the system usability index (Figure 5).

ID	SUS Item
q1	I think that I would like to use this system frequently
q2	I found the system unnecessarily complex
q3	I thought the system was easy to use
q4	I think that I would need the support of a technical person to be able to use this system
q5	I found the various functions in this system were well integrated
q6	I thought there was too much inconsistency in this system
q7	I would imagine that most people would learn to use this system very quickly
q8	I found the system very cumbersome to use
q9	I felt very confident using the system
q10	I needed to learn a lot of things before I could get going with this system

Figure 4. SUS Questionnaire

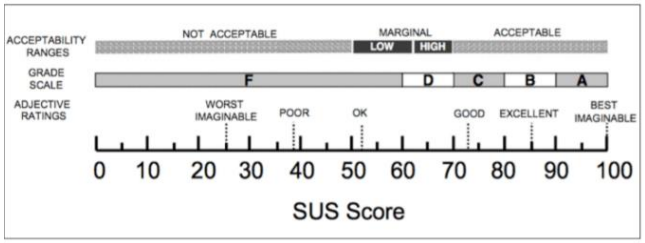


Figure 5. SUS Score Rating

$$SUS\ Score = 2.5 * \{\sum(5 - P) + \sum(N - 1)\} \quad (1)$$

where P represents positive statement score and N is negative statement score.

Figure 4 illustrates three types of ratings, acceptability ranges, grade scale, and adjective ratings based on SUS score results. A score underneath 50 specifies poor usability of the system that means it is not acceptable. A SUS score between 50 – 70 indicates median acceptability of the system, while a score exceeding 70 shows acceptable rate of usability [22, 23]. A hypothesis test performed a t-test to evaluate the difference usability for two factors, gender and user expertise in using the AR app. The evaluation was also carried out on the results of the pre and post-tests to determine the increase in user knowledge after using the AR application for cultural education in the SMB II museum.

6) Production

The production stage is when all the parts of a multimedia project come together and the app goes out for distribution. AR applications that have been tested and evaluated are then ready to be widely deployed and used by users. At this final phase, our developed AR will be uploaded to Playstore. People can download freely and make extensive use of the SMB II museum AR application.

III. RESULTS AND DISCUSSION

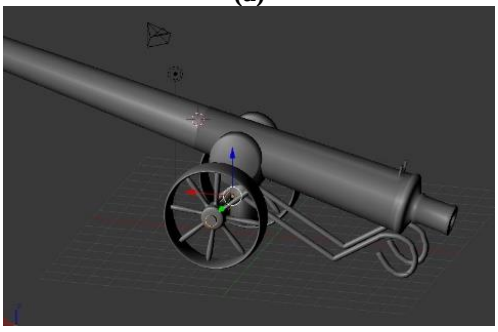
The proposed method in this study effectively developed an AR application to visualize 3D object of SMB II Museum collections. This application can be run in Android Operating System at least Lolipop Version. The testing phase was carried out by involving museum visitors at the SMB II museum of various ages and educational backgrounds. Random samples were taken for reasons that the application can be accepted and used without obstacles by museum visitors in general for culture education media in SMB II museum. The implementation result of the developed AR application was evaluated and discussed for improvement.

A. 3D OBJECT AND MARKER DESIGN

The dataset contained 20 samples of the SMB II museum collections were selected and considered to represent four categories of cultural artefacts, namely clothing, weapons, art, and equipment. The design of 3D objects is also an effort to preserve cultural objects in digital form. These objects are no longer produced and are no longer used in the daily life of the people of Palembang so that the 3D object designs of these objects have succeeded in creating digital objects that are no longer produced but are still alive as part of the culture and history of the oldest city in Indonesia.

The following Figure 6 showed the colonial canon artefact (a) and its 3D object reconstruction result (b). Each designed 3D object is equipped with a marker that is generated to be detected quickly and precisely by the AR app so that it effectively display information of its virtual object through AR app. Figure 7 shows a sample of AR markers design for Palembang cultural artefacts, Labu and Peridon.

(a)



(b)

Figure 6. (a) The Canon artefact and (b) its 3D reconstruction result

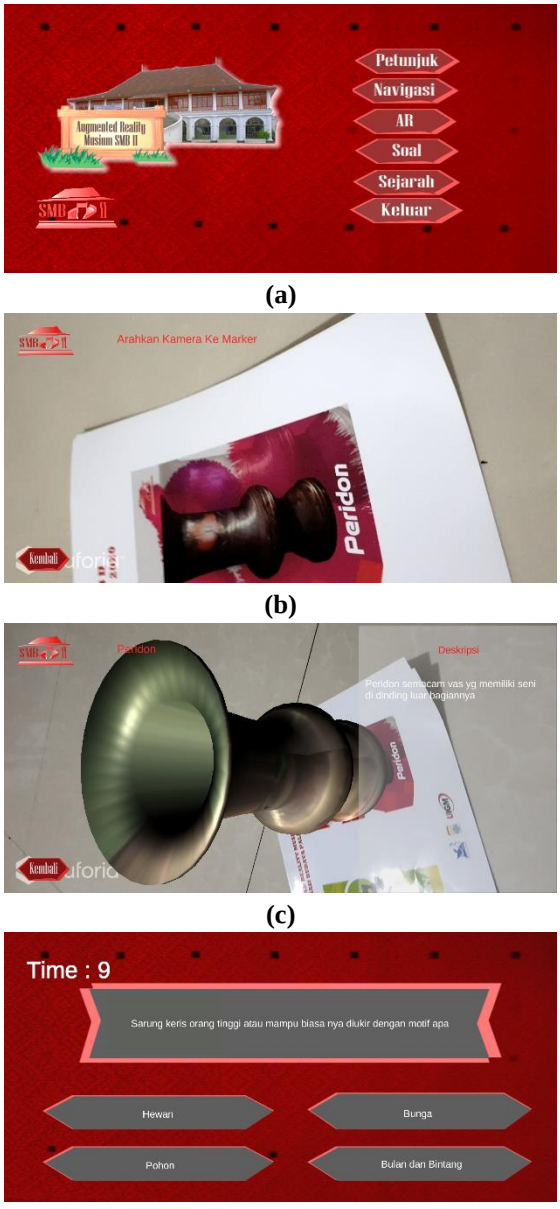
(a) **(b)**

Figure 7. Marker Design of Cultural Artefacts (a) Labu (b) Peridon

B.2 AR APP USER INTERFACE

The AR application interfaces were designed as in Fig. 8(a-d). The main or home interface appears when user run the AR app (Fig. 8a). They can choose the Instruction menu to see user manual for using the application. For novice users, it is recommended to read the instructions at the beginning for the AR application requires interaction between the real environment and virtual object through markers. Users can display the visualization of 3D objects by selecting the AR menu and application device camera will automatically turn on. Furthermore, by pointing the camera of the application device at the marker (Figure 8b), the application will detect a marker to recognize what 3D object corresponds to the marker. Previously designed 3D objects are added to the real environment image captured by the camera and then displayed on the screen by the AR SMB II application (Figure 8c) using the Unity engine and Vuforia embedded in the application. To measure knowledge about culture and museum collections, users can access the exercise menu which displays random 10 questions regarding museums SMB II (Figure 8d). Each question has to be answered in 10 seconds and the total score will be displayed as an indicator of the user's knowledge level with a high score of 100. The higher the score, the better user's knowledge about the SMB II museum and its cultural artefacts.

Users can interact using markers by rotating the marker that made the 3D object also rotated to match the marker movement direction. This feature made museum visitors as if accessing the museum's collection through the Apps. AR's ability to integrate virtual objects with objects in the real environment has provided an added new experience for SMB II visitors who cannot directly access the real museum collections.



(a)

(b)

(c)

(d)

Figure 8- Interface of SMB II Museum AR app (a) Home (b) Display AR (c) 3D Object Visualization, and (d) Exercises Menu

C. AR APP TESTING

Based on the black box testing conducted, it is known that the developed AR app for SMB II Museum was appropriate the designs and concepts prepared at the initial stages of application development life cycle. For the 2.3 x 3.3 inches size of marker, the AR applications were tested for various distances between marker and camera to evaluate its responsiveness in marker detection process. Figure 9 illustrates the variables to be measured during testing, the distance (*d*) and the angle (*a*) between the AR application device and the marker. The user tested the app with various values of *a* and *d* (Figure 10). It was found that the camera should be 10 to 30 cm distance from the marker for Vuforia

engine implemented in the app to detect the marker accurately. In term of marker detection effectiveness, the testing results showed that the camera position of the AR application device should be located at an angle of 30° to 90° to the marker.

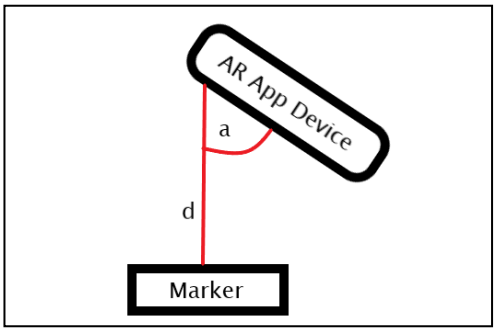


Figure 9. Illustration of test variables a and d

Figure 10. AR App Testing by Museum Visitors

There are several smartphone screen sizes which are suitable for the application. It is ranging from 4.5-inch to 5.5 inch of screen diagonal. Tests were carried out with various hardware specifications to measure application responsiveness. Table 1 represents the response time of the application for some hardware specifications. Based on the results presented in Table 2, it was found that the response time rate was 0.599 seconds. It means the AR app able to detect the marker and show 3D object quickly in less than a second.

Table 1. Testing results of response time

Hardware Specification	Result (s)
Octa-core 2.7 Ghz Processor; 6Gb RAM, 12MP Camera	0.368
Octa-Core 1.7 GHz Processor; 1Gb RAM, 5 MP Camera	0.457
Qualcomm MSM8916 Octa-core Processor, 1Gb RAM; 2 MP Camera	0.973

D. AR APP USABILITY EVALUATION

In this study, the SUS questionnaire is given to 15 respondents taken by random sampling dan come from various backgrounds. Millennials were chosen as respondents because most of the museum visitors were students and the application was intended to attract millennials interest in cultural education at the museum. 15 respondents are the minimum sample needed to use the SUS method and its effectiveness has been tested in measuring the reusability of the system in previous researches [20–22]. The respondents filled the online questionnaire after using the AR App.

Based on the survey results revealed that the average SUS score 78.3, so that it can be concluded the developed AR app is acceptable and have a 'good' subjective rating. The SUS evaluation result of SMB II Museum AR is presented in detail as the following Table 2. The evaluation was conducted for two factors, gender and experience in using AR applications. Users who have used AR applications are categorized as expert and users who have never used AR applications are categorized as novice.

Table 2. SUS Survey Results

Factor	Category	Frequency	SUS Score
Gender	Male	10	78.5
	Female	5	75.5
Expertise in Using AR App	Expert	9	81.4
	Novice	6	71.7

A *t*-test was conducted as part of our research methodology on the mean of SUS scores results. Based on the Lilliefors normality test with $\alpha = 0.05$, the questionnaire results were normally distributed with $L_0 = 0.159$ and $L_0 < L_{table}$ so the process was continued to hypothesis testing. Hypothesis H_1 and H_2 were generated. The following hypotheses were tested based on the SUS survey results:

H_1: There was no difference usability between male and female in using the AR of SMB II museum.

H_2: There was no difference usability between expert and novice AR App users.

The results of the *t*-test are illustrated in Table 3 for H_1 and Table 4 for H_2.

Table 3. *t*-Test results of Hypotheses H_1

Criteria	Male	Female
Mean	78.5	75.5
Variance	108.6	66.9
Observations	10	5
df	13	
t Stat	0.56	
P(T<=t) one-tail	0.29	
t Critical one-tail	1.77	

Table 4. *t*-Test results of Hypotheses H_2

Criteria	Expert	Novice
Mean	81.38	71.67
Variance	57.98	94.17
Observations	9	6
df	13	
t Stat	2.175	
P(T<=t) one-tail	0.024	
t Critical one-tail	1.77	

The *t*-test results showed the *p*-value of hypotheses H_1 was greater than 0.05 that made the hypothesis accepted. It means that there was no significant difference in usability between male and female AR users. Meanwhile, the *p*-value of hypotheses H_2 was lower than 0.05, so the hypothesis was rejected that there was a significant difference in usability between the expert user whoever using AR app and novice who uses the AR SMB II as their first AR App. The proposed AR app needs interaction between marker and application device not only through the screen like other standard application. But this condition does not affect the usability of the application which is on average Good index for novice users.

The AR application has functionality of exercise feature for cultural learning evaluation in the museum provides several questions regarding the museum. Through this feature, the level of user knowledge about the SMB II museum can be measured. The application is tested to measure whether there is an improvement in user knowledge after using the application without visiting the real museum. The testing was performed on 20 respondents who were given questions about the museum collection of SMB II. The results showed that users knowledge increase 28.5% on average after using the application. The *t*-test was used for the evaluation of user knowledge difference before and after using AR app for learning cultural artefacts (Table 5). The results show a difference between pre and post-test results. User knowledge slightly increased after using the developed AR App for cultural artefact education.

It concluded that without visiting the museum, users could learn Palembang culture through virtual 3D collections augmented to the real environment through the AR Museum SMB II application. The developed AR for the SMB II museum effectively provides a new learning experience in Palembang cultural artefacts education.

Table 5. *t*-Test results of Pre and Post-test difference

Criteria	Pre-test	Post-Test
Mean	7.15	10
Variance	2.98	0
Observations	20	20
df	10	
t Stat	-7.39	
P(T<=t) one-tail	2.7 e-7	
t Critical one-tail	1.73	

IV. CONCLUSION

In this study, augmented reality technology that has expanded its use in education for learning developed for Palembang cultural artefact visualization and education. The method proposed in this study effectively developed an AR application to visualize 3D object of SMB II Museum collections and created new digital 3D objects of Palembang cultural artefacts. The approach taken in developing AR applications has reconstructed cultural artefacts that cannot be produced or used anymore as if comes to life. The digitization of the collection is an innovation that provides a new learning experience through the use of AR technology and also contributes to the preservation of Palembang cultural objects.

The application provides more experience for users in learning the SMB II museum collection by successfully increasing user knowledge by 28.5% after using the application without visiting the real museum. In term of effectiveness and efficiency, some testing scenarios were performed. The results showed that the application could run its functionality as designed with time responsiveness for detecting marker was 0.599 seconds on average. The app usability was also evaluated using the SUS method. The SUS survey score of 78.3 means the developed AR of the SMB II museum is acceptable to millennial users. Based on hypotheses tests, was found no difference between male and female user usability. But there was significant different usability between novice and expert user for AR needs interaction between marker and application device not only through screen touching like other standard application. Besides that, it is necessary to develop a web-based app to make it easier for users to learn the museum collection without being bothered by the installation process, especially for novice users. The AR app will be improved based on these evaluation results for future works. The use of AR in the SMB II Museum leads to an enhanced interactive learning experience that promotes cultural heritage preservation in Palembang. During the Covid-19 pandemic, the existence of the developed AR application is expected to be effective in supporting museum cultural artefacts education through distance learning when the museum is closed to the public.

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