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Game-based augmented reality learning of Sarawak history in enhancing cultural heritage preservation

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ABSTRACT

The augmented reality (AR) technology had been proliferating for years. However, the implementation of AR technology still has room to be explored, especially in the form of cultural heritage preservation. The aim of this study is to enhance AR technology in game-based cultural heritage and history preservation in Sarawak, as well as supplement the gamified experiences in learning James Brooke's history. Three research objectives are proposed: to design an AR game prototype for the history of James Brooke; to develop an AR game prototype with a collaborative learning element; and to evaluate an AR game prototype for enhancing cultural heritage preservation. This study proposes a game-based prototype that contains AR markers to assign each with different game features. Furthermore, collaborative learning theory is enhanced through AR experiences with multiplayer support. The game-based prototype is evaluated by a group of participants through prototype measuring and testing. The participants feel mediocre about the challenge and knowledge factors of the prototype. Overall, this study highlights the enhancement of cultural heritage preservation through AR game-based experiences intensively learned from James Brooke's history in Sarawak. These implementations have an apparent promising contribution to make in protecting the available cultural heritage in Sarawak and extensively to the country's cultural heritage preservation.

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1. INTRODUCTION

Augmented reality (AR) is the experience where virtual or digital contents are input into the real world. It is defined as a real-time direct or indirect view of a physical, real-world environment that has been enhanced or augmented by superimposing it with computer-generated input. AR is interactive and also combines with 3D contents, presenting the virtual and real world at the same time. Referring to Milgram's reality-virtuality (VR) continuum [1], it claims that a continuum is a step over the real environment and the virtual environment and consists of AR and AR. AR is more preferable to reality, and AV is more into the virtual-only environment.

The gaming industry enthusiastically contributes to building up the influence, values, and identity of society. Also, the introduction of smartphones has brought new opportunities to be combined with gaming technology. AR, one of the most trending technologies, is introduced to superimpose virtual objects into the real environment [2]. Besides, AR has different emerging mechanisms compared to VR, because VR is rendered in a completely virtual environment and does not require any real objects to interact with [3]. AR games are usually developed on handy devices such as smartphones, tablets, and any portable console with a camera. Some of the games might need extra sensor inputs like a gyroscope and accelerometer to support the interaction with the game content. A big company like Google also has strong support for AR technology and is estimated to be covered by 100 million Android devices. This result comes from 2 billion active users, which is 5% of the estimation value [4].

Sarawak had been paying attention to the development of AR technology for years. The centre of technical excellence (CENTEXS), which was founded in October 2014, collaborates with EON reality for the purpose of training more technical workers that the Sarawak state needs to industrialize the economy, especially in AR technology [5]. The present government policy also impacted the development of AR technology within Sarawak [6]. Thus, the enhancement of AR technology is a considerable factor in deciding how the game will develop. Sarawak history and heritage is the preferred title because it has an extraordinary relationship with a famous person once upon a time, James Brooke, the White Rajah, and the people of Sarawak. James Brooke was a significant historical figure during the reign from 1841 until 1868 in Sarawak, once known as part of the territory of Brunei [7], [8]. Thus, James Brooke plays the most important role throughout the content of the study. Based on this backdrop, this research investigated the opportunities to enhance historical heritage preservation in Sarawak using game-based AR in the case study of James Brooke's history.

2. PREVIOUS WORKS

In the previous studies, there were some general AR enhancement domains, including medical and military [9]‒[12]. The improvements mostly involve new domains like education and automotive marketing. It means that AR offers special and unique digital experiences and engages the user in a memorable way.

2.1. Enhancement of AR

AR raises the perception level of human beings to interact with the real world. For instance, medical AR takes its motivation to develop the system and view the data instantly in front of the patient. It may require an immediate process of in-situ visualization of co-registered heterogeneous data. Ultrasound imaging is also used in AR applications in the medical field. The optical see-through device projects the condition of the fetus on the abdomen when the technician scans through the body of the pregnant woman [9]. Besides, AR could provide useful information on the battlefield with the information annotated on the head mounted display (HMD) device [10]. Micro-electro-mechanical systems (MEMS) sensors are implemented into cockpit helmet tracking and act as optical inertial trackers [12]. Another example of military application is the planning of military training in urban areas [11]. The terrain is also animated with the AR implementation, which is very practical for strategic intervention planning.

AR technology also brings new combinations to teaching and learning (T&L) methods in education [13]. The combination of virtual representation and the real world encourages the learning process to be simpler from a complicated and abstract concept, which is why researchers continue to accept AR [14]. This phenomenon is impossible to experience in the real world, and it is also leading AR education technology to emerge in the future. Also, mobile applications are becoming more popular in recent years, especially in the field of education [15], [16]. The proliferation of smartphones and tablets has made it possible to develop a variety of educational apps, from language learning programs to educational games [17]. Mobile applications have many educational benefits, such as accessing learning materials anytime and anywhere, increasing student engagement and motivation, and allowing students to learn at their own pace [18].

Moreover, the automotive industry also plays the most relevant role in using AR technology. The widespread QR code is the most common example in this industry: when the users scan onto the marker, either a flat 2D image or a 3D object, the complex information is retrieved by the mobile and computer. The scanned target also transformed into augmented information that might carry model details, type of engine, dimension, interior design details, and other car information. Further to the studies of Yang *et al.* [19], they suggest that the combination of virtual and real environments, which is a unique feature of AR technology, is capable of providing unique sensory experiences.

Each of the implementations and enhancements studied above is leading the AR technology for the purpose of giving opportunities and solving specific functionality in their fields, respectively. Medical surgery and military applications have offered much more complicated and professional skills and may require a higher cost in terms of time and money for development. Besides, educational applications and marketing in the vehicle industry have shown easier ways to achieve and are more feasible to develop, especially at the undergraduate student level. As compared to both of these application fields, AR marketing applications, for example, have shown interactive information inside the automobile, but education products are more than that. Not only interactive information, but education AR applications could further provide more possibilities, like tests, knowledge, and multiplayer interaction. As the ways become richer, it could become an educational game and should be investigated.

2.2. Location-based AR

The fundamental concept of location-based AR is to retrieve the location of the device and deliver information onto the screen about its geographical coordinates. It is focused on determining the location of an object or person and overlaying their geographic coordinates on the screens of specialized devices in a more interactive way than just working with positioning services. Location-based systems are closely related to the global positioning system (GPS), and their functioning always depends on each other. GPS is an important feature that has been integrated into current mobile phones. It has great coverage, reliability, and positioning accuracy that are widely accepted around the world [20]. Based on the study of Burkard *et al.* [21], they proposed a location-based AR prototype that is used as an innovative representation of location-specific information in diverse applications. The study pointed out that location-based AR produces better robustness than image-based AR.

2.3. Collaborative AR

Based on the research of Syahrul *et al.* [22], collaborative AR is the multi-user interface embedded in an AR environment. It allows the sharing and connectivity of AR representations. The use of collaborative AR provides real-world interaction and communication that are accessible in all moments and places [23]. The availability of multiple AR presentations on several computing devices can be applied for face-to-face collaboration or remote collaboration. Multi-user involvement is an important feature of a collaborative AR interface that allows multiple users to gather in a room and cooperate together [24]. Ismail and Sunar [24] mentioned that the collaborative AR interface needs to be independent so the users can have their own independent viewport, which is known as observation independence. Additionally, depending on the features of the system, each observer in the shared AR environment would see different superimposed objects.

Some researchers emphasize that the collaborative mode could enhance intrinsic motivation toward the game. For example, the study of massive open online courses (MOOCs) implemented with gamification elements discussed the importance of collaboration, which encourages the development of strong interpersonal bonds among the players and leads individuals to respect collaboration and personal contributions [25]. Another study showed that gamified learning platforms (called GamiClass) were conducted toward undergraduates and had a high impact of game elements on collaborative learner types [26]. These researches were carried out among a group of players and evaluated collaboration that highly affected the members.

There are several examples of using collaboration AR technology. The systems considered the use of collaborative AR to improve the children's socialization, communication skills, and emotional intelligence in primary school [27], and the players can walk around and unlock the 3D models with an AR exercise [28]. Multiplayer AR games allow players to stay in a shared physical environment filled with interactive digital objects, which is also an example of collaborative AR [29]. These examples brought some key lessons about how users could interact with shared AR contents as usual. AR technology decreases the gap between task separation and communication space. Thus, face-to-face collaboration has been improved with the support of AR technology.

2.4. Similar games

The relevant works of AR need to be more specific to the game elements that could be related to the current study. The appropriate works gathered are important to understand the background of the ongoing research. They are the references with the focus of the study defined; a brief preliminary literature review can help to support the rationale. Temple treasure hunt game [30] and AR smash tanks! [31] are the existing game-based enhancements related to history learning and cultural heritage preservation to be comprehensively compared with the current study.

– Temple treasure hunt game
  An adventurous game with the journey to explore treasure trails leading to the ancient treasure buried in the Shiva Temple. The system uses cutting-edge AR to scan through the marker and show the mortal models; it is also using location-based tracking technologies to allocate the AR card within the temple. The game created a mobile AR game to experience the existence of and learn about the Shiva gods. The game can be played alone by creating the treasure trails automatically or in multiplayer mode by sharing the trails with others.

– AR smash tanks!
  A multiplayer-focused AR game that smashes tanks with another player. The game is designed by using the slingshot mechanic to launch the tanks into the opponent's field. Sometimes, special items like worms will drop into the scene from the sky; the player can pick and activate them to cause some extra effects for the player himself or bad effects on the opponent. Since the game is designed with robust multiplayer options, it produces an excellent experience when playing together with friends in a few impromptu activities.

The games mentioned have been evaluated by walking through the content. These games provided the knowledge to support the research on the current study, in which the temple treasure hunt game provided an overall concept for constructing the location-based AR feature and the way to present cultural information. Also, AR smash tanks! has a collaborative feature and provides an important concept in gamification design. These games had shown their own advantages from different perspectives, and these knowledges could be important references for the prototype design, such as the way to implement collaborative mode and the location tracking feature.

3. METHOD

The research methodology is decided based on achieving the research's objectives. The methodology consists of four phases. Each phase contains several research activities to achieve each research objective. First, the research investigation and the motivation of the proposed solution; then, the research prototype proposal and design; and lastly, the evaluation. The proposed research methodology for this research is depicted in Figure 1.

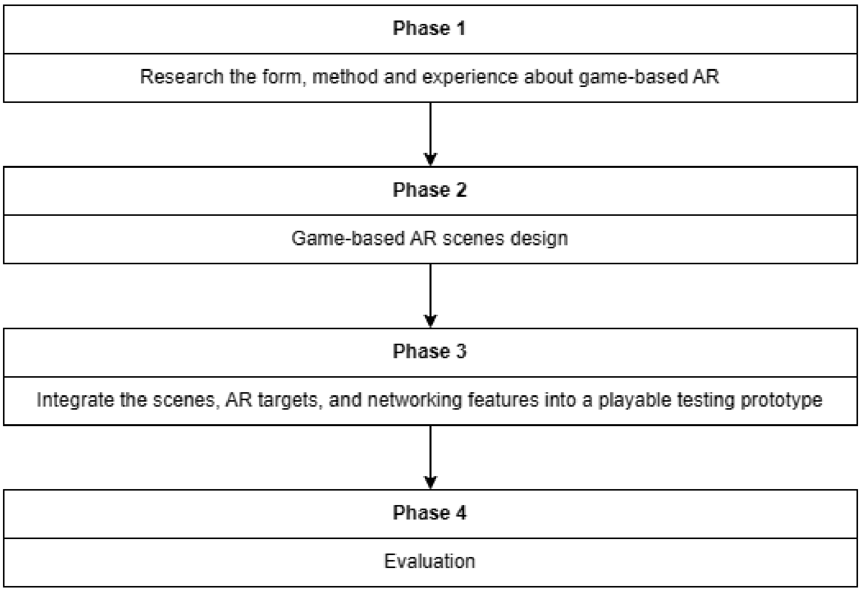

Figure 1. Proposed research methodology

3.1. Investigate the game-based AR

The study started with an investigation about the related design of cultural heritage preservation game-based enhancement with AR technology. The relevant enhancements have been studied in terms of how the AR technique is supplemented for each idea, respectively. Most of the implementations are using mobile phones or tablets to interact with AR objects, even using specific devices as long as the virtual items could be shown for specific purposes. For the design, the game-based AR is designed in the form of gamified features that disclose fun elements and increase AR learning experiences. The combinations of the gameplay required creative and innovative ideas to design the proposed game-based solution in an interesting way. When the development investigation is ready, the work should proceed into the next phases, which involve research prototyping.

3.2. AR gamified elements design

The process is categorized into game-based AR scenes and routing, unique design AR targets, networking infrastructure, and collaborative elements of the study.

- Game-based AR scenes design
  Generally, game-based AR is designed and implemented within the Unity 3D platform. It is used to build up the game-based environment and features in 2D mode for menu UI design and 3D mode for 3D objects and AR scenes. For instance, MathMythosAR2 and FancyBookAR [32] implemented game elements such as points, badges, leaderboards, stories, avatars, and teams to create engaging and immersive learning experiences for mathematics and English as a second language. An AR foreign language education proposed by Lee [33] also designed similar game elements, in addition to performance graphs and teammates.
- AR targets design
  The AR targets might require external photo editing tools to support the aesthetic design. For instance, if the AR target is paper, it could be designed by hand drawing or a combination of shapes. These arts may not produce a good quality if they are photographed on real paper. The designed AR targets were uploaded into the Vuforia database and registered into the Vuforia SDK [34] in unity editor. For better AR marker calibration purposes, the richness of the image vectors and vector-based features are needed in designing the AR markers.
- Networking features
  The GPS locating service is also tested to ensure that the range between the device and target is within the error range. The instant distance detection is displayed on the scene to ensure that players can always indicate their position and provide the threshold of the landmark reach point.
- Collaborative features
  The functionality of Photon PUN is verified, and the multiplayer connection is successfully connected in the game-based scenes and the AR markers before the integration testing. The multiplayer collaborative would involve a master player who creates the lobby and a guest player who joins the same lobby. Both of the players' data are synchronized as long as they stay within the lobby. An example from Elshahawy *et al.* [35] shows an AR tour application that supports collaborative interaction to enhance the tourism experience. The users can share views and interact with each other when they enter the same scene.

3.3. Integrate the game-based AR features into a complete research prototype

The development continues to integrate the components into a full prototype and test their functionality. The AR features will be tested such that the objects will be superimposed onto the targets when they are applied to the game scenes. The designed scenes also need to be examined so the entry for each flow is correct. The networking infrastructure needs to respond to the available and correct values when it is combined into the whole prototype, especially to ensure the data keeps updating during the gameplay. The whole walkthrough needs to be confirmed to ensure there are no catastrophe bugs that might affect the evaluation process.

3.4. Evaluation

The game-based AR prototype needed to be evaluated after the prototyping was done. As stated in the objective, the prototype also needs to be reviewed by the tester to fulfill their contentment about the gaming experience and the effectiveness of game-based collaborative learning with its elements. The comments and suggestions need to be collected from the test group in order to enhance and improve the current research prototype. The testing results can also prove the effectiveness of collaborative learning through a game-based platform. The evaluation countermeasures were also implemented for the player after the game was published. The players can simply give a star rating that is intuitive to identify the experience of the game. After that, the evaluation could be classified into subjects that constrain the scope of reporting the problem. If necessary, the additional text field could allow the players to give extra comments about the game.

4. THE PROPOSED GAME-BASED AR TESTING PROTOTYPE

The proposed solution is called Brooke History AR. This section discusses the proposed prototype and its features and implementation, including the game collaborative environment setup, the walkthrough of the game, and the UI design. Besides, the quiz of the game was also designed using an AR environment in order to examine the player's learning outcome. At the game-ending scene, the score is also recorded on the scoreboard for the player to review and improve for the next play.

4.1. AR exploration environment

– Popup tutorial

The flow of the gameplay is the most fundamental step that needed to be done inside the game-based AR scenes. When the player(s) started the game, there was a tutorial process that helped the player(s) understand the process of exploration. The tutorial includes the introduction of the game and the preparation of the quiz marker(s). The player(s) would browse the hint buttons while exploring the field and turn green after it was found. It also explains how the quiz can proceed when the current phase of hints is found. The last step of the tutorials wrapped up the explanation, and you were able to refer to it anytime with the question button.

– Hints and clues

The players can also check the hints while playing through the testing prototype. The game-based AR scene shows only three hints at the beginning of the stage. After the player(s) unlocked the hints and finished the quiz in that phase, more hints appeared, and the players had to continue the game. Each hint related to different historical facts about Sarawak's Jame Brooke. There is also extra information, like a hint sentence, and the players are able to track the targeted hint card.

– Quiz challenge

If the players found all of the hints in the current phase, they had to proceed with the quiz challenge. The game required the players to scan the quiz card. The question object appeared as the players scanned the quiz card, and they had to answer the question by touching the answer object. When the players complete the quiz, the game proceeds to show the quiz result, which they still have to scan on the quiz card. The result contains the number of questions and the percentage of the correct answer. It also shows the titles of the players based on their percentages. The quiz is essential in order to examine the player's learning progress through the proposed game-based AR prototype.

– AR tracking markers

The implementation of the AR tracking marker, also known as the hints card and quiz card in the game, is to recognize the cards while the players scan on the card surface by using the camera. The environment of the scanning process must be bright enough to observe the markers, and the size of the marker surface must be suitable to be recognized by the camera. The Vuforia AR SDK is the tool used to implement the AR tracking feature in the proposed prototype. The marker database is also loaded to be used for tracking purposes. After the marker calibration process, the 3D object(s) or AR scene(s) are displayed on the marker(s).

– Geographical distance system

The geographic distance feature is one of the core functionalities implemented in the prototype to find the hidden hint cards in the field. This feature allowed the players to search for the cards by the distance indicator. The players must enable the GPS locating service on their smartphone so they can get the value of the distance to the target; otherwise, the distance indicator will show "Waiting," which means they always wait for the GPS locating service to be allowed. Besides learning about the history, players also learned about each landmark at a different location and the importance of a particular historical fact through this feature.

4.2. Navigation system

Navigation system that is important to build up the flow for the whole testing prototype. This system allowed the players to navigate throughout every scene in the game other than the exploration scene, including the splash screen, main menu, quiz review, scoreboard, and lobby selection. In the main menu, a transform algorithm is applied to move the screen to a different position and navigate to the targeted content. Thus, it creates a flowing effect without changing the scene.

4.3. Scoreboard system

The development of the scoreboard system involved the whole prototype flow, including the main menu and game exploration scene. The implementation of the scoreboard typically uses the global variable that enables the prototype to access the value from every scene. This system saves player's score once the flow of the gameplay is completed. The scoreboard list keeps the result of four players only. If there are fifth player completed the game, the oldest player's record is removed and three players' record iterate into the next slot. The fifth player is allocated to the empty slot as most recent player.

4.4. Collaborative interaction

The multiplayer system enables the players to play the game and explore the field together. The interaction mode between the players is to collaborate and find out the hint cards allocated in the field as soon as possible. The Photon PUN SDK is required to be installed in the Unity editor to enable the multiplayer feature. PUN setup needed to be setup with the app ID after the installation was done. The game-based scenes are integrated with the multiplayer feature to allow collaborative learning and increase the effectiveness of the learning experiences through this proposed game-based AR.

5. RESULTS AND DISCUSSION

The full game-based AR is ready after all implementation is done and distributed for the players to explore the full scenes. When the game is launched, it shows the splash screen with the James Brooke logo and greetings to the players. Afterwards, the main menu appears as shown in Figure 2. The players can view the question banks and answer here with a spoiler alert. The players can also look at the scoreboard and know their historical gameplay results. There is also a quit button provided for the players to exit the game-based prototype. When the players have to start the game, the host player needs to create the lobby and wait for the partner as shown in Figure 3. Then, the guest player has to join the lobby with the same room ID, and both players' names should appear on the room list. When everything is ready, the game starts by clicking the "Go" button.

The players enter the AR camera screen with a pop-up tutorial as shown in Figure 4. The players have to read through the tutorial so they understand the flow of the game. After that, the players should start the exploration. The players need to find all the hint cards that are hidden around the field. The players have to refer to the distance indicator and hint sentences given to find out the cards. The players can also change to another hint card tracker in the hint detail window. Once the players find the hint, they need to scan the card and unlock the hint as the button appears. The hint content superimposes on the card, and the player(s) gain knowledge when they observe it as shown in Figure 5. In the hint list window, the hint button turned green as it was unlocked. After all of the hints are found, the players should proceed to the quiz challenge.

In the quiz challenge, the players need to scan the quiz cards that have been provided throughout the game. The quiz object appears as a multiple-choice question with a question object and choice objects. The players need to touch a choice object to answer the question. When all of the questions are answered, the game proceeds to the result scene, which shows the mark and title that the players owned as shown in Figure 6. If the game is not finished yet, it will continue to the next phase, and the players have to find out more hints. Otherwise, the game will calculate the cumulative result from each phase of the quiz and show the players' names and game duration for the whole gameplay process. The result is stored on the scoreboard in this step. After that, the players can return to the main menu.

Figure 2. Main menu of the game

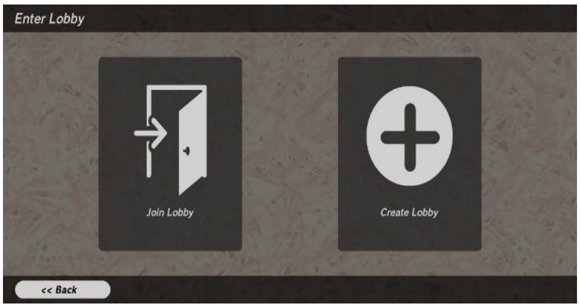

Figure 3. Join or create lobby

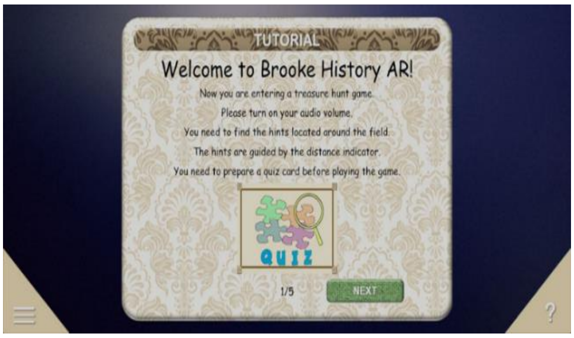

Figure 4. Popup tutorial

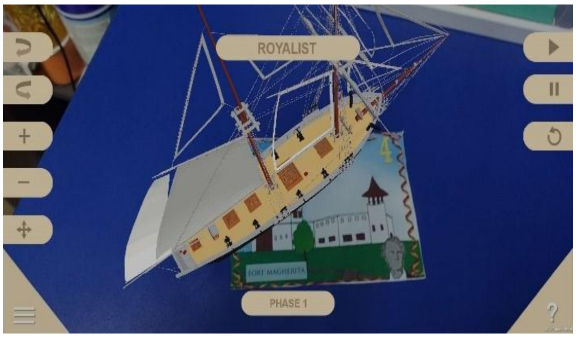

Figure 5. The hint content superimposes on the card

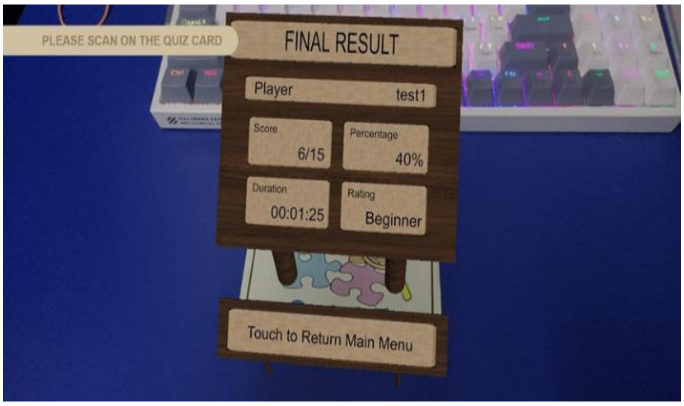

Figure 6. Final result scene of the game

To gather the results for the testing, twenty (20) participants were invited to evaluate the game-based AR features through dedicated gameplay durations and answering the distributed questionnaire. The collection of results was not based on respondents' job position or age, but they must have a basic understanding of English to understand the content of the game-based testing prototype. As the respondents attended the test, they were given a brief explanation of the purpose of the experiment and instructions on how to complete the test. They were also instructed to perform specific tasks that might fulfill the questionnaire objective. The questionnaire is divided into three (3) parts: the pre-test questionnaire, usability testing, and functional testing, which have been classified into Tables 1-3, respectively.

Tables 1-3 summarized the questionnaire that had been conducted for the players in the testing. The pre-experiment questionnaire included the experience with AR and further questions about the understanding regarding AR. The questionnaire also gathered the participants' experience with any other treasure-hunting game. Usability testing was done by the respondents throughout the game-based AR scenes and interactions in this section. It is vital to guarantee the design suggestions that are proposed to improve the ergonomic quality of the game-based elements [36]. Functional testing consisted of two steps. The first is to identify the functions implemented in the program; the second step involves selecting test data that can be used to check whether the program implements the functionality correctly [37].

Table 1. Pre-test questionnaire

No	Question
1	How do you describe your gender?
2	How old are you?
3	Do you have experience with AR?
4	If yes, how much do you understand about AR?
5	Do you experience with treasure hunt before?

Table 2. Usability testing questionnaire

No	Factor	Question
1	Knowledge	The game improves my knowledge in history of James Brooke in Sarawak.
2		I understand the hints taught in the game.
3		I want to know more about the history of James Brooke in Sarawak.
4	Autonomy	I understand how to walk through the game process by the popup tutorials provided.
5		I know how to approach the hints with the distance indicator provided.
6		I feel sense of control over the game.
7	Immersion	I was playing a game and didn't notice the time passing.
8		I feel emotionally invested in the game with the score and title I get after the quizzes.
9		I was playing the game and not thinking about anything other than the game.
10	Challenge	The hints provided in the game that help me to answer the quizzes.
11		I feel the difficulties of the game increase while enter into the next phase of the game.
12		The difficulty of the game is suitable for me.
13	Social Interaction	I can cooperate well with my teammate while playing the game.
14		I can easily join with my teammate to play the game.
15		The collaboration between the teammate helps me improve my game playing skills.

Table 3. Functional testing questionnaire

No	Question
1	I can touch on the button while playing the game.
2	I can scan on the AR markers while playing the game.
3	I can flip the books while I found the flipbook hint.
4	The audio and video contents are audible while I found the hints.
5	I can unlock the hints when I found them.
6	I can touch the button during the quizzes.
7	I can connect to server while I am starting a new game.
8	I can join or create the lobby while I am starting a new game.
9	The distance indicator provides an appropriate distance for me to locate the hints.
10	The prompt sentence provided in the game is useful for me to play the game.
11	The distance indicator provided in the game is useful for me to find the hints.

The collection of the results is continued to calculate the GameFlow Scale from Killi's model [38]. The measurement begins with flow antecedents and consequences from the flow experience of the game. The number of questions, according to an alphabet, is indicated as (a) usability testing and (b) functional testing. Based on the research from Kiili *et al.* [39], the flow dimension could be categorized into ten parts: challenge, goal, feedback, control, playability, rewarding experience, concentration, loss of self-consciousness, time distortion, and construct. In addition, the knowledge element would be the extra flow dimension to evaluate. The model from [38] also gives autotelic experience as a part of the flow dimension. Cronbach's alpha estimation is the method to calculate the reliability of the flow.

Table 4 illustrates the results of mean scores, standard deviations, and reliability estimates of flow dimensions. The higher the mean scores, the more effective it is to provide a beneficial condition for the players to experience the game flow. However, the reliability of flow antecedents shows a low dependability score. For the sub-categories in flow antecedents, the challenges in the game application show poor reliability. The dimensions of feedback and playability did not have good reliability but were still better than the dimensions of challenge. Besides, the flow experiences were generally of good reliability (α =.6527). For the categories within the flow experiences, the concentration element gave a neutral reliability for the overall experience. The control element, which was mostly related to the functionality of the game application, was found reasonable (α =.6471) for the Cronbach's alpha estimation. The knowledge improvement was estimated to have a neutral reliability, but it was lower than the dimension of concentration.

Table 4. Mean scores, standard deviations and reliability estimates of flow dimensions

No	Flow dimension	Mean	SD	Reliability
	Flow antecedents			.0286
11a	Challenge	3.85	.8751	.1428
12a	Challenge	4.50	.7609	
4a	Feedback	4.20	.7678	.4631
5a	Feedback	4.10	.7182	
10b	Playability	4.40	.6806	.4456
11b	Playability	4.35	.5871	
	Flow experiences			.6527
7a	Concentration	3.95	.8870	.5616
9a	Concentration	4.15	.9333	
1b	Control	4.50	.6070	.6471
2b	Control	4.50	.5130	
3b	Control	4.05	.8256	
5b	Control	4.55	.6048	
6b	Control	4.55	.6048	
1a	Knowledge	4.45	.5104	.4590
2a	Knowledge	4.45	.6048	
3a	Knowledge	4.75	.4442	

Overall, it can be justified that the design of the game challenge is the major factor improving the flow experience, but the assumption is doubtful since the flow antecedents show a poor reliability value. However, the challenging element of the game is still worth improving since it has the lowest and most considerable gap between others' reliability. Besides, the knowledge factor still has room for improvement since the reliability is not high. The knowledge factor is more in demand than other reliability factors because it is much more relatable to the objective of this study.

6. CONCLUSION AND FUTURE WORKS

This study sought to contribute to cultural heritage preservation with game-based AR learning technology. There are several related works that have been researched and related to the current study. The location-based system and multiplayer collaboratively engaging game elements consider associative, cognitive, and situational learning methods. Similar games were also investigated for the purpose of emphasizing and discussing the important features that are needed for prototyping. A game prototype is prepared as an instance to find out the knowledge about AR technology. It is proposed with four phases of research methodology, starting with a preliminary investigation of AR technology and continuing with scene designs. Twenty (20) respondents were chosen for the testing, and the results were tested by Killi's GameFlow scale. The GameFlow scale found that the challenge and knowledge factors have low reliability. In short, the research conducted was based on the study's objective.

Thus, some solutions are suggested to be applied in the future to improve the current study. First, the design of the hint cards might be able to be designed in more interactive ways. It means that the hint content could provide more informative knowledge during the exploration. For example, the cards could be implemented with multiple AR tracking targets to provide more hint options while in scene exploration. The cards could also be designed with interactive minigames that grant rewards or achievements to the players. A more reasonable assessment of the game difficulties is also needed to be reconsidered. The question bank and hints might need to be retrieved from the database as compared to the current static contents. The players might receive different contents as they start a new game every time. These questions and hints are also distributed with more reasonable difficulties for each phase of the game.

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