Design of An Interactive Module for Historical Building Learning Using Board Game Puzzle Based on Multi-Marker Augmented Reality

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Abstract. Augmented Reality (AR) technology is one of the new technologies that can display the virtual world into the real world. Augmented reality technology is widely applied into the educational field to help the learning process by representing an object in more realistic and detailed way. However, most of the implementations that carried out only using AR to show up an object from a single marker, even though there are still many ways on using AR functions to represent an information in more detailed and interesting ways. This study aims to develop a learning media to introduce historical building specifically Indonesian Temple's using multi-marker augmented reality. This study used ADDIE Model to develop suitable media for learning process. Based on the results of expert testing, the developed media obtained an average score 3,76 for media evaluation and 3,84 for material evaluation, which means the developed media was very feasible as a learning medium. Therefore, through this research we expect to provide a recommendation for AR application models using multi-marker AR method, furthermore the modules developed are intended to become information resource and learning material about historical building especially temples in Indonesia.

Keywords: historical building, board game puzzle, multi marker augmented reality

1 Introduction

Technologies are meant to make human life become easier and more pleasant. Various types of new technologies are constantly being developed to help human activities. Technology Augmented Reality (AR) is one of the new technologies that can be used to connect the virtual world with the real world.

In education sector, AR technology is widely used to support teaching and learning processes. With the help of AR technology, learning materials can be conveyed and explained in more specific and detailed manner. Therefore, a lot of research and development has been conducted to implement AR technology in the educational field.

An examples of research that implements AR technology in the educational field is the development of an AR application for learning about ancient animals [1]; the development of learning media for presenting and learning historical buildings in Indonesia by displaying the 3D objects of those buildings [2]; the development of learning media using AR technology to introduce historical buildings such as temples in
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Yogyakarta, with the purpose of allowing people to learn more about temples without going to the temple sites directly [3]. And many more research that studies the implementation of AR technology on learning media.

Through those studies, it revealed that the same method is commonly used to develop an AR application. Many AR applications only used the basic AR function to display an object through a marker, therefore the information presented by the application is not optimal. For instance, if an application can display several objects simultaneously, users can compare those objects to determine the difference between each object. Moreover, representation of 3D objects simultaneously can be used to elaborate the details or characteristics that exist on that object.

For example, to present information about the Borobudur Temple which has wide dimensions, single 3D object will be difficult to provide a detailed picture of characteristics of the temple [4], [5]. By using the multi-marker method, these characteristics can be divided into several smaller objects, which can provide more detailed information.

The development of learning media using multi-marker augmented reality method has been applied in several previous studies. For example, to create media that displays piece of objects on marker, but in this media the virtual images provided can not interact with each other or are still in separate unit, therefore if there is an error while forming the object, the application cannot detect it [6], [7]. Other research has developed media that can display several parts of an object and can become a single unit when combined. This research relies on marker coordinates so that when the markers are placed correctly, it will display the object as a whole [8].

This study aims to develop a learning module that implements a multi-marker tracking method into board game puzzle media. The proposed media can introduce historical buildings by displaying parts of an object using puzzle pieces, when these pieces are combined, they will display the entire building as a whole. The division of a temple building into several parts can describe the characteristics or important parts of a temple in more detail. The media are expected to help the learning process of historical buildings, especially temples in Indonesia. Through this research we expect to provide a recommendation model for applying the AR technology to the educational field.

2 Method

The development method used by this research adapted from ADDIE models [9]. This method was chosen because, in addition to focusing on application development, it also focuses on good learning material design so that the learning objectives can be achieved. ADDIE Model has 5 stages used in the development process including the stages of analysis, design, development, implementation, and evaluation. The stages of ADDIE Model development can be seen in Fig. 1.

![Figure 1. ADDIE Model development method](image)

The analysis stage is used to identify existing problems, then processed it into application requirement data. The analysis stage is divided into two sections, the media analysis stage and the learning material analysis. Media analysis is used to find the
requirement of the users in the application, at this stage data collection techniques carried out using observation and interview methods. On the other side, the analysis of learning materials is carried out to find the information regarding to learning subject about temples that will be written into the learning module.

There are two phases of development in the design stage, application design and learning media design. Application design is used to construct the results of the requirement analysis into an application prototype. In this stage, the process to determining the proper learning media model that will be used to implement multi-marker method being carried out. In the learning materials design, used to search for learning material that will be written on the learning media.

The development stage is carried out to process design data into an application that can be used by users. The feasibility evaluation of the application is also carried out using the expert judgment method in this stage. There are four experts consisting of two media experts and two material experts who will judge the media feasibility. The assessment instrument that will be used in expert judgement adapted from the Questionare for Learning media Evaluation by Wahono. This method is carried out to assess the feasibility of applications based on aspects of the media or developed applications and the material aspects contained in learning media.

During the implementation stage, the developed media is used by users using of pre and post-test experimental groups method. This method was performed to assess the efficiency of learning media based on the learning outcomes achieved through the use of learning media in the learning process. The participants that will be used in the implementation stage is junior high school student consist 16-20 participants. Participants selected using simple random sampling method without special treatment.

Formative and summative testing is carried out in the evaluation stage. Formative testing is used at all stages of development to ensure that media are developed in accordance to the goals and learning objective. A summative evaluation is performed to assess the quality of the learning media. For example, use the experimental group method during the implementation phase. However, as the implementation stage is still in progress, implementation test data cannot yet be shown in this paper. The summative evaluation mostly used questionnaires instruments for the assessment.

The questionnaire assessment scale refers to Likert Scale to determine the assessment criteria. Assessment is carried out by analyzing the accuracy of the learning application to each statement in the questionare. Each component of the statement is scored between one (1) up to four (4), each point of the score represents the feasibility level of the application. The grade of testing based on score can be seen in Table 1.

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 – 1.50</td>
<td>Very inappropriate</td>
</tr>
<tr>
<td>1.51 – 2.50</td>
<td>Less Eligible</td>
</tr>
<tr>
<td>2.51 – 3.50</td>
<td>Decent Enough</td>
</tr>
<tr>
<td>3.51 – 4.00</td>
<td>Very decent</td>
</tr>
</tbody>
</table>
3 Requirement Analysis

The requirement analysis stage is divided into two phases, media analysis and material analysis. Media requirement analysis was carried out by studying and analyzing the previous research literature about development of learning media for historical buildings using AR technology. The purpose of this analysis is to look for the lack and problem of the previous applications, and also present the solutions that can be provided using the multi-marker method.

Material analysis phase used observation and interview methods. Learning material analysis conducted in a junior highschool to explore some information about learning material that used in educational and learning process on historical buildings subject.

From the requirement analysis process, we obtained the criteria that should be meet by learning media which will be developed. The requirement criteria are determined based on the learning objectives to be achieved. The required criteria for the learning media can be seen in Table 2.

<table>
<thead>
<tr>
<th>NO</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The media must have game aspect</td>
</tr>
<tr>
<td>2</td>
<td>The media can explain the historical building that left behind by Hindu-Hindu-Buddhist Kingdom in Indonesia</td>
</tr>
<tr>
<td>3</td>
<td>The media can explain the function of the temple building</td>
</tr>
<tr>
<td>4</td>
<td>The media can describe the characteristic of the temple</td>
</tr>
<tr>
<td>5</td>
<td>The media can show the important parts of the temple</td>
</tr>
</tbody>
</table>

The first criterion refers to the purpose of learning media to make the learning process become easier and more enjoyable. The second criterion based on the learning curriculum in Indonesia, which stipulates that students need to understand the historical buildings left by the Hindu-Buddhist Kingdom which once existed in Indonesia. The third and fourth criteria used to introduce the temple building in detail to the users. The fifth criterion was determined based on the results of media analysis which found that users were unable to see detailed virtual images of temples, especially important parts such as statues and temple reliefs.

4 Design of Learning Media

Based on the requirement from the analysis stage, then we proposed three game-based AR application models to the user, such as using media board game puzzles [6], flashcard media like [10], and media board game monopoly [11]. And then, we compared the model to determine which learning media model that fits the criteria that have been determined in the analysis stage. The comparison analysis carried out using checklist-based testing by the experts to assess whether the media can meet the requirement criteria. The result of comparison analysis can be seen on Table 3.

<table>
<thead>
<tr>
<th>Number of Requirement</th>
<th>Media</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Puzzle</td>
<td>Flashcard</td>
</tr>
<tr>
<td>Req. No. 1</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Req. No. 2</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Req. No. 3</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Puzzle and monopoly media both have interesting game aspect that can enticing the user to use the media, but flashcard can’t provide interesting gaming experience like those two. For requirement number two (2) to four (4) all model can provide information about temple building using description panel / text from AR application. However, for requirement number 5 only puzzle media that can show up the important part of a temple in the best way.

Puzzles media can be used to display multiple objects simultaneously using puzzle pieces as a marker. The puzzle pieces then can represent the part of the temple using 3D models. In addition, the process of putting together the right puzzle pieces can be used to show up new animations or objects by applying the multi-marker method. So, we decided to use a board game puzzle as learning media to implement the multi-marker AR method.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Learning Media Models</th>
<th>Evaluation</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The media is made using 20 pieces (pcs) puzzles with 4 pieces which will display a temple building when combined</td>
<td>The game model is too easy because there are only 4 pieces of puzzles / pictures that need to be arranged</td>
<td>Each piece marker used different images</td>
</tr>
<tr>
<td>2</td>
<td>The media is made using 20 pieces (pcs) puzzles with different images If 4 pieces of related puzzle are combined it will display a temple building</td>
<td>Users feel confused to find matching puzzle pairs without clue</td>
<td>Provides animation and sound effects when 2 pieces of the same puzzle are combined</td>
</tr>
<tr>
<td>3</td>
<td>The media is made using 20 pieces (pcs) puzzles with different images that If 2 pieces of the related puzzle meet, an animation &amp; sound effect will appear If 4 pieces of related puzzle are combined it will display a temple building</td>
<td>Users still feel confused to find the appropriate piece of puzzle because there are too many puzzle combinations that need to be tried</td>
<td>Add an introductory story that describes the characteristics of the temples that will show up from each puzzle piece</td>
</tr>
<tr>
<td>4</td>
<td>The media is made using 20 pieces (pcs) puzzles with different images If 2 pieces of the related puzzle meet, an animation &amp; sound effect will appear If 4 pieces of related puzzle are combined it will display a temple building Before the game starts the teacher/judge will read a story explaining the temple features that can be found in each puzzle piece</td>
<td>Users can find puzzle pieces according to given criteria, but the time needed to complete the puzzle is still too long Users also still find it difficult to find the right piece, because they have to find the correct part of the puzzle while listening to the story</td>
<td>Giving notes which like a word scramble game containing the characteristics of the temple. So when the story is read the user can search for the appropriate characteristics on the note sheet</td>
</tr>
</tbody>
</table>
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#### Iteration 5

The media is made using 20 pieces (pcs) puzzles with different images. If 2 pieces of the related puzzle meet, an animation & sound effect will appear. If 4 pieces of related puzzle are combined, it will display a temple building. Before the game starts, the teacher/judge will read a story explaining the temple features that can be found in each puzzle piece. The user searches for the characteristics of the temple in the note based on the story they heard. The user can arrange the puzzle by looking for the characteristics of the temple in the marker with the help of the notes.

Users can easily search for puzzle pieces that match the stated characteristics from the notes. The addition of word scramble notes in the learning module makes the game aspect more interesting. Model can be used.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Learning Media Models</th>
<th>Evaluation</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>The media is made using 20 pieces (pcs) puzzles with different images. If 2 pieces of the related puzzle meet, an animation &amp; sound effect will appear. If 4 pieces of related puzzle are combined, it will display a temple building. Before the game starts, the teacher/judge will read a story explaining the temple features that can be found in each puzzle piece. The user searches for the characteristics of the temple in the note based on the story they heard. The user can arrange the puzzle by looking for the characteristics of the temple in the marker with the help of the notes.</td>
<td>Users can easily search for puzzle pieces that match the stated characteristics from the notes. The addition of word scramble notes in the learning module makes the game aspect more interesting.</td>
<td>Model can be used.</td>
</tr>
</tbody>
</table>

After the proper model being decided, then we determine the best puzzle model that can be used to be a learning media. During this phase, mockup or prototypes are used to represent the media that will be developed. Prototypes are used to find the problem and suitable solutions in application development [12]. The prototypes were tested by expert and users to obtain feedback on media improvement. The phases of designing a board game puzzle media based on multi-marker AR method are presented in Table 4.

### 4.1 Media design

There are three media used in the learning module, namely board game puzzle media, storycards and AR Temple applications which will later be developed using Android Smartphone media. Board game puzzles are made using images of historical buildings which can later be used as AR markers. Each puzzle set consists of four pieces (pcs) puzzles that have different images. Fig. 2 is an example of the game puzzle design.

![Figure 2. Board game puzzle as AR marker](image)

Storycard is made to help users to find the right pair of puzzles. The storycard contains an introductory story regarding information on a temple. In the story there is some sentences that describes the characteristics of the temple which will be displayed.
as 3D objects on the marker. Along with the storycard media, there will also be notes containing words that precisely describe the characteristic of the temple based on the storycard. The example of storycard media can be seen in Fig. 3.

![Figure 3. Storycard of Singosari Temple](image)

In the process of AR application design the design is focused on the implementation concept and application interfaces. During this phase, multiple application designs are created in the form of context personas, storyboards, user flows, and application prototype designs. Context personas represent states and problems that users experience [13]. The problem that users had in this research is they need to learning a huge amount of material in a short learning time. Therefore, users need learning media that can provide detailed information in an entertaining way.

The storyboard provides overview of the concept application that will be developed [14]. Fig. 4 is the illustration of the media concept that will be developed and its usage model which is described in a storyboard. The picture in box A represents the learning process that happened in school. Then, there is a leaning media that can make the learning process more enjoyable (Box B). Users can scan the puzzle pieces as AR marker to display a characteristics or part of the temple (Box C). Users can try to combine the puzzle pieces to find the correct combination (Box D). If the puzzle is correctly solved, the application will show the full image of a temple (Box E). Users can also the temple information details on the information menu.
Userflow describes the flow or steps that need to be taken by the user to use the application [15]. Userflow design is described in a reality sequence that describes the appearance of the application that will be seen by the user and the interactions that can be carried out by the user.

4.2 Learning Materials Design

Material design was performed to determine the material that will be loaded into the learning module. The learning material is adjusted to the learning curriculum that applied in schools. According to the Merdeka Curriculum, the course about historical buildings are included in the material chapter of the Hindu-Buddhist Kingdom in Indonesia [16].

Based on these courses, the material contained must be able to explain the historical buildings left by the kingdoms that once existed in Indonesia. There are five (5) temples used as learning materials for this module: The Borobudur Temple and Prambanan Temple which are legacies of the Ancient Mataram Kingdom; The Tikus Temple a legacy of the Majapahit Kingdom; The Singosari Temple a legacy of the Singosari Kingdom; and Muara Takus Temple a legacy of the Sriwijaya Kingdom.

5 Result

Based on the analysis and design phase results, the media is developed into an AR application based on Android Smartphone with the name PARADISA "Parade Candi Indonesia". There are several features in the application that can be used by users, such as main menus, AR scenes, marker combinations and temple information.

5.1 Main Menus

Fig. 5 show the appearance of the main menu page. The main page of the application has several components, there are the name of the application and several menus that can be selected by the user. It has three navigation buttons that users can use to navigate in the application such as Play, How to Play button and the Exit button.
5.2 AR Scenes

Fig. 6 show the appearance of the AR Scene page. The AR Scene page is the page that appears when the user touches the play button on the main menu. This page will open the device's camera to access the app's main feature which is augmented reality.

5.3 Marker Combination

Fig. 7 show an example of using the marker combination feature that brings up the virtual 3D image of Singosari Temple by completing a set of puzzles. The marker combination feature is one of the features on the AR Scene page. This feature allows
the user to combine several markers that detected by the camera to show up a new object or an object as a whole.

5.4 Temple Information Panel

Fig. 8 show the appearance of the Singosari Temple information panel. Temple information is an application feature which display a information panel that contains information about the displayed temple object. The information panel will appear when the users touch the information button at the bottom of the page.

6 Evaluation

The evaluation stage used to evaluate whether the developed media has achieved development and learning objectives. The method used in the evaluation stage is using
the expert judgment method. There are 4 experts consisting of two (2) computer science teachers as media experts and two (2) historical teachers as material experts who test the developed media. Fig. 9 shows the media evaluation process with the expert.

The assessment instrument was adapted from the learning media assessment questionnaire proposed by Wahono [17]. This assessment instrument examines the feasibility of learning media from various important aspects such as system usability, quality of information presented, audio-visual quality, and suitability of the learning material displayed. Therefore, this instrument was chosen because it represents the requirement criteria of learning media mentioned in the analysis stage.

The media expert assessment questionnaire consists of three (3) assessment aspects including software engineering aspects, visual communication aspects, and media design aspects. The results of the media expert assessment is presented in Table 5.

<table>
<thead>
<tr>
<th>Evaluation Aspect</th>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Engineering</td>
<td>3.85</td>
<td>Very decent</td>
</tr>
<tr>
<td>Multimedia</td>
<td>3.75</td>
<td>Very decent</td>
</tr>
<tr>
<td>Media Design</td>
<td>3.69</td>
<td>Very decent</td>
</tr>
<tr>
<td><strong>Avg. Score</strong></td>
<td><strong>3.76</strong></td>
<td><strong>Very decent</strong></td>
</tr>
</tbody>
</table>

The assessment questionnaire for material experts consists of two (2) assessment aspects namely course material and evaluation (assessment). The results of the material evaluation is presented in Table 6.

<table>
<thead>
<tr>
<th>Evaluation Aspect</th>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Material</td>
<td>3.89</td>
<td>Very Decent</td>
</tr>
<tr>
<td>Course Evaluation</td>
<td>3.79</td>
<td>Very Decent</td>
</tr>
<tr>
<td><strong>Avg. Score</strong></td>
<td><strong>3.84</strong></td>
<td><strong>Very Decent</strong></td>
</tr>
</tbody>
</table>

From the results of the tests, the media assessment got very decent grade with an averange score of 3.76. Software engineering aspect had a score of 3.85 with very decent grade. Application can run smoothly, however there are some minor bugs such as
colliding sound when the puzzle is combined. In multimedia aspect, the obtained score is 3.75 with very a decent grade, the expert considers that application needs more improvement on the application interface and animation so that the application can become more attractive. Media design got a score of 3.69 with very decent grade, the application workflow is considered rather difficult to use, particularly for children. Therefore, they suggest creating a guidebook so that users can easily understand how to use the application and use the application independently.

In the material evaluation, the media also got very decent grade with an average score of 3.84. The course material aspect got score of 3.89 with very decent grade, the content of the learning material presented in the application had meet the learning objective on learning the historical building course. The course evaluation aspect also got very decent grade with a score of 3.79. The evaluation method from the learning media can clearly measure the learning outcomes.

7 Conclusion

According to this research, board game puzzle media is one of the appropriate media to implement multi-marker augmented reality methods. From the assessment result of the board game puzzle, the learning media get average score at 3.76 in media aspect and 3.84 in material aspect. Which means that the developed learning media is very decent and can be applied in the educational field to help the learning process of historical buildings especially Temples in Indonesia.

The development of learning media using the multi-marker method can be used to display several objects from several puzzle pieces simultaneously, therefore the media can represent a temple building in more detailed way by showing the characteristics of the temple on each puzzle pieces. The game aspect offered in learning media can also engage the users interest so they can focused on learning the course.

In the future, the developed learning media is expected to be used as a recommendation or design model for implementing the multi-marker method. The model of the learning media can be applied to other learning courses, such as introducing parts of the human body, or describing the chemical reaction process when atomic molecules change into a new compound, etc.

References