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Augmented reality borobudur temple: Development of the aves booklet on the avadana relief story

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ABSTRACT

The issue identified in the aves sub-material for the class The media has not provided a thorough explanation of the structure and morphology of birds. The objective of this study is to create aves booklet media using augmented reality technology and evaluate its appropriateness through expert evaluations and user feedback. The study methodology employed is exploratory descriptive research, which is subsequently followed by development research utilizing the ADDIE model. Utilizing validation evaluation instruments for data analysis. The review of the augmented reality-based Aves booklet by media experts yielded a validity and feasibility score of 91.6%, while material specialists rated it at 80%. Meanwhile, Biology teachers rated the user reaction to augmented reality-based aves *booklets* as 92.5, indicating a very excellent evaluation. Similarly, students' user responses received a rating of 83.25%, indicating a good assessment.

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INTRODUCTION

Borobudur Temple is a Buddhist-style temple building located in Borobudur, Magelang, Central Java. The Borobudur Temple is composed of three tiers: Kamadhatu, Rupadhatu, and Arupadhatu (Borobudur Conservation Center, 2017). At the Rupadhatu level there are Avadana reliefs that highlight the diversity of fauna. The story of the Avadana relief depicts a heroic story. The Avadana relief depicts the same story as the Jataka, with the main character in Avadana not being the Buddha, but other figures or mostly animal incarnations and one of them is the Aves class animal. In research, Ashari et al., (2021) stated that they had succeeded in identifying 19 types of birds in the Lalitavistara relief.

An effective method of promoting local knowledge is by utilizing the diverse stories depicted in Avadana reliefs sculpted at Borobudur Temple as a means of formal education (Samvara, 2023).

As stated by Suryana (2016), formal education refers to the structured and systematic education provided in schools, which adheres to specific curricular guidelines.

Classroom learning encompasses various components that are directly associated with the process of acquiring knowledge (Widianto, 2017). The learning process consists of three interconnected components: students, teachers, and learning resources/media (Samsinar, 2020). An essential element in the process of acquiring knowledge is the presence of educational materials that assist teachers in facilitating the teaching and learning process (Beama et al., 2020). Utilizing educational media can stimulate students' inquisitiveness, however solely relying on verbal explanations from the teacher may hinder students' comprehensive understanding of the subject topic (Aisyah et al., 2022).

According to the findings of interviews conducted with visitors from SMA Negeri 4 Medan in Borobudur Temple in November 2023, it was determined that the main appeal of Borobudur Temple lies in its distinctiveness and historical narratives. Little is known about the tale behind the reliefs carved on Borobudur Temple. It would be highly intriguing to utilize these reliefs as a medium for 2-dimensional or 3-dimensional animation. According to a study conducted by Putra et al. (2019), 58% of teens between the ages of 16 and 18 had not visited Borobudur Temple, but 92.8% of them expressed a desire to learn about the stories depicted on the reliefs.

The findings of interviews conducted with Biology teachers at Tarakanita High School Magelang, as well as the results of surveys discussing the challenges and requirements for learning media in classes that still utilize conventional methods, specifically the Aves picture stamp collection, have been obtained. Nevertheless, the media is lacking in detail or provides insufficient information for students to comprehend the various types, traits, and structures of the human body. In addition, the findings of the Biology learning media needs questionnaire indicated that 57.6% of students encountered challenges in comprehending Biology material, while 91.9% of students expressed a preference for technology-based learning media, such as augmented reality. This preference can be attributed to the abstract and intricate nature of Biology content.

Augmented reality technology can be used as a learning media idea to overcome the problems that have been described. In learning, augmented reality has an important role in conveying knowledge with displays loaded with 3-dimensional animation. Augmented reality technology is considered an interesting learning medium and can help the effectiveness and efficiency of achieving learning goals. Apart from that, learning media with augmented reality is a tool used between teachers and students in learning that is able to connect or convey information so as to create a quality learning process.

This research aims to create augmented reality-based aves booklets that depict the Avadana relief story of the Borobudur Temple. The feasibility of these learning media will be assessed by media experts and material experts. Additionally, user responses will be evaluated by Biology teachers and class X students.

RESEARCH METHODS

Research Design

The research methodology employed in this study is exploratory descriptive research, which is subsequently followed by development research or Research and Development (R&D). Exploratory descriptive research is a type of research that focuses on describing the findings without using them to draw broader conclusions (Sugiyono, 2017). This study involved an exploratory descriptive research approach, focusing on the Avadana balustrade located in the second corridor of the Borobudur Temple. Specifically, the research examined the reliefs panels 39-58, which depict the story of the Rishi and Tiger, as well as the reliefs panels 62-80, which depict the story of the Glittering Peacock. The research methods employed encompass research and

development (R&D) methodologies. R&D research is a methodology that focuses on developing a product and subsequently evaluating its appropriateness through testing (Sugiono, 2016). The research design employed is the ADDIE model, as described by Molenda in 2003. The ADDIE model comprises the stages of Analysis, Design, Development, Implementation, and Evaluation. Nevertheless, this research only progressed to the level of development. This was motivated by time constraints and significant costs.

Population and Samples

The population under study consists of pupils in class X at SMA Tarakanita Magelang, located in Magelang City, within the Central Java Province. The research sample consisted of 33 pupils in the X grade. The employed sampling technique is random sampling, which ensures that every element in the population has an equal chance of being selected as a sample.

Instruments

The instruments used in exploratory descriptive research were the exploration method and Aves identification questionnaire. The exploratory research began with an initial inspection of the relief panels of the Avadana balustrade of the second corridor of Borobudur Temple accompanied by young cultural experts from the museum and cultural heritage unit of Borobudur Temple, then the panels were grouped into two relief stories, namely "Resi and Harimau" panels. 39-58 and the relief story "The Glittering Peacock" panels 62-80. The next stage is the exploration stage which is accompanied by intermediate cultural experts from the museum and cultural heritage unit of Borobudur Temple by carrying out exploration in a clockwise direction and documenting each relief that contains aves reliefs. After the exploration stage, namely the stage of identifying the aves relief on the aves identification questionnaire which is verified by the field supervisor. The process of identifying aves reliefs refers to several accurate book guidelines. After being revised and verified by the field supervisor, the data from exploratory descriptive research can be continued to the development research.

The data required for the development of augmented reality-based aves booklet media is collected using the following instruments: 1) media expert validation sheet; 2) material expert validation sheet; 3) user response sheet for biology professors; 4) user response sheet for students. The validation instrument grid for media experts and material experts is presented in Table I, while the user response instrument grid for Biology teachers and students is presented in Table 2.

Table I. Validation instrument grid for augmented reality-based aves brochure, designed for media professionals and material specialists.

Aspect	Criteria
Media	Appeal to the media
	Precise selection of backdrop, color, and text
	Media feasibility
	Visual acuity
	Efficiency of media
	Media presentation format
Material	The use of media can catalyze student engagement and motivation in the learning process. Study of living organisms and their interactions.
	The utilization of media can enhance students' understanding of the narrative behind the reliefs at Borobudur Temple.
Language	The language employed is readily comprehensible.
	The text on the media is quite legible.

(Latifah Adaptation, 2022)

Table 2. Instrument grid for Biology instructors and students

Aspect	Criteria
Media	Appeal to the media
	Precise choice of backdrop, color, and text
	Media feasibility
	Visual acuity
	Efficiency in media
	Media presentation format
Material	The use of media can serve as a catalyst for motivating pupils in their learning process. Study of living organisms and their interactions.
	Media has the potential to enhance students' understanding of the narrative depicted in the reliefs at Borobudur Temple.
Language	The language employed is readily comprehensible.
	The text on the media is legible.

(Latifah Adaptation, 2022)

Procedures

This study is a preliminary investigation that aims to describe and explore a particular topic, followed by a phase of research and development (R&D). The methodology for this study is outlined in Table 3.

Table 3. Methodology for creating augmented reality-based aves booklets

Data Type	Method of collecting data
Exploratory descriptive research	The purpose of this study is to explore and identify the bird-themed reliefs on the Avadana balustrade of Borobudur Temple.
Analysis	Curriculum analysis, assessment of students' learning media requirements, evaluation of issues in the educational environment, and examination of difficulties in the Borobudur Temple Area.
Design	The process involves identifying the contents of the booklet and creating a framework for an Aves booklet that incorporates augmented reality. This is done using software such as Adobe Illustrator, Corel Draw, Blender, Unity, and Vuforia.
Development	Verification of media specialists and subject matter experts, together with evaluation of user feedback from Biology educators and students
Implementation	The implementation of media is absent.
Evaluation	An assessment is conducted at every level.

Data Analysis

The evaluation of the Aves booklet media was conducted using augmented reality by specialists in media and materials. The analysis was done descriptively using the feasibility percentage technique, as described by Hasanah et al. (2016). The percentage data findings are

subsequently transformed into Table 4. The received scores are transformed into a conversion table by the utilization of a mathematical method.

$$P = \frac{\sum p}{\sum pi} \times 100\%$$

(Hasanah et al., 2016)

Definitions:

P : represents the percentage.

$\sum p$: represents the answer given by a respondent for a certain item

$\sum pi$: represents the total number of ideal values present in a single item

Table 4. Guidelines for making decisions on product revisions

Intervals	Qualitative	Information
0% - 54%	Invalid	Revised
55% - 64%	Not enough	Revised
65% - 74%	Enough	Partially revised
75% - 89%	Valid	No need for revision
90% - 100%	Very valid	No need for revision

(Hasanah et al., 2016)

Assessment of user feedback on avian booklets utilizing augmented reality, conducted by Biology educators and students. The formula used is.

$$P = \frac{\sum p}{\sum pi} \times 100\%$$

(Hasanah et al., 2016)

Definitions:

P : represents the percentage.

$\sum p$: represents the answer given by a respondent for a certain item

$\sum pi$: represents the total number of ideal values present in a single item

The measurement can be established by utilizing response testing data acquired from Biology instructors and students and referring to the assessment scale table supplied in Table 5.

Table 5. Score interval for data analysis

Score Range (%)	Mark	Category
86 – 100	A	Very good
76 – 85	B	Good
66 – 75	C	Enough
55 – 65	D	Not enough
≤54	E	Very less

(Widoyoko, 2012)

RESULTS

The avian species discovered in the Avadana relief narrative at Borobudur Temple are documented in Table 6, based on the findings of an exploratory descriptive study. The outcomes of development research or Research and Development (R&D) conducted under the ADDIE methodology. The research design employed is the ADDIE model. Here is the explanation. During the analysis stage, we conduct a thorough examination of the curriculum, students' learning media

requirements, issues in the school environment, and concerns in the Borobudur Temple Area. During the curriculum analysis stage, the aves material is incorporated into the Biodiversity chapter of the Merdeka Curriculum implementation at Tarakanita High School in Magelang.

Table 6. Types of Aves in the Avadana Relief Story at Borobudur Temple

Class	Famili/Genus	Types of Aves	Place it on the Relief
Aves	Haliastur sp.	Bondol eagle	II.B, 39, II.B, 41, II.B, 57
	Apodidae	Swallow	II.B, 44
	Ardea	Egret	II.B, 46
	Acridotheres sp.	Starling	II.B, 57
	Todirhamphus sp.	River kingfisher	II.B, 58
	Pavo	Female green peacock	II.B, 40, II.B, 57, II.B, 62
		Male green peacock	II.B, 62, II.B, 63, II.B, 64, II.B, 65
	Picus sp.	Woodpecker	II.B, 63
	Columba sp.	Pigeons	II.B, 75

The examination of learning media demands for the Aves sub-material reveals that conventional learning media, specifically a collection of Aves picture stamps, are still being used. However, this media fails to provide a detailed explanation of the structure and morphology of Aves. In addition, students have challenges while attempting to grasp abstract concepts in Biology and express a need for learning resources that use technology. The findings of the assessment conducted on the Borobudur Temple region reveal that a significant number of tourists are unaware of the narrative shown by the reliefs carved on the temple. It would be captivating to transform these reliefs into three-dimensional animations, such as augmented reality, to enhance visitor experience.

Table 7. Product assessment results by media experts and material experts

MEDIA EXPERT	
Indicator	Score
Augmented reality-based Aves booklet size	87.5%
Cover design (cover)	100%
Content design	87.5%
Language	91.6%
Percentage: 91.6%	
Category: Very Valid/Very Eligible	
MATERIAL EXPERT	
Indicator	Score
Up-to-date material	75%
Material accuracy	75%
The Aves booklet presentation technique is based on augmented reality	100%
Language	70%
Percentage: 80%	
Category: Valid/Eligible	

The second step involves the design process. This step involves the development of the Aves booklet product concept using augmented reality technology. The stages involve selecting the content of the Aves booklet that is based on augmented reality. Additionally, the framework for

compiling the Aves booklet is designed using applications such as Adobe Illustrator, Corel Draw, Blender, Unity, and Vuforia.

In the development stage, the framework for compiling aves booklets based on augmented reality is established. In addition, during this phase, professionals conduct validation and Biology professors and students evaluate user comments. Table 7 displays the outcomes of the media validation evaluation conducted by media professionals and material experts.

Biology teachers and 33 class X students at SMA Taraknita Magelang tested user responses to the Aves booklet using augmented reality technology. Table 8 displays the results of evaluations carried out by Biology teachers and students regarding user responses.

Table 8. Evaluation of user responses conducted by Biology educators and students

BIOLOGY TEACHER	
Indicator	**Score**
Media	87.5%
Material	100%
Language	100%
Percentage: 92.5%	
Category: Very good	
STUDENTS	
Indicator	**Score**
Media	81.36%
Material	85.6%
Language	84.7%
Percentage: 83.25%	
Category: Good	

During the implementation stage, the augmented reality-based Aves booklet media has not been put into action. Meanwhile, the Evaluation stage is conducted at each preceding stage to assess and enhance the augmented reality-based Aves booklet.

DISCUSSION

An exploratory study was conducted on February 27, 2024, to examine the Avadana balustrade in the Hallway of two Borobudur Temples. The focus of the study was on the relief story of Rishi and the Tiger panels 39-58, as well as the story of the Merak Gemerlap relief panel 62-80. The study was conducted under the supervision and verification of Ari Swastikawati, S.Si., MA, from the Borobudur Temple Museum and Cultural Heritage Unit agency. The Avadana relief story revealed the presence of 10 distinct aves reliefs, including the bondol eagle (Haliastur sp.), swallow (Aerodramus sp.), great white egret (*Ardea alba*), buffalo starling (*Acridotheres javanicus*), seagull (Larus sp.), river kingfisher (*Todirhamphus chloris*), female green peacock (*Pavo muticus*), male green peacock (*Pavo muticus*), woodpecker (Picus sp.), and dove (Columba sp.).

Subsequently, the research progressed by employing the ADDIE for development research. However, in this research, the medium was either not utilized or merely reached the developmental phase. The initial phase is Analysis, specifically curriculum analysis, which encompasses content on aves in the Biodiversity chapter. Moreover, a study on students' learning media preferences revealed that 93.9% of students expressed a desire for technology-driven learning resources, including augmented reality. The analysis of issues in the school environment, specifically interviews with Biology teachers, reveals that at Tarakanita Magelang High School, particularly in Class 10 aves sub-material, they continue to utilize aves image stamp collections as a learning medium. However, this medium fails to provide a comprehensive explanation of the structure and morphology of aves.

The investigation of the issues at Borobudur Temple, namely an interview with a tourist, reveals that visitors lack knowledge about the narrative shown in the reliefs at the temple. It is suggested that presenting this information through a 3-dimensional animation would be captivating.

In the Design stage, the focus is on determining the content of the augmented reality-based aves booklet. This includes the covers, the overall identity of the booklet (including the author's name), a foreword, a table of contents, instructions on how to use the augmented reality features of the booklet, and an introduction. The augmented reality-based aves booklet includes information about Borobudur Temple and the validated identification of aves reliefs by Mrs. Ari Swastikawati, S.Sc., MA on March 6, 2024. The booklet consists of 10 types of aves, along with a cover page expressing gratitude, a glossary, and references. The next step involves designing a framework for creating augmented reality-based aves books that have already been compiled. When creating designs, I utilize software such as Corel Draw, Blender, Unity, and Vuforia.

During the Development stage, a validation assessment is conducted by professionals in the media and material fields. The creation of augmented reality-based aves booklets necessitates a validation phase conducted by specialists, as exemplified by Aprilia's research (2022). The validation assessment conducted by the material expert for the booklet yielded a score of 77.4%, indicating an acceptable level of quality. Similarly, the assessment for the media resulted in a score of 98.3%, indicating a very feasible level of quality. In Perdana's research (2022), the practicality of AR-based learning media material on cell material was rated 4.50 out of 5.00. The media expert assessment was conducted by Rahma Mahargiyaningtyas, S.ST. from the Borobudur Temple Unit Museum and Cultural Heritage agency, achieving a score of 91.6% in the highly valid/highly feasible area. Dr. Setiyo Prajoko, M.Pd. from Tidar University conducted the material assessment and achieved a score of 80% in the valid/eligible category. The input provided by media and material specialists is displayed in Table 9.

Table 9. Expert input on the development of an augmented reality-based aves booklet

Stages	Before Assessment	Evaluation
Assessment from media experts	media specialists evaluate the media in physical form, specifically printed on sturdy cardboard utilizing augmented reality technology with barcode scanning labeled "Scan Me". Additionally, the design of the booklet is excessively compact and crowded.	Evaluation findings from media experts produced a score of 91.6% in the "very valid/very feasible" category. Media experts suggested using art paper for the booklet instead of the current paper, replacing the barcode scan text "scan me" with just "scan", and optimizing the booklet design to avoid overcrowding.
Assessment from material experts	Currently, the media is evaluated by professionals who specialize in physical files. Their main task is to identify 10 different types of birds, with some of them being identified at the species level.	The evaluation findings from subject matter experts indicated that 80% of the assessed information was categorized as "valid/feasible". Material specialists advise that if you are uncertain, you can only determine the identification of an object at the family or genus level.

Continuing to receive comments and input from experts, efforts are being made to enhance the media used for learning to develop high-quality and visually appealing educational materials for pupils. According to a study conducted by Haryadi & Al Kansaa (2021), the use of technology-based learning material in the classroom might enhance students' interest and motivation in

learning. In addition, learning media plays a crucial role in facilitating successful and high-quality learning interactions between teachers and students (Hatauruk et al., 2022).

In addition, the evaluation of user responses conducted by Biology professors yielded a score of 92.5% in the excellent category. Similarly, the average user response assessment findings from class X students at Tarakanita High School Magelang were 83.25% in the good category. According to the evaluation conducted by media and material specialists, it can be inferred that the Aves booklet based on augmented reality is valid and appropriate as a learning tool for the Aves sub-material in class, meeting several requirements. These criteria consist of validation assessments conducted by professionals in the field of materials, experts in the field of media, and tests based on user responses.

Additionally, during the Implementation stage, the utilization of augmented reality-based aves booklet media was not put into practice or evaluated. The Evaluation stage is conducted during the entire process of analysis, design, and development. Evaluations to enhance augmented reality-based Aves booklet media are derived from suggestions and input provided by media specialists and material experts. The objective is to assess and enhance the augmented reality-based Aves booklet to make it appropriate as an educational tool for class X Aves sub-material.

CONCLUSION

The validation assessment conducted by experts concluded that the Aves booklet, which utilizes augmented reality, received an average score of 85.8%. This assessment categorizes the booklet as suitable for use as a learning medium for the Aves sub-material in class 5, placing it in the "very good" category. Additionally, the user response assessment conducted by class X students yielded an average score of 83.25%, categorizing it as "good". This research implies that as an alternative learning media, namely in the form of augmented reality-based aves booklets on the Avadana relief story at Borobudur Temple in Biology learning in the aves sub-material and to highlight the existence of relief stories carved at Borobudur Temple through Biology learning in the aves sub-material to introduce students to the aves animal carved in the story of the Avadana relief at Borobudur Temple.

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