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Integration of Augmented Reality Based on Cirebon Script Digital Heritage in Grade VIII Junior High School Arts and Culture Learning

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ABSTRACT

This study aimed to develop and integrate an Augmented Reality (AR) application based on the digital heritage of the Cirebon script into Grade VIII Arts and Culture learning at a junior high school in Cirebon, Indonesia. The research employed a Research and Development approach using the ADDIE model. The application was developed with Unity and Vuforia Engine using marker-based tracking and included a home page, learning menu, material pages, AR scanning, an information page, markers, and three-dimensional cultural objects. A field trial was conducted with 34 Grade VIII students selected through purposive sampling following the implementation of the application in one learning session. All 34 students completed the evaluation questionnaire; however, 674 of the expected 680 item responses were valid and available for descriptive analysis because six responses were missing, while 30 questionnaires with complete responses were included in the Cronbach's alpha reliability analysis. The overall mean score of 2.81 out of 4 (70.33%) was calculated using all available valid item responses, indicating that the application was perceived positively. Interactivity and multimedia integration achieved the highest aspect score (74.63%), whereas technical functionality obtained the lowest score (68.05%). The reliability coefficient (Cronbach's alpha = 0.976) indicates excellent internal consistency. The findings demonstrate that the application is feasible as a supporting learning medium and offers potential for the digital preservation of the Cirebon script. Nevertheless, improvements in scanning stability, device compatibility, and cultural content validation are recommended before broader implementation.

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1. INTRODUCTION

Cirebon Script is part of the region's cultural heritage, encompassing historical values, identity, language, and the cultural expression of the Cirebon community. In Grade VIII

junior high school (SMP) Cultural Arts education, local script materials are still commonly delivered through lectures, textbooks, or static images. Such instructional approaches have not fully enabled students to observe the forms of the script, understand how to read and write it, relate the script to cultural objects, or actively explore the learning materials. This condition highlights the need for a more contextual, interactive learning medium that aligns with students' familiarity with digital technology [1], [2], [3].

The preservation of the Cirebon Script should be positioned within the framework of digital heritage, which refers to the process of documenting, managing, protecting, and providing access to cultural resources in digital form while maintaining their authenticity, accessibility, and long-term sustainability. Digital preservation requires proper access management, source documentation, format maintenance, and strategies to address hardware and software obsolescence [4], [5], [6]. Therefore, a cultural application should not merely display script characters but should also integrate their forms, pronunciation, writing conventions, historical background, meanings, and associated cultural artifacts into a comprehensive digital resource [2], [7], [8].

Augmented Reality (AR) is particularly relevant because it enables virtual information, including text, images, and three-dimensional objects, to be overlaid onto the real environment in real time. In educational settings, AR allows students to interact with markers and digital models without leaving the classroom context. Over the past two decades, the development of AR has increasingly focused on supporting learning objectives, instructional tasks, learner interaction, and assessment, rather than functioning solely as a visual demonstration tool [9], [10], [11], [12].

Empirical evidence indicates that AR can enhance learners' responses, knowledge acquisition, skills, and academic performance. However, its effectiveness depends on factors such as visual quality, duration of use, device readiness, and the design of learning activities [13], [14], [15]. Active and well-structured pedagogical approaches strengthen the educational benefits of AR, whereas complex user interfaces and excessive cognitive load may reduce its effectiveness [16], [17]. In the context of regional script learning, Android-based AR applications have been developed for the Sundanese Script and the Ka Ga Nga Rejang Script, both receiving positive user responses [18], [19], [20].

Within the broader context of cultural heritage, AR has been widely utilized for education, interpretation, documentation, reconstruction, and enhancing users' experiences with cultural objects [21], [22], [23]. Nevertheless, the development of an integrated AR application for the Cirebon Script that combines script learning, Cirebon historical buildings and artifacts, Cultural Arts learning activities, and an evaluation of students' responses remains limited. Therefore, this study aims to develop an Augmented Reality application based on the digital heritage of the Cirebon Script, design its integration into Cultural Arts learning, evaluate its functionality and usability, and describe the responses of Grade VIII junior high school students toward its implementation.

2. METHOD

This study employed a Research and Development (R&D) approach using the ADDIE instructional design framework developed by [24]. In this study, ADDIE served as a

systematic framework for developing and evaluating the instructional product rather than as the overall educational research design. The framework was selected because it provides a structured and iterative process that facilitates continuous revision and improvement throughout the development cycle.

The research consisted of six sequential phases. The first phase, needs analysis, involved identifying students' and teachers' learning needs through classroom observations, curriculum analysis, and a review of learning resources related to the Cirebon script. In addition, the researchers assessed the availability and technical specifications of Android devices to ensure that the developed application could be implemented effectively in the learning environment.

The second phase, instructional and application design, focused on developing the instructional structure and application prototype. This stage included formulating learning objectives, preparing storyboards and flowcharts, designing the user interface, developing augmented reality (AR) markers, organizing learning materials, creating three-dimensional cultural objects, and preparing evaluation instruments. The design process emphasized the alignment between instructional objectives, learning content, and application features to support meaningful learning experiences.

The third phase, software development, involved constructing the application using Unity integrated with the Vuforia Engine based on a marker-based tracking system. Learning materials, multimedia components, animations, audio, and interactive AR features were integrated into a functional Android application. After development, the application underwent internal technical testing, including black-box testing to verify software functionality, marker recognition testing, compatibility testing across Android devices, and debugging to identify and correct technical problems before classroom implementation.

The fifth phase, classroom implementation, consisted of a field trial involving 34 Grade VIII junior high school students. During the implementation, students participated in an orientation session, explored the learning materials through the application, scanned AR markers to visualize three-dimensional representations of the Cirebon script, interacted with multimedia content, and engaged in classroom discussions. After completing the learning activities, students were asked to evaluate the application by completing a response questionnaire.

The final phase, student-response evaluation, assessed students' perceptions of the developed application. Data were collected through classroom observations, functional testing, documentation, and a student response questionnaire consisting of 20 statements measured on a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). The questionnaire evaluated interface design, navigation, functionality, marker scanning performance, virtual object accuracy, visual quality, multimedia integration, interactivity, response time, system stability, clarity of instructional content, perceived usefulness, user satisfaction, and the overall feasibility of the application.

The collected data were analyzed using descriptive statistics, including mean scores and percentage achievements. The assessment criteria were classified as very poor (1.00–1.75), fair (1.76–2.50), good (2.51–3.25), and very good (3.26–4.00). Because a small number of questionnaire items contained missing responses, descriptive statistics were

calculated using all valid item responses. In contrast, the internal consistency of the questionnaire was assessed using Cronbach's alpha based only on questionnaires with complete responses. This approach ensured that the descriptive analysis represented the maximum amount of available data while maintaining the accuracy of the reliability analysis.

3. RESULTS AND DISCUSSION

3.1 Results

Application Product and Learning Integration

The product developed is an Android-based application employing a marker-based tracking approach. The application consists of a home page, a Learn menu, learning content pages, an AR Scan menu, an About page, AR markers, and three-dimensional (3D) models. The Learn menu provides introductory materials on the Cirebon Script, including examples of words and sentences, reading and writing instructions, as well as information about Sunyaragi Cave, the Great Mosque of Cipta Rasa, the Singa Barong Royal Carriage, and the Ki Santomo Cannon. The AR Scan menu activates the device's camera to detect AR markers and display the corresponding virtual 3D objects.

Table 1. Application Features and Their Learning Functions

Feature	Main Function	Learning Function
Home Page	Provides access to the Learn, AR Scan, and About menus.	Guides students in selecting learning activities.
Learn	Displays learning materials on the Cirebon Script and cultural heritage objects.	Provides foundational knowledge.
Learning Materials	Presents script forms, transliterations, historical background, and explanations.	Supports conceptual understanding and cultural literacy.
AR Scan	Detects markers and displays 3D models.	Enables visual and contextual observation.
About	Explains the objectives, benefits, technology, and application version.	Introduces the purpose and scope of the application.

The integration of augmented reality (AR) into the learning process was designed through a sequence of learning activities, including orientation, content exploration, marker scanning, object observation, discussion, and reflection. Teachers play a central role in guiding learning objectives, connecting virtual objects with cultural information, and reinforcing students' understanding. This instructional pattern is essential because the availability of three-dimensional models alone does not automatically produce meaningful learning experiences. AR provides greater educational benefits when integrated with active, collaborative, and well-structured learning activities [25].

Stage I Testing and Product Revision

Internal testing was conducted to evaluate page navigation, button functionality, readability of the learning material list, marker detection, and the visualization of 3D objects. Overall, the core functions operated as intended. However, several aspects required improvement, including the consistency of terminology related to the Cirebon Script,

spelling on the About page, truncated learning content, object size and texture, and marker detection stability. Product revisions were carried out by standardizing terminology, improving the interface layout, adjusting font sizes, optimizing digital assets, and enhancing marker quality.

Students' Responses to the Application

Table 2. Summary of Research Data

Component	Result
Number of respondents	34 eighth-grade junior high school students
Number of questionnaire items	20 statements
Valid responses	674 out of 680 expected responses
Complete responses for reliability analysis	30 respondents
Overall mean score	2.81 out of 4
Achievement percentage	70.33%
Category	Good
Cronbach's alpha	0.976

A total of 34 students completed the questionnaire. Of the 680 expected responses, 674 were completed, while six responses were left unanswered. Thirty respondents provided complete responses for the reliability analysis. The overall mean score was 2.81 on a four-point scale, equivalent to 70.33%, indicating that the application was evaluated as good. Furthermore, the Cronbach's alpha coefficient of 0.976 indicates excellent internal consistency. Nevertheless, this high coefficient should be interpreted alongside the quality of item wording to ensure that the questionnaire items do not contain excessively similar or redundant indicators.

Table 3. Students' Responses by Assessment Aspect

Aspect	Mean Score	Achievement	Category
User Interface and Ease of Use	2.80	70.10%	Good
Functionality and Technical Performance	2.72	68.05%	Good
Interactivity and Multimedia Integration	2.99	74.63%	Good
Content Quality, Learning Benefits, and Instructional Effectiveness	2.85	71.24%	Good
Design Quality, User Satisfaction, and Feasibility	2.82	70.50%	Good

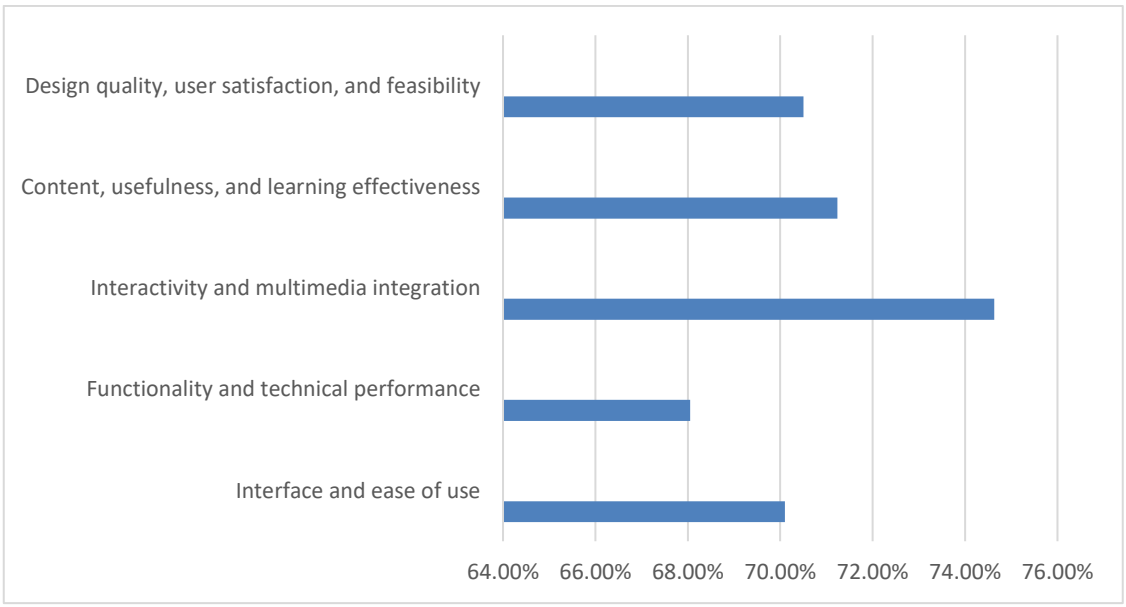

Figure 1. Summary of the Application Assessment by Aspect

The interactivity and multimedia integration aspect achieved the highest score, reaching 74.63%. At the item level, the integration of text, images, and virtual objects obtained a score of 79.41%, indicating that multimodal content presentation is one of the application's primary strengths. This finding is consistent with the principles of multimedia learning, which suggest that verbal and visual information enhance understanding when presented in a relevant and balanced manner. Previous studies on regional script learning have also demonstrated that presenting script forms, writing, and pronunciation through Android-based media can improve accessibility and user engagement.

The functionality and technical performance aspect recorded the lowest score, at 68.05%. The item evaluating whether the application operated without technical issues received 62.50%. These findings indicate the need for further optimization of model and texture sizes, marker quality, response time, graphics settings, lighting conditions, and device compatibility. Previous studies have shown that usability, user experience, and cognitive load are closely interconnected in augmented reality applications for cultural heritage. Technical limitations may distract users from the cultural narratives intended to be conveyed through the application.

Contribution to Digital Heritage

The application has the potential to serve as an initial platform for documenting the Cirebon Script and other local cultural heritage objects by integrating script content, historical information, markers, and three-dimensional models within a single system. However, digital heritage should not be evaluated solely based on the successful visualization of virtual objects. Long-term sustainability requires expert validation, clearly documented content sources, comprehensive metadata, asset backup procedures, version management, and maintenance documentation. These elements are essential to ensure that

the digital content remains authentic, updatable, and reusable for future preservation and educational purposes.

Research Limitations

The questionnaire results in this study reflect users' responses regarding the application's acceptance, quality, usability, and perceived usefulness after being used by students. However, these findings should not be interpreted as causal evidence of improvements in learning outcomes, interest, or motivation, as the study did not employ a pretest–posttest comparison. Furthermore, the evaluation was limited by the number of participants and the range of devices available for testing. Future research should incorporate well-documented expert validation, evaluate the application across a wider variety of devices, and employ experimental research designs to provide stronger evidence of its impact on learning outcomes.

3.2 Discussion

The findings demonstrate that the developed Android-based Augmented Reality (AR) application successfully integrates digital heritage content with Arts and Culture learning for Grade VIII students. Unlike conventional learning media, the application combines textual explanations, visual illustrations, three-dimensional (3D) cultural objects, and marker-based AR technology within a single learning environment. This integration enables students to access information about the Cirebon Script and its associated cultural heritage through interactive exploration rather than passive observation. The inclusion of learning materials, transliterations, historical explanations, and virtual cultural objects reflects the principles of contextual learning, whereby students construct knowledge by connecting abstract concepts with authentic cultural representations. The structured learning sequence consisting of orientation, exploration, marker scanning, observation, discussion, and reflection further supports meaningful learning because AR technology functions as a learning facilitator rather than merely a visualization tool. This finding is consistent with previous studies reporting that AR produces greater educational benefits when embedded within well-planned instructional activities that encourage interaction, collaboration, and reflection rather than functioning as an isolated technological feature [25].

The product development process also demonstrates the importance of iterative refinement in educational technology development. Internal testing confirmed that the application was functionally operational, while simultaneously identifying several technical and instructional aspects requiring improvement. Revisions involving terminology standardization, interface refinement, optimization of digital assets, enhancement of marker quality, and improvements in 3D visualization illustrate the iterative nature of the ADDIE framework. Such revisions are particularly important in AR-based applications because instructional effectiveness depends not only on the accuracy of learning content but also on software stability, usability, and visual performance. This finding supports the view that educational applications should undergo continuous evaluation before wider implementation to ensure both pedagogical quality and technical reliability.

Student responses indicate a generally positive acceptance of the developed application. The overall mean score of 2.81 out of 4 (70.33%) places the application in the good category, suggesting that students perceived the application as useful, understandable, and engaging during classroom activities. Nevertheless, these findings should be interpreted as evidence of user acceptance rather than as confirmation of educational effectiveness. The questionnaire measured students' perceptions after using the application and did not evaluate whether learning achievement, cultural understanding, or motivation improved as a direct consequence of the intervention. Therefore, the results primarily demonstrate that the application was positively received by its intended users, providing an important initial indicator of its practicality for classroom use.

The reliability analysis further strengthens the credibility of the evaluation instrument. The Cronbach's alpha coefficient of 0.976 indicates excellent internal consistency among questionnaire items, suggesting that the instrument measured students' perceptions consistently. However, a reliability coefficient of this magnitude should also be interpreted cautiously because extremely high alpha values may indicate overlap or redundancy among questionnaire items. Consequently, future studies should complement reliability analysis with construct validity procedures, such as exploratory or confirmatory factor analysis, to ensure that each indicator measures a distinct aspect of application quality while maintaining strong internal consistency.

Among the evaluated aspects, Interactivity and Multimedia Integration achieved the highest score (74.63%), indicating that students particularly appreciated the application's ability to combine text, images, animations, and three-dimensional virtual objects into an integrated learning experience. The highest individual item concerned the integration of text, images, and virtual objects (79.41%), suggesting that multimodal presentation successfully enhanced students' engagement with the learning materials. This finding is consistent with the Cognitive Theory of Multimedia Learning proposed by Mayer, which argues that learners understand information more effectively when verbal and visual representations are presented in complementary ways rather than separately. Previous research on Android-based learning media for regional scripts has similarly shown that multimedia integration increases learner engagement, accessibility, and comprehension by allowing students to interact directly with instructional content instead of relying solely on printed materials.

In contrast, Functionality and Technical Performance received the lowest evaluation (68.05%), although it remained within the good category. The relatively lower score reflects several technical challenges experienced during implementation, particularly regarding application stability, marker detection, response time, and compatibility across Android devices. The questionnaire item addressing whether the application operated without technical problems obtained only 62.50%, indicating that technical performance remains an important area for improvement. These findings highlight a common challenge in AR-based educational applications, where software quality substantially influences user experience. Delays in marker recognition, unstable rendering, or inconsistent performance across devices may increase users' cognitive load and divert attention from instructional objectives. Therefore, future development should prioritize optimization of graphics rendering, marker

quality, lighting tolerance, texture resolution, and cross-device compatibility to improve application stability under diverse classroom conditions.

The findings also demonstrate the application's contribution to the preservation of digital cultural heritage. Beyond functioning as an instructional medium, the application digitally documents elements of the Cirebon Script together with culturally significant objects such as Sunyaragi Cave, the Great Mosque of Cipta Rasa, the Singa Barong Royal Carriage, and the Ki Santomo Cannon. Integrating historical narratives, script forms, transliterations, markers, and three-dimensional models within a unified digital platform represents an innovative approach to introducing local cultural heritage to younger generations. Such integration aligns with contemporary digital heritage initiatives that emphasize the use of immersive technologies to improve cultural accessibility while supporting educational activities. Nevertheless, effective digital preservation requires more than technological visualization. The authenticity and long-term sustainability of digital heritage depend on expert validation, transparent documentation of cultural sources, comprehensive metadata, systematic version control, digital asset preservation, and regular maintenance procedures. Without these components, digital heritage applications risk becoming temporary visualization tools rather than sustainable preservation resources.

Despite these positive findings, several limitations should be acknowledged. First, the evaluation focused exclusively on students' perceptions of application quality, usability, and acceptance without measuring changes in learning outcomes through experimental comparisons. Second, the implementation involved a relatively limited sample from a single educational setting, thereby restricting the generalizability of the findings. Third, differences in Android device specifications may have influenced application performance and user experience during implementation. Consequently, future research should incorporate broader participant samples, conduct expert validation involving both educational technology specialists and cultural heritage experts, evaluate application performance across a wider range of devices, and employ experimental or quasi-experimental research designs using pretest–posttest measures. Such studies would provide stronger empirical evidence regarding the effectiveness of AR-based digital heritage applications in improving cultural literacy, student engagement, and learning achievement while supporting the sustainable preservation of regional cultural heritage.

4. CONCLUSION

This study resulted in the development of an Augmented Reality (AR) application based on the digital heritage of the Cirebon Script to support Grade VIII Arts and Culture learning. Developed using the ADDIE framework with Unity and the Vuforia Engine, the application integrates instructional materials with marker-based AR features, including a home page, learning menu, learning materials, AR scanning, markers, and three-dimensional cultural objects. The learning activities were structured through orientation, exploration, marker scanning, observation, discussion, and reflection to encourage students' engagement with both the instructional content and the cultural heritage represented in the application.

Student responses indicated a generally positive level of acceptance, with an overall mean score of 2.81 out of 4 (70.33%). Interactivity and multimedia integration received the

highest evaluation, whereas technical functionality and system performance were identified as aspects requiring further refinement. The questionnaire demonstrated excellent internal consistency, with a Cronbach's alpha coefficient of 0.976. These findings provide preliminary evidence that students will accept the application and shows promise as a supplementary learning resource for introducing and promoting the digital preservation of the Cirebon Script. However, the present study does not provide sufficient evidence to establish comprehensive educational feasibility or effectiveness. Future research should therefore strengthen cultural content validation, improve device compatibility and scanning stability, and evaluate the application's impact on learning outcomes through more rigorous research designs involving larger and more diverse samples.

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