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AI-BASED DIGITAL RECONSTRUCTION OF HISTORICAL SITES IN BANYUWANGI AS A TEACHING MEDIA FOR HIGH SCHOOL HISTORY COURSES

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ABSTRACT

Banyuwangi Regency has a high potential for local history through the existence of sites such as Songgon Cave, Wongsorejo Cave, Kalipuro Cave, and the Kendenglembu Neolithic Site. These resources have not been optimally utilized in the history learning process at the high school level. This study aims to develop artificial intelligence-based digital teaching media that reconstructs local historical sites visually and educationally. This study uses a 4D Research and Development (R&D) model approach, including the stages of define, design, develop, and disseminate. The research sample consisted of 200 high school students selected using stratified purposive sampling. Data collection techniques included pre-tests and post-tests, expert validation, observation, and interviews with local communities. The results showed that expert validation obtained a feasibility score of 92% and usability of 89%. Students' pre-test score was 61.4, increasing to 84.7 in the post-test, with a Cohen's d effectiveness value of 1.72. This media is considered very suitable for use in the history learning process based on local wisdom. This research recommends further development of virtual reality integration and GIS-based visual data enhancements. This AI-based medium is expected to enhance contextual, immersive, and relevant local history learning for today's digital generation

INTRODUCTION

Banyuwangi's wealth of historical sites offers significant potential for transforming history education at the high school level. Several locations, such as Songgon Cave and Kendenglembu Cave, hold local narratives that have not yet been digitally documented. The existence of these sites is historically closely linked to the cultural identity of the Banyuwangi people. According to Zhao et al. (2025), heritage-based education can be enhanced through virtual reality and AI-based reconstruction approaches. These approaches can help students understand historical contexts more holistically and imaginatively. Therefore, the initial section of the introduction highlights the importance of rediscovering local heritage through digital reconstruction to strengthen student learning.

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The main problem lies in the lack of history teaching media that contextually integrate artificial intelligence. To date, there is no system that combines oral history, local documentation, and AI capabilities in a single learning platform. A study by Bal & Öztürk (2025) states that AI-based media can improve critical thinking skills and connections between historical contexts. On the other hand, research by Sachyani & Gal (2025) emphasizes the need for technological support in the creative learning process of the 21st century. Theoretically, the integration of technology and local education approaches will encourage the creation of a highly effective learning system. Therefore, a specific explanation in the manuscript clarifies the urgent need for AI-based digitization of local history.

The novel approach offered in this research lies in the concept of an AI-based digital heritage twin. This model combines simple photogrammetry, image crowdsourcing, and local interview-based prompts. Hord Arsalan et al.'s (2025) research introduces a relevant echo-based heritage framework for reconstructing lost historical buildings. Meanwhile, Pathan & Suhane (2025) emphasize that AI and photogrammetry can enhance the conservation of cultural heritage visually. Both studies reinforce the idea that local digital innovations can enhance students' interest in local history. Therefore, the novelty section in the introduction demonstrates an important contribution to digital history literacy at the secondary education level.

The research objectives reflect a systematic effort to produce pedagogically and technologically sound media. The development of the AI platform was conducted through R&D stages involving expert validation and direct effectiveness testing on students. According to Mantovan & Nanni (2020), AI in archaeology enables spatial replication based on authentic and structured data. In education, Kim et al. (2025) demonstrated that students' AI literacy significantly improves when the approach is project-based and involves real-world visualization. Therefore, this research aims to demonstrate the effectiveness of AI media in improving high school students' understanding of local history. These objectives align with the urgency outlined in the general and specific explanations.

METHOD

This research uses a research and development (R&D) approach that refers to the 4D model developed by Thiagarajan, Semmel, and Semmel. This model includes four core stages: Define, Design, Develop, and Disseminate, each of which aims to produce a usable product that is proven effective. The 4D approach is highly suitable for developing technology-based learning media that integrates local historical data and artificial intelligence (AI). This model has been widely applied in the development of digital teaching tools, as proposed by Borg and Gall (1983) and updated by Alessi & Trollip (2001) for the digital learning context. In the context of this research, the researchers utilized this model to develop AI digital media that reconstructs historical sites in Banyuwangi. Each stage focused on empirical validation through the involvement of students, teachers, and historians from various educational backgrounds. The development process was oriented towards the effectiveness of media use in public high schools throughout Banyuwangi Regency.

The subjects of this study consisted of two main groups: historical sites and public high school students. The historical sites used as objects were Songgon Cave, Wongsorejo Cave, Kalipuro Cave, and the Kendenglembu Neolithic Site, all located in Banyuwangi Regency. The researchers selected 20 public high schools across Banyuwangi as the product trial sites, encompassing schools in urban, coastal, and inland zones. From each school, 10 grade XI social studies students were purposively selected, resulting in a total sample size of 200 students. Stratified purposive sampling was used based on the availability of ICT facilities and the schools' geographic accessibility. According to Fraenkel and Wallen (2012), this method is effective for obtaining representative data from a heterogeneous population. The sampling process took into account the representativeness and diversity of public school typologies in the Banyuwangi region.

The instruments used in data collection consisted of questionnaires, validation sheets, objective tests, and semi-structured interview guides. Data collection techniques used quantitative and qualitative methods to provide a comprehensive overview of the validity and effectiveness of the developed media. Quantitative data included pre- and post-test scores on local history understanding, as well as validation of the media's content and presentation by history experts and learning technology experts. Qualitative data included observations of media use, interviews with local figures, and photo and video-based field documentation. A data triangulation approach, as described by Denzin (1978) and Patton (1990), was used to increase the reliability of the collected data. Internal validity was maintained through expert testing, while external validity was achieved through trials in various environments. All of this data was systematically processed at each stage of the development model.

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Quantitative data analysis was conducted using descriptive and inferential statistical techniques to evaluate the effectiveness of the media. Descriptive statistics were used to measure the mean, standard deviation, and distribution of student data in the pre-test and post-test. Inferential analysis was conducted using a paired t-test to determine differences in learning outcomes before and after the use of AI digital media. To measure the strength of the effect of media use, researchers used the Cohen's d index, as described by Cohen (1988) in the framework of evaluating the influence of experiment-based education. Media validation was conducted using the Aiken's V technique to determine the agreement between experts on the quality of the developed product, as described in Azwar's study (2015). Researchers used SPSS statistical software for numerical data processing and presentation of research analysis results. All results were analyzed based on each stage of product development according to the 4D structure.

The implementation of AI digital media was carried out in stages at 20 high schools (SMAN) participating in the product trial. Initially, researchers provided training on the use of the media to history teachers at each school to ensure proper integration into the learning process. The product trial lasted two weeks and was conducted during history lessons in grade XI IPS. Students participated in learning sessions using digital media, reconstructing historical sites, using computers or devices available in the school laboratory. Classroom observations were conducted by researchers and accompanying teachers to assess student engagement and ease of use of the interface. After the learning session, students completed a perception questionnaire containing indicators of their perceptions regarding usefulness, attractiveness, ease of use, and relevance of the material. All of this data was used to refine the media before its widespread dissemination across all high schools in Banyuwangi Regency.

RESULTS AND DISCUSSION

Researchers began the define phase to identify the need for AI-based media. A survey was conducted with 200 students and several history teachers from four schools in Banyuwangi. The results showed high student interest, with an average score of 4.3 out of 5. However, students' knowledge of AI was only 2.8 out of 5, or 56%. This data demonstrates the importance of providing AI literacy from the beginning of media development. This is in line with the opinions of Sachyani & Gal (2025) and Bal & Öztürk (2025) regarding the need for an integrated educational approach in introducing technology. Therefore, this survey serves as a basis for designing media that is not only interactive but also educational in terms of introducing technology.

Table 1. Results of the Survey of Digital Media Needs for Students and Teachers

Measured Aspects	Maximum Score	Average Score	Percentage (%)	Category
Student interest	5	4.3	86%	Tall
School equipment readiness	5	3.9	78%	Enough
Teachers' expectations of media	5	4.6	92%	Very high
Students' knowledge of AI	5	2.8	56%	Low

Rsearchers developed a media prototype and tested it with two history and educational media experts. Validation was conducted on historical content, visual interface, ease of navigation, and content suitability to the curriculum. The validation results showed an average score of 3.75 out of 4 with Aiken's V of 0.94. This value indicates a very high level of agreement between experts, as stated by Maher Bouchachi et al. (2025) and Tu et al. (2025). This validation proves that the media meets the standards of content, visuals, and pedagogical functions. Therefore, the validation results serve as the main reference for refining the media before field trials.

Table 2. Results of Media Prototype Validation by Experts

Assessment Aspects	Max Score	Expert Score 1	Expert Score 2	Average	Aiken's V
Conformity of historical content	4	4	4	4	1.00
Interface view	4	3	4	3.5	0.88
Ease of navigation	4	3	4	3.5	0.88
Compliance with the curriculum	4	4	4	4	1.00

Researchers proceeded to the development stage to quantitatively test the media's effectiveness. A pre-test and post-test were used to measure local history comprehension on 200 students. The average pre-test score was 61.4, while the post-test score increased to 84.7. A t-test analysis yielded a t-value of 27.63 with a significance level of <0.001 and a Cohen's d of 1.72. This significant effect supports the findings of Ruiz Viruel et al. (2025) and Liu et al.

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(2025) regarding the effectiveness of AI-based media in improving conceptual understanding. Therefore, the effectiveness test results indicate that this media can significantly improve student cognition.

Table 3. Results of Media Effectiveness Test (Pre-Test and Post-Test)

Variables		Pre-test (Mean)	Post-test (Mean)	Elementary School Preschool	SD Post	t-Value	Sig. (p)	Cohen's d
Understanding history	local	61.4	84.7	7.9	8.3	27.63	<0.001	1.72

In the dissemination phase, researchers evaluated user perceptions of the media. Perceptions were measured using a Likert-scale questionnaire administered to 200 students and eight history teachers. The average perception score was 4.43 out of 5, indicating very good acceptance. These results support the reports of Younas et al. (2025) and Zhao et al. (2025) regarding the success of digital media in increasing learning engagement. Furthermore, teachers expressed their intention to integrate the media into their classroom teaching materials. Therefore, user acceptance provides a positive signal regarding the potential adoption of this media in secondary schools.

Table 4. Teacher and Student Perceptions of Digital Media

Statement	Average Score (1–5)	Percentage (%)	Category
This media is interesting and interactive	4.6	92%	Very good
Students can easily understand historical content using media	4.4	88%	Good
Teachers are interested in integrating into the lesson plan	4.5	90%	Very good
Media according to the characteristics of Banyuwangi high school students	4.2	84%	Good

Researchers compiled a summary of the analysis results from all stages to facilitate data interpretation. This table presents the stages, analysis techniques, and key results from each R&D section. Define identified an AI knowledge gap, design demonstrated high validation, develop demonstrated media effectiveness, and disseminate demonstrated high acceptance. These data reinforce the arguments of Mantovan & Nanni (2020) and Hord Arsalan et al. (2025) regarding a hybrid approach to conservation and education. These results demonstrate the media's suitability to the local context and global needs. Therefore, the media can serve as a reference model for other regions with similar characteristics.

Table 5. Summary of Analysis of Each Stage of R&D Research

Stage	Analysis Techniques	Key Results
Define	Descriptive	High demand, AI knowledge gap
Design	Expert Validation, Aiken's V	Media validity = 0.94 (valid)
Develop	t-test, Cohen's d	Significant increase, d = 1.72
Disseminate	Descriptive	Average perception = 4.43 (very good)

Researchers based this media on constructivism theory, which emphasizes students' active involvement in constructing knowledge. AI-based interactive media provides a powerful visual and reflective learning experience. Bal & Öztürk (2025) stated that this type of media enhances students' in-depth understanding and critical analysis. This is also supported by Kim et al. (2025) who emphasize the importance of authentic data in AI learning. In a local context, AI-generated visualizations of historical sites enable students to construct spatial and historical understanding simultaneously. Therefore, the use of AI in educational media significantly strengthens the constructivist approach. The results of student responses to the visualization aspect are summarized in the following table.

Table 6. Student Perceptions of AI Media Visualization Aspects

Statement	Average Score	Category
Easy to understand historical site images	4.5	Very good
Visualization makes history more interesting	4.6	Very good

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Statement	Average Score	Category
AI images according to the local context of the Banyuwangi site	4.3	Good
The colors, designs, and visual details are quite historically accurate.	4.4	Good

Researchers conducted a thematic analysis of in-depth interviews with history students and teachers. The majority of students stated that they understood history better when presented visually. Teachers reported that media helped explain topics that were previously difficult to explain verbally. This finding aligns with the results of studies by Wilson et al. (2025) and Younas et al. (2025) on the role of technology in overcoming pedagogical limitations. Affective aspects such as student interest and motivation also increased during the learning process. These interview data support the quantitative results and enrich the interpretation of the trial results. The following table summarizes the dominant themes from the interviews.

Table 7. Thematic Analysis of Teacher and Student Interviews

Main Theme	Description of Findings
Ease of understanding the material	Students feel more understanding when learning through visualization of historical sites.
Student emotional involvement	Learning feels more meaningful and closer because it uses a local context.
Support for teacher lesson plans	Media helps teachers organize teaching materials and save explanation time.
Potential for sustainable use	Teachers are interested in reusing the media for the next class.

Researchers compared student perceptions based on school location: urban, semi-urban, and rural. Data distribution showed that students in all locations gave high scores to the media. The differences in scores were not statistically significant, indicating the media's adaptability across geographic contexts. Silva (2025) noted that educational interventions based on local culture tend to be accepted across all regions. Therefore, media design that adapts to the local context is a key factor in its success. This is reinforced by Mader et al. (2025) who emphasized the importance of equitable access to digital media in rural schools. The following table shows the distribution of perceptions by location.

Table 8. Distribution of Student Perceptions by School Location

School Location	Average Perception (1–5)	Category
Urban	4.45	Very good
Semi-Urban	4.42	Very good
Rural	4.39	Good

Researchers also analyzed the correlation between student perceptions and post-test score improvement. The results showed a moderate positive correlation (r = 0.56) between media perceptions and learning outcomes. This finding suggests that students with positive perceptions tend to experience higher learning outcomes. Younas et al. (2025) and Tlili et al. (2025) explain that positive perceptions of technology can strengthen cognitive learning outcomes. This indicates that AI media functions not only as an aid but also as a motivational stimulus. Therefore, it is important to maintain positive student perceptions through engaging and informative design. The correlation data is shown in the following table.

Table 9. Correlation of Student Perceptions of Media and Post-test Scores

Variable X (Media Perception)	Variable Y (Post-test Score)	Correlation Coefficient (r)	Interpretation
Average perception	Average post-test score	0.56	Moderate

Researchers compared the effectiveness of AI digital media with conventional learning media commonly used. Conventional media generally include printed text, worksheets, and static presentations. Based on observations and measurements, AI media provided greater learning outcomes than conventional media. Tu et al. (2025) noted that AI-based interactive media had stronger diagnostic and visualization effects. Ruiz Viruel et al. (2025) also found that AI media was twice as effective in project-based learning contexts. Therefore, the integration of AI in teaching media can replace conventional approaches more adaptively. The data comparison is shown in the following table.

Table 10. Comparison of the Effectiveness of AI Media and Conventional Media

Media Types	Pre-test Average	Post-test Average	Difference	Effect Size (Cohen's d)
Conventional Media	60.1	73.2	13.1	0.74

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Media Types	Pre-test Average	Post-test Average	Difference	Effect Size (Cohen's d)
AI Digital Media	61.4	84.7	23.3	1.72

Based on the results of the open questionnaire and group discussions, the researchers identified several aspects that needed improvement. Students proposed the addition of an audio-narration feature to enrich the learning experience. Teachers suggested that the media be developed in an offline format so that it could be used without internet. These findings support the suggestions of Aljuboori et al. (2025) and Zhao et al. (2025) regarding the importance of technical adaptation in media development. These recommendations will be used for improvements in the next version. Therefore, user involvement in format evaluation is crucial for the sustainability of the media. A summary of user recommendations is presented in the table below.

Table 11. User Recommendations for Media Development

Recommended Aspects	Recommendation Description
Audio narration	Add voice guidance for each visual object
Offline format	Developing a version that can run without internet
Adding quizzes	Provide practice questions at the end of the interactive session
Integration into RPP	Format that conforms to the national syllabus structure

Researchers concluded that the AI-based digital reconstruction of historical sites in Banyuwangi was feasible to implement. All R&D stages produced consistent and valid quantitative and qualitative data. Expert validation, value enhancement, and user perceptions reinforced the success of the media development. Studies by Yidan Wang & Zhou (2025) and Mantovan & Nanni (2020) also demonstrated the significant potential of AI technology in culture-based education. Empirical data and local narratives demonstrated that this media was not only effective but also relevant. Therefore, it could serve as an inspiring history learning model for the development of locally-based digital education. These findings emphasize the media's contribution to contextual and modern history learning.

CONCLUSION

This study demonstrates that AI-based digital reconstruction of Banyuwangi's historical sites has proven effective as a teaching tool. This effectiveness is reinforced by a significant increase in student scores through pre- and post-tests on 200 respondents. The results of the statistical test using the t-test showed a significance value below 0.001, while the effect size (Cohen's d) value of 1.72 indicates a very strong impact. These findings align with the study by Kim et al. (2025) which showed that AI encourages increased literacy and student retention through contextual learning experiences. Expert validation yielded an average score of 93.75% and an Aiken's V value of 0.94, indicating that the media is suitable for wide-scale implementation. This supports the view of Mantovan and Nanni (2020) that AI-based digital reconstruction can enrich cultural conservation and bring students closer to local heritage. Therefore, the involvement of intelligent technology based on local data can strengthen the history learning experience in a real and meaningful way.

Further development of this digital media requires more precise digitization processes based on laser scanning or GIS-assisted photogrammetry. Maher Bouchachi et al. (2025) note that digitization accuracy is key in AI-based architectural reconstruction, especially when physical documentation is limited. The addition of local sources and oral history recordings will enrich the AI prompt sources, making the visualization more authentic and contextual. The Heritage Digital Twin-based development model proposed by Arsalan et al. (2025) can serve as a reference in integrating AI and local culture. Further testing through longitudinal trials is needed to gauge the resilience of students' understanding of local history materials. VR or AR-based approaches should be considered to provide more immersive and personalized virtual exploration of historical sites. Thus, increasing technical and contextual accuracy in digital media will promote deeper and more transformative history learning.

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