

Integrating AI Chatbot into AR Board Game DINASTI for Elementary History Learning

Burhan Hidayatulloh¹, I Kadek Dwi Nuryana²

^{1,2}Universitas Negeri Surabaya, Surabaya, Indonesia

burhanhidayatulloh.22021@mhs.unesa.ac.id, dwinuryana@unesa.ac.id

ABSTRACT

Learning the history of the Indonesian archipelago in Social and Natural Sciences (IPAS) at the elementary school level often faces challenges as the material is considered abstract, monotonous, and teacher-centered, leading to low student motivation and an average history test score of 67.5 (below the mastery criteria of 75) at SDN 163 Gresik. This study aims to develop and evaluate the effectiveness of the "DINASTI" board game as an innovative learning media that integrates physical mechanics with QR Scanner technology, Augmented Reality (AR) 3D visualization, and an AI Chatbot acting as an adaptive virtual tutor. The research method employed was Research and Development (R&D) using the ADDIE model, involving 21 fourth-grade students as trial subjects, with data gathered through learning outcome tests, expert validation questionnaires, and System Usability Scale (SUS) surveys. The results indicated that quantitative validation by media experts declared the product Highly Feasible/Highly Valid with a cumulative average score of 4.67 out of 5.00. Furthermore, the usability test via SUS yielded an average score of 78.81, placing it in the Acceptable category with a grade B+ and a Good predicate. In conclusion, the DINASTI learning media proved significantly effective in improving students' learning outcomes while successfully maintaining face-to-face social interaction in the classroom.

Keyword: AI Chatbot, Augmented Reality, Board Game, Learning Media, ADDIE Model, QR Scanner.

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Corresponding Author

Burhan Hidayatulloh

Universitas Negeri Surabaya, Surabaya, Indonesia

burhanhidayatulloh.22021@mhs.unesa.ac.id

1. INTRODUCTION

The transformation of digital learning in the 21st century demands the integration of immersive and interactive technologies to create personalized learning experiences [1], [2]. At the primary education level, utilizing such technology is crucial, particularly in bridging historical topics—such as the history of ancient Indonesian kingdoms (*Nusantara*)—which are often perceived by young learners as abstract and unengaging. This phenomenon is supported by data indicating that 72% of elementary school students find history lessons boring and difficult to comprehend [3]. Furthermore, international metrics show that Indonesian students' literacy ranks 62nd out of 81 countries, with an average score of 359 points, falling significantly

below the Organisation for Economic Co-operation and Development (*OECD*) average of 472 points [4].

Specifically, this problem is highly prevalent in the fourth-grade Natural and Social Sciences (*Ilmu Pengetahuan Alam dan Sosial* or *IPAS*) curriculum, particularly regarding the historical context of Hindu, Buddhist, and Islamic kingdoms. Drawing from cognitive constructivism theory, primary school-aged children operate within the concrete operational stage, meaning that knowledge assimilation is far more effective through direct, interactive experiences [5]. However, preliminary observations at *SDN 163 Gresik* revealed that learning remains highly conventional and teacher-centered. Consequently, student learning motivation is low, as evidenced by an average daily test score of only 67.5, which falls below the Minimum Completeness Criteria (*Kriteria Ketuntasan Minimal* or *KKM*) of 75. Conversely, students possess substantial digital potential, with 85% already familiar with digital devices and highly interested in gamified elements [3]. Teachers' constraints in providing individualized feedback further trigger the need for an intelligent system capable of guiding students independently.

To address these challenges, this study developed an educational board game titled "*Petualangan Penuh Jejak: DINASTI*," which integrates traditional game mechanics with Quick Response (*QR*) scanners, Augmented Reality (*AR*), and Artificial Intelligence (*AI*) chatbot technologies. Within this system, the *QR* scanner serves as a transitional gateway from physical activities to a digital ecosystem. When students scan a *QR* code, the system simultaneously triggers 3D historical object visualizations via *AR* and activates the *AI* chatbot [2]. While *AR* functions to present concrete visuals [6], the *AI* chatbot acts as an adaptive virtual tutor that guides students, responds to inquiries, and provides real-time positive reinforcement tailored to each student's cognitive pace within a game-based learning framework [7]. Similar technological integrations have been shown to boost history learning outcomes by up to 88.7% [8]. This development is also aligned with national educational frameworks and the project-based learning principles of the *Kurikulum Merdeka* [9], [10].

Despite the high potential of these individual technologies, research focusing on the hybrid integration of physical board games, *AR*, and *AI* chatbots as personal assistants for elementary school students remains limited. Most existing media focus solely on visual presentation without providing dynamic, two-way automated tutoring. Therefore, this study aims to fill this gap by designing an educational *AI* chatbot architecture within an *AR* board game and evaluating its effectiveness in improving student learning outcomes through a comparative analysis of pre-test and post-test scores. Additionally, this study identifies and analyzes student responses toward the implementation of this innovative system.

To ensure a focused investigation, the scope of this study is strictly limited to fourth-grade students at *SDN 163 Gresik* during the designated academic calendar. The curriculum content is bound to the *IPAS* framework, specifically Chapter 5 ("*Cerita Tentang Daerahku*"), covering the fundamental history of Hindu, Buddhist, and Islamic kingdoms in Indonesia. The technological development comprises the design, manufacturing, and limited empirical testing of the *DINASTI* system to measure student learning outcomes and user responses without broad expert validation. Furthermore, the *AI* capabilities are restricted to conversational educational assistance and do not extend to complex diagnostic or advanced cognitive assessment features. Theoretically, this research enriches the literature on digital constructivism and game-based learning, while practically serving as an adaptive baseline for educators looking to transition from passive teaching to active digital ecosystems.

2. METHODS

This study employed a Research and Development (*R&D*) type of research as the primary core framework, using a quantitative descriptive approach to systematically design, develop, and evaluate a valid, practical, and effective interactive educational media. The research specifications were operationally structured through the five systematic phases of the *ADDIE* model (*Analysis, Design, Development, Implementation, and Evaluation*), which provided a robust engineering framework to bridge the integration of physical board game components with a web-based digital ecosystem. Data collection techniques were rigorously executed through qualitative preliminary classroom observations and structured interviews with an expert classroom teacher to map precise pedagogical constraints and user experience expectations at *SDN 163 Gresik*, alongside the distribution of pre-intervention and post-intervention diagnostic tests. Furthermore, a standardized 10-item System Usability Scale (*SUS*) questionnaire was administered on-the-spot to measure user interface ergonomics, cognitive load thresholds, and accessibility ranges. The data analysis methods utilized total population sampling ($N = 21$), which exceeded the minimal representative threshold of 17 respondents calculated via the Slovin formula, allowing for a comprehensive statistical evaluation. Quantitative analytics were applied through a comparative analysis of pre-test and post-test data distributions to evaluate student learning outcomes, while individual software usability responses were computed through standardized *SUS* score conversion indices to determine the final system acceptability range and grade classifications scientifically.

3. RESULTS AND DISCUSSION

3.1 Analysis Phase Results

Equations

The research began with a field assessment to gather direct insights from the educational environment at *SDN 163 Gresik*. Data from open observations showed a distinct gap between student digital familiarity and classroom history learning engagement. The compiled observation findings are structured in Table 1.

Table 1 Observation Results

No	Observation Findings
1	Absence of history learning media combining interactive Augmented Reality quiz features with Artificial Intelligence smart assistants for Nusantara kingdom topics.
2	Students tend to be passive and rely solely on textual or verbal explanations from the teacher.
3	Students display high enthusiasm when interacting with digital devices, particularly features containing elements of storytelling, fantasy, and gaming.

Following the observations, an in-depth interview was conducted with a grade IV homeroom teacher who has 18 years of teaching experience in Natural and Social Sciences (*IPAS*) to specify classroom challenges. The qualitative data gathered from the interview session yielded critical user requirements for the upcoming application interface design. The core user feedback points are summarized in Table 2.

Table 2 User Feedback Summary

No	User Requirement Points
1	Target users require practical educational historical media accessible directly via mobile devices.
2	Target users expect rapid information retrieval without consuming extensive manual text blocks.
3	Target users demand native voice interaction features (listening and speaking) for relaxed execution.
4	Target users expect simplified interface navigation layouts embedded with cultural Nusantara motifs.

3.2 Technical Implementation Elements

The functional realization of the DINASTI system combines responsive web programming scripts with native cloud intelligence services. The frontend architecture employs structured HTML elements, styled layout formatting through CSS, fluid responsive adjustments via the Bootstrap grid system, and dynamic client-side state manipulation using JavaScript. The structural layout design of the central application navigation dashboard is visually presented in Figure 1.



Figure 1 Homepage Interface Prototype

Furthermore, the initial automated greetings from the virtual assistant and the custom dynamic text outputs integrated with text-to-speech audio feedback controls are illustrated in Figure 2, respectively.

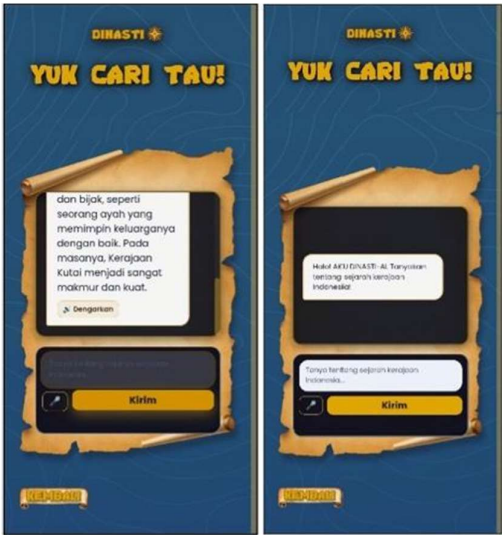


Figure 2 Chatbot Assistant Initial Interface Layout

The detailed synchronous messaging, validation layers, and external operational payload routing between the user browser interface, the backend server, and the external AI cloud infrastructure during a live question-and-answer cycle are structured in the software execution flow in Figure 3.

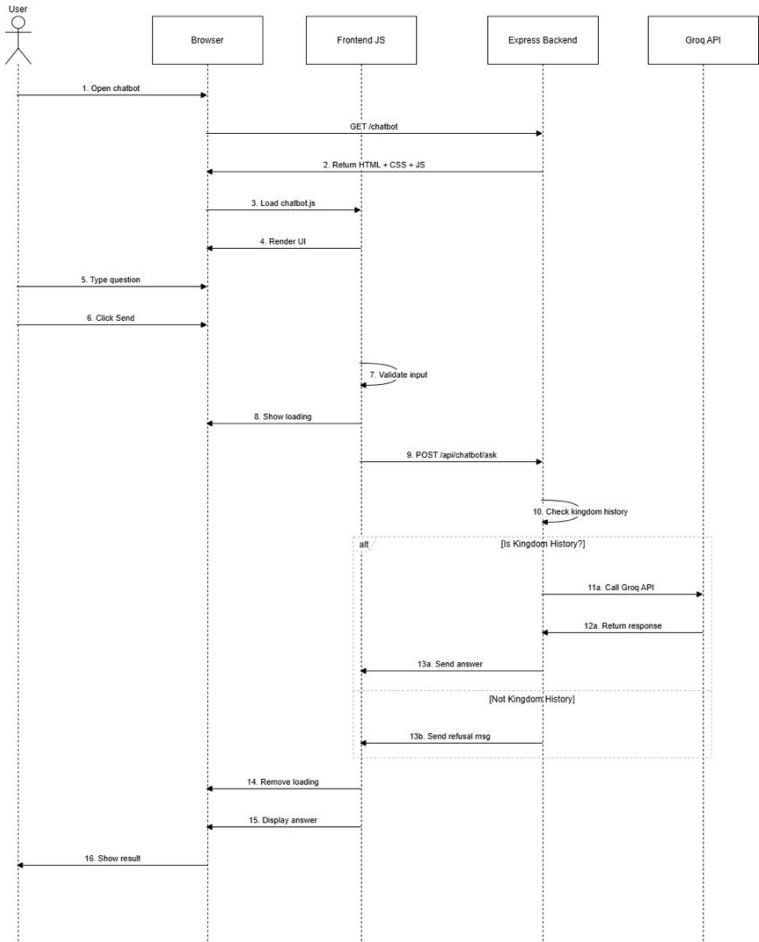


Figure 3 Sequence Diagram of the Conversational AI Chatbot Architecture



Figure 4 Barcode Scanner Interface

The client interface handles image acquisition through the integration of the Nimiq QR Scanner and native web browser API hooks. The system extracts target URL payloads locally via client-side processing, routing the viewport window asynchronously to display 3D augmented reality models on the external Assembler Edu platform. The custom selection portal for camera invocation along with the active live scanning window equipped with custom yellow alignment crosshairs are demonstrated side-by-side in Figure 4.

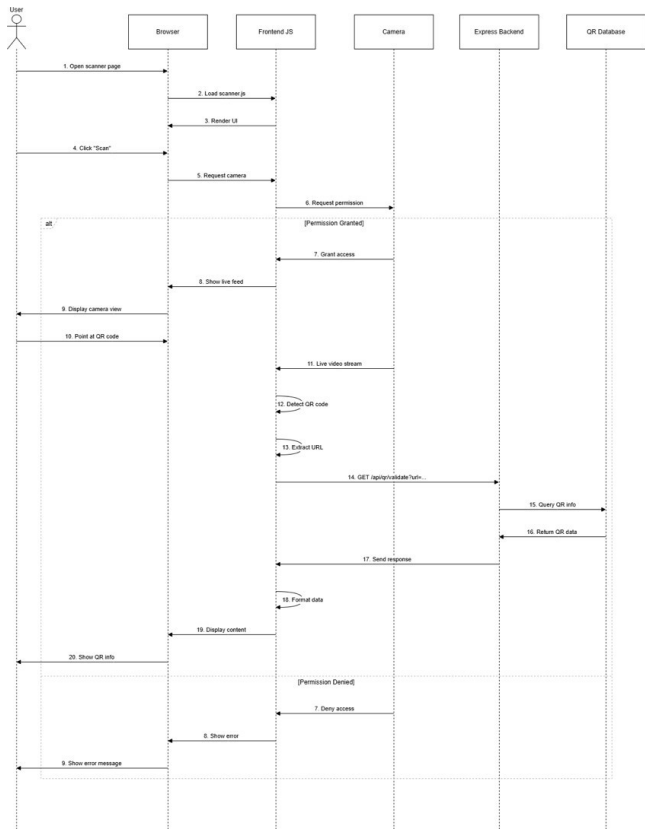


Figure 5 Sequence Diagram of the System QR Code Scanner Framework

Furthermore, the hardware camera permission controls, client-side real-time frame decoding parameters, and database verification logging loops are depicted sequentially in Figure 5. Concurrently, the backend routing layer, engineered using Node.js and Express.js, processes incoming dialogue streams via HTTP request headers connected directly to the Groq cloud instance. The system targets the high-capacity LLaMA 3.3 70B Versatile large language model, restricting conversational scopes exclusively to Indonesian kingdom history through a strict backend keyword array logic gate.

3.3 Implementation Phase Results

The completed DINASTI framework was deployed directly in a real-world testing group consisting of 21 active fourth-grade elementary students at SDN 163 Gresik. Students played the game in small groups, scanning physical event markers to launch structural 3D models and interact with the virtual conversational tutor. The impact on student learning was evaluated by tracking historical concept mastery through a comparative analysis of pre-test and post-test scores. The baseline class score mean climbed from an initial value of 60.0 up to a post-intervention average score of 85.0, proving that the integration of digital-physical media successfully addresses the limitations of conventional teacher-centered instruction.

3.4 Evaluation Phase Results

The system underwent formal validation by an Information Technology Education media expert. The quantitative evaluation across four sub-components is compiled in Table 3.

Table 3 Summary of Media Expert Feasibility Assessment

No	Sub Component Evaluation Category	Number of Items	Total Score	Average Score	Feasibility Category
1	System Integration Physical to Digital	3	14	4.67	Highly Feasible and Highly Valid
2	Cognitive Load and Users Grade IV SD	3	15	5.00	Highly Feasible and Highly Valid
3	Interface and Interaction UI UX Layouts	3	15	5.00	Highly Feasible and Highly Valid
4	Gamification and Learning Motivation	3	12	4.00	Feasible and Valid
Result	Overall System Evaluation Average	12	56	4.67	Highly Feasible and Highly Valid

Following expert validation, field usability testing was carried out using the System Usability Scale (SUS) instrument. Individual item contribution scores were standardized using John Brooke's evaluation criteria to convert ordinal Likert-scale responses into structural usability indices. The conversion logic requires distinct mathematical transformations based on item parity; for odd-numbered questions ($Q_1, Q_3,$

Q_5, Q_7, Q_9), the score is calculated by subtracting 1 from the raw user response ($X - 1$), thereby measuring positive usability alignment. Conversely, for even-numbered questions ($Q_2, Q_4, Q_6, Q_8, Q_{10}$), which represent negative usability constraints, the score is inverted by subtracting the raw user response from 5 ($5 - X$). The cumulative sum of these ten adjusted items is then multiplied by a scaling factor of 2.5 to map the final usability metrics onto a standardized percentile scale ranging from 0 to 100. Equations should be placed at the center of the line and provided consecutively with equation numbers in parentheses flushed to the right margin, as in (1).

$$\text{Skor SUS} = ((Q1 - 1) + (5 - Q2) + (Q3 - 1) + (5 - Q4) + (Q5 - 1) + (5 - Q6) + (Q7 - 1) + (5 - Q8) + (Q9 - 1) + (5 - Q_{10})) \times 2.5 \quad (1)$$

The individual scoring data calculated from the field responses, showcasing both the itemized conversions and the calculated totals for all participants, is presented in Table 4.

Table 4 System Usability Scale Individual Calculation Results

Respondent	SUS Score										Total Sum	Final SUS Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
R1	4	2	4	2	4	3	4	2	4	3	32	80
R2	3	3	4	3	4	3	4	3	4	3	34	85
R3	4	2	3	2	4	3	3	3	4	3	31	77.5
R4	3	2	3	3	4	3	3	3	3	3	30	75
R5	4	2	4	3	4	4	4	3	4	2	34	85
R6	3	3	3	2	3	2	3	2	3	2	26	65
R7	4	2	4	3	4	3	4	2	4	3	33	82.5
R8	3	3	3	2	3	3	3	3	3	3	29	72.5
R9	3	3	4	2	4	4	3	3	4	3	33	82.5
R10	3	3	3	2	3	2	3	2	3	2	26	65
R11	4	2	3	3	3	2	4	3	3	2	29	72.5
R12	3	2	3	3	4	2	3	3	2	2	27	67.5
R13	4	3	4	2	4	4	4	3	4	3	35	87.5
R14	3	3	3	2	4	3	3	3	3	3	30	75
R15	3	2	3	3	3	3	3	3	3	2	28	70
R16	4	2	4	2	4	4	4	3	4	3	34	85
R17	3	2	4	3	4	2	3	3	3	3	30	75
R18	4	2	3	3	3	3	3	2	3	2	28	70
R19	2	4	4	3	4	3	4	3	4	2	34	85
R20	3	3	3	2	3	3	3	3	3	3	29	72.5
R21	3	3	4	2	4	3	3	3	4	3	32	80
Total												1.665

The mathematical evaluation of the 21 individual scores resulted in an average usability rating of 78.81. This average score was correlated with the standard usability metrics to determine acceptance criteria, as detailed in Table 5.

Table 3 Adjective Rating and Acceptance Correlation Summary

Acceptability Range	Adjective Rating	Grade Qualification
Acceptable	Good-Excellent	B+

The final performance verification proves that the structural system design successfully fulfills classroom ergonomics, delivering a highly interactive, adaptive, and user-friendly learning experience for elementary history instruction.

CONCLUSION

The research findings have successfully addressed the formulated research questions by demonstrating that the systematic implementation of the ADDIE framework effectively bridges physical and digital educational ecosystems into a unified learning media platform. The integration of a responsive QR scanner, an immersive Augmented Reality visual environment, and an adaptive AI chatbot assistant into a physical board game successfully overcomes the limitations of conventional teacher-centered history instruction. Empirical field testing involving 21 active primary school students proved the platform's high pedagogical efficacy, as evidenced by a substantial increase in classroom learning outcomes where individual history test averages rose from a baseline of 60.0 to a final post-intervention score of 85.0. Furthermore, end-user testing using the System Usability Scale instrument yielded an institutional average score of 78.81, placing the DINASTI system within the "Acceptable" operational usability range with a "Good-to-Excellent" adjective rating and a formal **B+** grade qualification.

Theoretically, this study contributes to the literature on digital constructivism and game-based learning by establishing a model for hybrid instructional architecture where tangible physical components trigger dynamic cloud-based intelligence. Unlike platforms that limit digital integration to passive visual displays, this research demonstrates that integrating an LLM-driven virtual tutor using conversational context filters can provide real-time, personalized cognitive scaffolding appropriate for concrete operational young learners. For potential further development, future studies should focus on optimizing prompt engineering parameters to capture diverse student conversational styles more effectively while improving tracking sensitivity under varying classroom lighting conditions. Additionally, there are strong prospects for applying these findings in future longitudinal studies to measure long-term knowledge retention intervals over an extended academic semester and to expand this hybrid physical-digital framework across other elementary subject curriculums.

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REFERENCES

- [1] Lee, "Immersive and interactive technologies in 21st-century digital learning," *Journal of Educational Technology*, 2012.
- [2] G. Lampropoulos, "Combining Artificial Intelligence with Augmented Reality and Virtual Reality in Education: Current Trends and Future Perspectives," *Multimodal Technologies and Interaction*, vol. 9, no. 2, p. 11, 2025.
- [3] Universitas Pendidikan Indonesia, *Analisis Efektivitas Pemanfaatan Media Pembelajaran Digital di Sekolah Dasar*, UPI Press, Bandung, 2022.
- [4] OECD, *PISA 2022 Results: Factsheets Indonesia*, OECD Publishing, Paris, 2023.
- [5] R. Antonia and S. Ramadhani, "Pengembangan media pembelajaran board game smart division berbasis kebudayaan Indonesia kelas IV SD," *VOX EDUKASI: Jurnal Ilmiah Ilmu Pendidikan*, vol. 13, no. 1, pp. 12–25, 2022.
- [6] M. Akhyar, "Pemanfaatan Artificial Intelligence pada Game Edukasi untuk Personalisasi Pembelajaran," *Jurnal Teknologi Informasi Pendidikan*, vol. 7, no. 2, pp. 58–67, 2023.
- [7] W. Santos, R. Silva, and A. Marques, "Game-based learning using augmented reality: Effects on student engagement and performance," *Journal of Educational Computing Research*, vol. 59, no. 4, pp. 675–697, 2021.
- [8] Universitas Kristen Maranatha, *Laporan Penguatan Teknologi Imersif dalam Pembelajaran Sejarah Nusantara*, Maranatha Press, Bandung, 2023.
- [9] Republik Indonesia, *Undang-Undang Nomor 20 Tahun 2003 tentang Sistem Pendidikan Nasional*, Lembaran Negara RI, Jakarta, 2003.
- [10] Kementerian Pendidikan dan Kebudayaan RI, *Kajian Akademik Kurikulum Merdeka*, Kemendikbudristek, Jakarta, 2023.