Jurnal Teknologi Riset Terapan (JATRA)
2986-7169, Vo 3, No 2, 2025, 1-21 https://doi.org/10.35912/jatra.v3i2.6127

Developing an Educational Game about the Nusantara Kingdom Using the Game Development Life Cycle Method

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Article History:
Received on 12 Mei 2025
1st Revision on 21 Mei 2025
2nd Revision on 28 Mei 2025
3rd Revision on 01 Juni 2025
Accepted on 12 Juni 2025

Abstract

Purpose: This study aims to develop a history-based educational game themed on the Nusantara Kingdoms as an alternative learning medium for fourth-grade elementary school students and to evaluate its effectiveness and usability.

Research Methodology: The study was conducted at MI Muhammadiyah 25 Surabaya involving 51 fourth-grade students. The game was developed using the Game Development Life Cycle (GDLC) method, which includes initiation, pre-production, production, testing, beta, and release stages. Unity was used as the game engine to develop a puzzle platformer educational game. Data collection techniques included Black Box Testing to evaluate system functionality and White Box Testing to analyze the internal logic and program flow, pre-test and post-test analyzed using the N-Gain method to measure learning improvement, and the System Usability Scale (SUS) questionnaire for usability evaluation.

Results: The results of Black Box Testing indicate that all game features functioned properly. Learning effectiveness analysis shows an improvement in students' understanding of historical material, with an average N-Gain score of 0.335 (34%), categorized as medium improvement. The SUS evaluation produced an average score of 70.59, indicating acceptable usability.

Conclusions: The developed educational game is effective, functional, and easy to use for elementary school students.

Limitations: This study involved a limited number of participants from one school, focused only on Nusantara Kingdoms material, and the game is available only on the Windows platform.

Contributions: This research contributes an interactive GDLC-based educational game as an alternative history learning medium for elementary education.

Keywords: *Educational Game, Game-Based Learning, GDLC, History Learning*

How to Cite: Khusnul, Q, A, M., Armin, A, P. (2025). Developing an Educational Game about the Nusantara Kingdom Using the Game Development Life Cycle Method. *Jurnal Teknologi Riset dan Terapan (Jatra)*, 3(2), 1-21.

1. Introduction

History education plays a crucial role in shaping a nation's national identity. Through the study of history, younger generations can understand their cultural roots, the struggles of national heroes, and the long process through which the Indonesian nation achieved and maintained its independence. History education is essential in forming national identity because it enables students to comprehend cultural foundations, heroic struggles, and the dynamic journey of the Indonesian people in attaining independence and preserving national sovereignty. History learning not only provides knowledge of the past but also contributes to the development of national character, such as patriotism and social awareness among students (Martdana & Atno, 2025).

However, in practice, history learning is often perceived by students as a monotonous subject due to teaching methods that are predominantly lecture-based and the limited use of interactive media. This condition affects students' motivation and engagement in the learning process and results in a low level of conceptual understanding of historical content. To enhance students' interest and participation, more innovative and contextual approaches to history instruction are required (Zahidah, 2025). The development of information and communication technology has created significant opportunities for the education sector to integrate digital media into the learning process. Technological integration in education allows for the creation of more engaging, interactive, and contextual learning experiences. Aoliyah (2023) states that the utilization of digital technology in history learning can significantly increase students' engagement and learning motivation. One increasingly adopted approach is the implementation of Game-Based Learning (GBL) and gamification media to enhance student involvement in history education.

The GBL approach enables students to learn actively through games designed to present historical content in an engaging and contextual manner, thereby improving students' motivation and understanding of the material (Syahr, Pratama, & Firdaus, 2025). The effectiveness of Game-Based Learning and gamification in history education is also supported by the successful development of educational games in other subject areas, such as natural disaster educational games, which have been shown to improve students' interest and comprehension through interactive digital media (Nisya, Wulansari, & Wartariyus, 2023). Recent studies have strengthened the evidence that Game-Based Learning (GBL) can significantly enhance students' engagement and learning outcomes. A meta-analysis conducted by Tokac, Novak, and Thompson (2020) found that GBL positively affects students' academic achievement compared to traditional learning approaches. In addition, research by Bressler and Bodzin (2020) highlights that digital Game-Based Learning environments are effective in promoting motivation, problem-solving skills, and conceptual understanding when instructional content is meaningfully integrated into gameplay. These findings support the use of educational games as an innovative medium for delivering historical content in a more engaging and student-centered manner.

The use of digital media in history learning has also been implemented at Madrasah Ibtidaiyah (MI) Muhammadiyah 25 Surabaya. Based on interviews with teachers, history lessons, particularly on the topic of Nusantara kingdoms, are delivered through a combination of teacher explanations and animated historical videos from YouTube. While this method helps students visually understand the material, teachers face difficulties in finding videos that align with the curriculum and the students' cognitive levels. This condition highlights the need for more structured, interactive, and student-centered history learning media tailored to elementary school learners. Research by Marbun and Meihan (2025) indicates that the use of educational games in history learning can enhance students' motivation, active participation, and understanding of the subject matter.

The development of history-based educational games adopting platformer and puzzle concepts themed around the Nusantara kingdoms is expected to provide a more meaningful learning experience. Through gameplay mechanics, students do not merely receive information passively but actively engage in adventure, exploration, and problem-solving related to historical content. This is consistent with the findings of Alisti, Wagistina, and Hartatiek (2025), who state that history-based educational games are effective in increasing learning engagement and strengthening students' understanding of historical concepts. Despite various studies on Game-Based Learning in history education, most previous research focuses primarily on measuring effectiveness without emphasizing the integration of structured game development models and specific local historical content tailored to elementary school students. Therefore, the novelty of this study lies in the systematic development of a history-based educational game using the Game Development Life Cycle (GDLC) framework, combined with platformer and puzzle mechanics specifically designed for the topic of Nusantara kingdoms at the elementary level. This study not only examines the effectiveness of the game in improving learning outcomes but also provides a structured development and evaluation process that integrates functionality testing, usability assessment, and learning gain analysis within a single educational game framework.

2. Literature Review

Research related to the development of history- and culture-based educational games has been widely conducted as an effort to increase learning interest and effectiveness, particularly among school-age students. According to these studies, incorporating game elements into learning materials can make the learning process more interactive and meaningful compared to conventional instructional approaches. In addition to focusing on historical content, the development of digital media–based educational games has also proven effective in various educational contexts, such as basic literacy applications for school students, which demonstrate improved understanding of learning materials through digital Game-Based Learning media (Utomo, Azizah, & Pangestu, 2022).

Research conducted by Rizki, Wijayanti, and Chamid (2025) entitled "Educational Game Story Adventure of Cakra Independence History Version" explains the development of an educational game related to the history of Indonesian independence. This game is specifically designed for elementary school students in grades 3 or 4. The method used in this study is the Game Development Life Cycle (GDLC) with the Construct 3 engine. The game features include book selection, gameplay, and quizzes. The results of the study involving 30 elementary school students indicate that the developed game successfully improved the effectiveness of history learning compared to conventional methods.

Research by Heningtyas, Ayumi, Wulansari, and Andrian (2024) entitled "*Game Edukasi Awal Berdirinya Kerajaan Majapahit dengan Metode Game Development Life Cycle*" discusses the development of a history educational game focusing on the establishment of the Majapahit Kingdom. The research subjects for this game are senior high school students. The game genre is Role-Playing Game (RPG), which is one of the most popular game genres. The method used in this research is GDLC, and the game was developed using RPG Maker. During the beta testing phase, a result of 92% was obtained, indicating that the game is attractive and easy to understand. The test results involving 20 senior high school students show that the developed game is more effective than conventional learning methods, with post-game scores reaching 88%, while conventional learning methods only achieved 31%.

Research conducted by Fadhil, Damayanti, and Sarudin (2024) entitled "*Penerapan Metode Game Development Life Cycle pada Game Edukasi Pengenalan Sejarah Suku Kluet*" explains the development of an educational game aimed at introducing the history of the Kluet Tribe. The method used in this study is GDLC with the Unity engine. The purpose of this research is to promote the culture of the Kluet Tribe, which resides in South Aceh and is rich in history and culture but remains relatively unknown, through a more engaging medium. This study employed two types of testing: alpha testing and beta testing. The alpha test (black box testing) results indicate that the application runs smoothly. The beta test results obtained through questionnaires show that 85% of respondents stated that the Kluet Tribe introduction game is interesting and interactive.

In addition to the development of history- and culture-based educational games, digital learning media have also been developed in the form of educational applications to improve students' literacy skills. Research by Wardana and Armin (2025) shows that the use of interactive digital learning media can increase learning motivation and help students understand learning materials more effectively, thereby strengthening the role of digital technology as a supporting learning medium across various fields.

Research by Adam and Anshori (2023) entitled "*Perancangan Game Puzzle Platformer Ploop Menggunakan Model Game Development Life Cycle*" explains the development of the puzzle platformer game Ploop. The method used is GDLC with the Unity engine. This research was conducted with the aim of sharpening players' abilities by avoiding challenges and solving designed puzzles. The game tells the story of a piece of dirt living inside the dirty human digestive system. Players are required to find a way out for the dirt by solving puzzles and avoiding obstacles. The test results indicate that the Ploop game is easy to play, interesting, and effective in stimulating players' thinking skills. Research by A. B. Putra, Nurkusuma, Khawarga, Fajar, and Meliana (2023) entitled "Development of Platformer Game Timun Mas for Increasing Interest of Generation Z to Indonesian Folklore" discusses the development of the Timun Mas game. The method used is the Game Development Life Cycle (GDLC)

with the Unity engine. This study aims to introduce the legend of Timun Mas to Generation Z through a more effective medium, namely games. The game is designed to present the story of Timun Mas in a platformer game format. Players role-play as Timun Mas, starting from the story of Mbok Srini meeting the hermit, the birth of Timun Mas, and the chase by Buto Ijo. The game ends with an endless run sequence in which players must evade Buto Ijo for one minute before the game concludes. The user experience test results show that legends presented in game form are more engaging, with a score of 85%, compared to narrative-only storytelling, which scored 78%.

Research by Ramadhan, Asriyanik, and Indrayana (2025) entitled "*Pengembangan Game 2D Platformer Sejarah Kerajaan Majapahit dengan Mengimplementasikan Metode Game Development Life Cycle (GDLC)*" explains the development of a historical game about the Majapahit Kingdom. The method used is the Game Development Life Cycle (GDLC) with the Unity engine. This research was conducted with the aim of increasing public interest in learning history through games. The results of the study involving 17 respondents indicate that the game received generally positive responses and is considered suitable to be played.

Research by Hakim, Pasha, and Adrian (2023) entitled "*Rancang Bangun Game Platform 2D Petualangan si Gajah Berbasis Android*" explains the implementation of the Game Development Life Cycle method in the development of the 2D platformer game Petualangan si Gajah. The method used is GDLC with the Unity engine. The results show that the game runs on the Android platform. Testing using the ISO 25010 standard resulted in functional suitability reaching 100%, usability at 90.34%, and portability at 100%.

Research by Tarisa, Hadi, and Setyasmara (2025) entitled "*Desain dan Pengembangan Gim Edukasi DBD Berbasis 2D Platformer dengan Metode Game Development Life Cycle*" discusses the development of a dengue fever educational game designed to educate children aged 9 to 13 about the dangers of dengue disease. The method used is the Game Development Life Cycle with the Unity engine. Testing was conducted using pre-test and post-test methods, which showed an increase in post-test scores. Usability feasibility was also tested using a Likert scale, indicating that the game is suitable for use.

Research by Janata, Priandika, and Gunawan (2022) entitled "*Pengembangan Game Petualangan Edukasi Pengenalan Satwa Dilindungi di Indonesia Menggunakan Construct 2*" explains the development of an educational adventure game aimed at introducing protected animals in Indonesia, in response to the decline of endangered species. The method used is the Game Development Life Cycle with the Construct 2 engine. Alpha testing results achieved 100%, indicating no errors in functional aspects. Based on beta testing involving 12 participants, the game obtained an average score of 89%.

Research by Ramadaniati, Metandi, and Cahyono (2025) entitled "*Rancang Bangun Game Edukasi Puzzle 2D sebagai Pengenalan Alat Permainan Tradisional Kalimantan Timur dengan GDLC*" explains the design of a 2D puzzle educational game introducing traditional games from East Kalimantan to children aged 9–12 years who are increasingly unfamiliar with regional traditional games. The method used is the Game Development Life Cycle with the Unity engine. Testing involving 39 respondents aged 9–12 years using questionnaires analyzed with a Likert scale resulted in an average indicator of "Very Good" with a percentage of 93%.

2.2 Game

A game is a type of play activity in which players attempt to achieve victory according to predetermined rules (Mufida, Putra, & Yusron, 2021). This activity not only provides entertainment but also trains concentration, strategic thinking, and problem-solving skills. Games are played by various age groups as a form of recreation to fill leisure time or reduce stress. With increasingly interactive designs and engaging narratives, games are able to attract attention and build players' emotional involvement. Along with technological advancements, games have transformed from mere entertainment into media with educational, social, and cognitive value.

2.3 Educational Games

Educational game media can be understood as a learning method that uses games with the aim of facilitating the learning process, making learning enjoyable, and even improving learning effectiveness (Alba, Parjito, & Priandika, 2023). Games function not only as entertainment media but also as interactive media capable of enhancing users' thinking skills and engagement in various Game-Based Learning contexts, as demonstrated in research on board games as creative educational media (Filashofia & Usman, 2025). Educational games are increasingly being developed because students tend to prefer playing games rather than engaging in conventional learning methods. The use of games as learning media is considered aligned with current educational approaches, where the world is increasingly dependent on technology. Effective interactive learning techniques for early childhood education involve the use of educational games, as most young children have a high level of curiosity about their surrounding environment (Fadhil et al., 2024).

2.4 Unity

Unity is a cross-platform game engine used to develop interactive and efficient 2D and 3D games. Unity provides various features such as physics systems, animation, scripting, and a visual interface that simplifies the game design and development process, even for beginner developers. One of Unity's main advantages is its ability to build applications for multiple platforms, including Android, iOS, Windows, and WebGL, using a single codebase. With its flexibility and comprehensive features, Unity is an effective tool for supporting the development of engaging and functional Game-Based Learning media.

2.5 Game Development Life Cycle

The Game Development Life Cycle (GDLC) is a game development method used to ensure that the game creation process is carried out in a structured and systematic manner, starting from the planning stage to the distribution stage to users. GDLC adopts software development principles but is adapted to the characteristics of games that emphasize interactivity, user experience, and entertainment elements. This model is widely used in educational game development because it accommodates both instructional design needs and technical aspects of game development. The Game Development Life Cycle (GDLC) consists of six main stages: initiation, pre-production, production, testing, beta, and release (Hakim et al., 2023). Figure 1 illustrates the stages of the GDLC method where each stage plays an important role in ensuring the quality of the resulting game in terms of functionality, design, and alignment with learning objectives. The phased approach of GDLC helps developers identify user requirements from the early stages and minimize errors in the final stages of development.

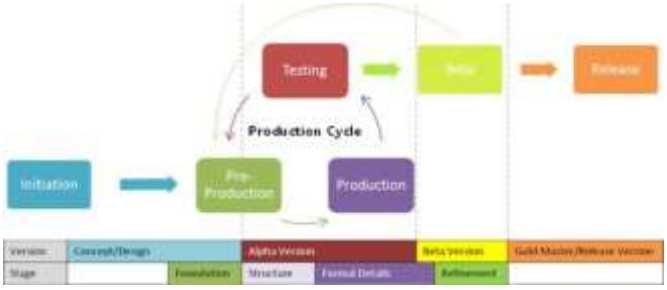

Figure 1. Game development life cycle stages

2.6 Black Box Testing

Black Box Testing is a software testing method that focuses on the external functions of a system without examining its internal structure or source code. Testers evaluate the relationship between input and output based on predefined specifications to ensure that the main functions operate correctly from the user's perspective. This approach is important in software testing because it provides an objective overview of system functionality without requiring knowledge of internal implementation, making it suitable for evaluating the functional quality of web-based applications and other information systems (Pratama, Lasimin, & Dadaprawir, 2023; Sultansyah et al., 2025). Black Box Testing has proven

effective in identifying functional errors and improving system quality before widespread use (Fitriana, Rahmadi, & Armin, 2024). In this study, Black Box Testing was selected because the primary objective of system testing is to ensure that all functional features of the educational game operate according to the predefined requirements from the user's perspective. Since the game is designed for elementary school students, functional correctness and user interaction reliability are prioritized over structural code analysis at this stage. Therefore, Black Box Testing is considered appropriate and accurate in verifying whether the implemented game features perform as expected before being evaluated for learning effectiveness.

2.7 White Box Testing

White Box Testing is a software testing approach that focuses on examining the internal structure, control flow, and logical paths of a program. Unlike black box testing, which evaluates system functionality based on external behavior, white box testing analyzes the source code structure, including conditional statements, loops, and branching mechanisms. This method is commonly applied to ensure logical correctness and structural reliability in software systems. One of the widely used techniques in white box testing is Cyclomatic Complexity analysis, introduced by McCabe (1976). Cyclomatic Complexity measures the number of independent execution paths in a program and helps determine the minimum number of test cases required for adequate path coverage. The complexity value can be calculated using the formula:

$$V(G) = P + 1 \tag{1}$$

Where *P*represents the number of predicate nodes (decision points) in the program (McCabe, 1976). A higher Cyclomatic Complexity value indicates more logical paths and increased testing effort, whereas a lower value suggests a more structured and maintainable control flow. In the context of educational game development, white box testing is particularly useful for verifying level progression logic, life reduction mechanisms, scoring systems, and win–lose conditions to ensure that the game operates according to the designed rules.

2.8 Pre-Test and Post-Test Evaluation

The System Usability Scale (SUS) is a widely used usability evaluation instrument in software and interactive application research to measure the extent to which a system can be used effectively, efficiently, and satisfactorily by users based on their perceptions of system usage experiences (Rahardian, Khodijah, & Rizki, 2025). This method employs a 10-item questionnaire with a Likert scale that is simple yet capable of providing a quantitative overview of system usability levels, making it easier for researchers to analyze design success from the end-user perspective (Rahardian et al., 2025). SUS has been proven effective in various evaluation contexts, including academic information systems, mobile applications, and other digital platforms, where the resulting scores can be interpreted into usability categories such as poor, acceptable, and good according to standard SUS guidelines, thereby providing a basis for system design improvements (F. A. A. Putra, Waluyo, Faturohman, Purwoprasetyo, & Setiawan, 2025; Rahardian et al., 2025). In this study, the pre-test and post-test design was employed to objectively measure students' learning improvement after interacting with the developed educational game. By comparing students' scores before and after the implementation, the effectiveness of the game in enhancing conceptual understanding can be quantitatively validated. This method ensures that learning outcomes are measured based on empirical evidence rather than subjective perception, thereby increasing the accuracy and reliability of the evaluation results.

2.9 System Usability Scale Testing

The System Usability Scale (SUS) is a usability evaluation instrument widely used in software and interactive application research to measure how effectively, efficiently, and satisfactorily a system can be used based on users' perceptions of their interaction experience (Rahardian et al., 2025). This method uses a 10-item questionnaire with a Likert scale that is simple yet capable of providing quantitative insights into system usability levels, thereby facilitating researchers in analyzing design success from the perspective of end users (Rahardian et al., 2025). SUS has proven effective in various evaluation

contexts, including academic information systems, mobile applications, and other digital platforms, where the resulting scores can be interpreted into usability categories such as poor, acceptable, and good according to standard SUS guidelines, thus providing a basis for system design improvement (F. A. A. Putra et al., 2025; Rahardian et al., 2025). The use of SUS in this research ensures that usability evaluation is conducted using a standardized and widely validated instrument. Since educational games require intuitive interaction and ease of use, especially for elementary school students, SUS provides a reliable framework for assessing user satisfaction and system usability. The standardized scoring and interpretation guidelines of SUS enhance the precision and credibility of the usability evaluation results.

3. Methodology

In this study, the researchers employed the Game Development Life Cycle (GDLC) method as the approach for developing the educational game. The GDLC stages were implemented systematically from initial concept development to final release.

3.1 Initiation

At this stage, the concept of the educational game was determined, including the game type, target users, and learning objectives. The game was designed for elementary school students to support history learning through interactive gameplay. The main educational content and core gameplay mechanics were defined to ensure alignment with the learning objectives.

3.2 Pre-Production

This stage involved the design and preparation of the game components. The game design and prototype development followed the pre-production principles described by Heningtyas et al. (2024) where the activities included determining the game title, genre, storyline, gameplay mechanics, and user interface design. Supporting materials such as flowcharts, asset requirements, and interaction design were also prepared to guide the development process.

3.3 Production

During the production stage, all previously designed components were implemented into the game system. This phase involved integrating visual assets, audio elements, and source code to build the game environment and mechanics. The output of this stage was a functional game prototype ready for testing.

3.4 Testing

The testing stage was conducted to ensure that the developed game functioned properly. Internal testing was performed to verify gameplay flow, system functionality, interface consistency, and stability. The results of this stage were used to identify errors and determine necessary improvements before proceeding to external testing.

3.5 Beta

The beta stage involved external testing with selected participants to identify additional bugs and evaluate overall game performance. The implementation of beta testing in this study followed the concept of closed and open beta testing described by Adam and Anshori (2023) and according to this research, beta testing was conducted using a closed beta approach, involving selected elementary school students as participants.

3.6 Release

The release stage marked the completion of the development process. After passing the testing and beta stages, the final version of the game was prepared as a learning medium for elementary school students.

4. Results and Discussions

4.1 Initiation

At the initiation stage, the researchers determined the game concept, target players, and development objectives of the Kerajaan Nusantara game. The concept adopted in this game is a puzzle platformer game. The game is designed to require players to avoid challenges and solve puzzles encountered during

gameplay. This study aims to assist history learning, which is often considered boring, to become more engaging and effective for fourth-grade students. The educational game was developed using the Unity engine, with assets obtained from websites that provide free asset resources.

Table 1. Concept design

Aspect	Description
Title	Kerajaan Nusantara
Target Users	Fourth-grade students
Application Type	Windows-based game
Mechanism	Platformer game with the task of collecting scattered image-based clues to open doors
Images	Images sourced from free asset provider websites

4.2 Pre-Production

The pre-production stage describes the planning process of the Kerajaan Nusantara educational game. This stage includes the game design process, covering the game title, background of development, genre, gameplay, and flowchart.

4.2.1 Game Title

Kerajaan Nusantara was chosen as the title of this educational game. The name was selected because it sounds simple yet attractive, making it easy for elementary school students to remember. In addition, the title represents the content of the game, which focuses on introducing the history of kingdoms in the Indonesian archipelago in an interactive and enjoyable manner.

4.2.2 Background of Game Development

The Kerajaan Nusantara game was developed due to the problem of students' low interest in learning history. History learning is commonly delivered through conventional lecture-based methods or YouTube videos. However, both methods are considered less effective, as some students remain uninterested in history lessons. Therefore, a new learning medium using a game-based approach, commonly played by children, was designed to improve students' understanding, learning effectiveness, and interest.

4.2.3 Genre

The Kerajaan Nusantara game is categorized as a puzzle platformer genre. This genre was chosen because it combines challenging gameplay elements with educational content. The platformer element presents challenges in navigating characters through various platforms, requiring players to walk, jump, and avoid obstacles to reach objectives. Meanwhile, puzzle elements are incorporated in the form of challenges that must be solved to progress to the next level. The combination of these genres is expected to enhance player engagement while encouraging critical thinking skills and comprehension of the historical material presented.

4.2.4 Gameplay

In this game, players progress through three stages sequentially, with the order of stages randomized each time the game begins. Kerajaan Nusantara consists of a total of eight stages, each representing a different kingdom. In each stage, players must control the character to collect five keys scattered throughout the level. After collecting all keys, players must find a door to access a quiz. The door can only be opened once all five keys have been collected. The quiz requires players to select objects from the collected keys that match the given kingdom theme. The game is considered successful if the player completes all stages while still having remaining lives. This mechanism is designed to encourage exploration, accuracy, and understanding of historical material in an enjoyable and interactive way.

4.2.5 Flowchart

Figure 2. Flowchart of the Kerajaan Nusantara Game

Figure 2 shows the flowchart serves to illustrate the main flow of the application. This diagram visualizes the stages from the initial page to the end of the game, making it easier for developers to understand the sequence of processes within the application. The main menu includes several options: exit, start game, book, and about. When players choose to start the game, they are first shown usage instructions before beginning the game. Players proceed to the next stage after successfully completing the previous one and still having remaining lives. If they fail, the game ends while completing three stages is considered finishing the game.

4.3 Production

During the production stage, the researchers carried out the game development process, which included creating and collecting visual assets and constructing the game system using Unity. Relevant visual assets suitable for educational purposes, such as characters, backgrounds, platformer elements, and challenges, were obtained from legally available free asset provider websites. The free asset websites used were itch.io and Kenney. Images for historical items were sourced through Google searches, while several icons were downloaded from the Iconify website. For font selection, the Kerajaan Nusantara game uses three fonts: Liberation, Baloo, and Inter, all downloaded from the DaFont website. Background sound effects and background music were obtained from free asset providers on itch.io. The selection of these asset sources aimed to accelerate the development process without compromising visual quality and game functionality. All assets were then arranged and integrated into Unity according to the previously designed plans, including User Interface (UI) elements, game logic, and stage flow settings. This process was conducted systematically to produce a complete, interactive educational game that helps fourth-grade students understand historical material in an enjoyable manner.

Figure 3. Main Menu Gameplay

Figure 3 shows the implementation of the planned main menu page. Users enter this page when first opening the game. The main menu contains several buttons: start game, book, about, and exit. When players choose to exit, a confirmation pop-up appears asking whether they really want to exit the game, as shown in Figure 3. Selecting yes exits the game, while selecting no returns the player to the main menu as shown in figure 4.

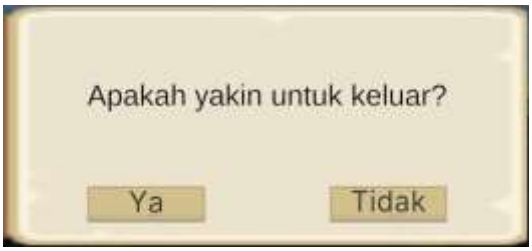

Figure 4. Exit confirmation gameplay

The book button on the main menu opens the book menu shown in Figure 5 the book menu contains all items used in the game, grouped according to their respective kingdoms. Players can view each item's description by selecting an image. The description appears as shown in Figure 5, consisting of the item image, title, and description. The descriptions in the book are more detailed versions of those shown in the key items during gameplay.

Figure 5. Book menu gameplay

Figure 6. Book description menu gameplay

Figure 7 shows the gameplay implementation. Gameplay elements include a timer that counts forward and accumulates total time at the end of the game, a life indicator that determines the number of stars obtained, and a pause button that allows users to temporarily stop the game.

Figure 7. Gameplay

Figure 8 shows the key items that players must collect. Each stage contains five key items representing historical relics of a kingdom. Each stage has a specific kingdom theme, and the relics are based on that theme. Of the five key items, only three match the kingdom theme, while the remaining two act as traps.

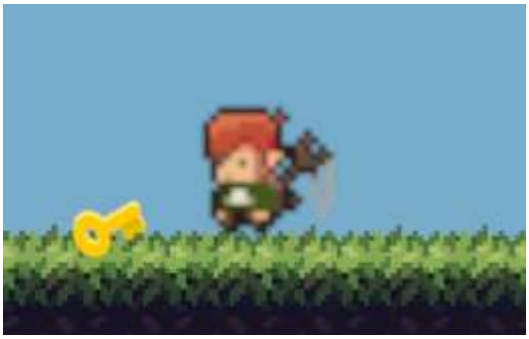

Figure 8. Key item gameplay

When players touch a key item, a pop-up appears as shown in Figure 9. The pop-up includes the item image, title, description, and a more details button. When the pop-up appears, the game timer stops, allowing players to read the information without time pressure. The more details button navigates to the book menu for players who want more detailed information.

Figure 9. Item pop-up implementation

If players have not collected all items, a warning pop-up appears, informing them that all key items must be collected first, as shown in Figure 10. The pop-up disappears automatically after a few seconds. The number of collected keys and remaining keys is displayed in the top-left corner of the screen, as shown in Figure 10. Players must collect all key items before opening the quiz door.

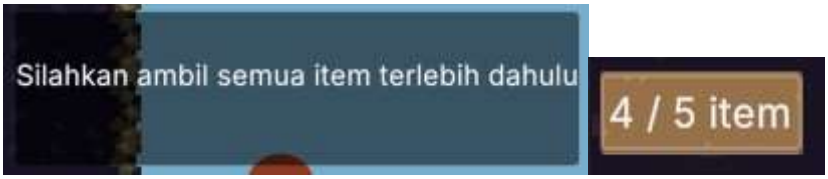

Figure 10. Warning and key counter implementation

After collecting all five key items, players search for a door as shown in Figure 11. The door interface consists of two sections: inventory and quiz. On the left side is the inventory, where players can access previously collected items and select those that match the kingdom theme displayed on the right.

Figure 11. Door quiz implementation

Figure 12 shows that players can view the same item description that appears when touching a key item. The selected item can be added to the quiz area by pressing the add button. Added items appear on the right side, as shown in Figure 12.

Figure 12. Answer input implementation

If players submit an incorrect answer, a message indicating an incorrect answer appears, as shown in Figure 13. Players can change their answer by pressing the minus button in Figure 13 and selecting a more appropriate answer. The message pop-up disappears after a few seconds.

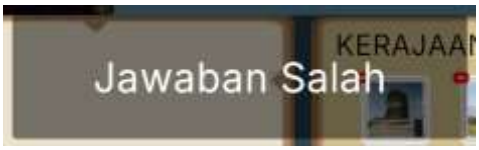

Figure 13. Incorrect answer pop-up implementation

Players can access the pause menu by pressing the pause button during gameplay. Figure 14 shows the pause menu interface, which includes buttons for continue, restart, main menu, and book. The pause menu appears as a pop-up, and pressing continue returns players to the gameplay stage.

Figure 14. Pause menu implementation

The restart button navigates players to restart the game from the beginning. A confirmation pop-up appears first, as shown in Figure 15. Selecting yes restarts the game, while selecting no returns players to the pause menu. Similarly, the main menu button displays a confirmation pop-up. Selecting yes returns players to the main menu, while selecting no navigates back to the pause menu.

Figure 15. Pause confirmation implementation

The game has two possible outcomes: level complete or game over. The game over screen appears as shown in Figure 16 when players fail to complete three stages. The game ends when players lose all their lives, which occurs when they submit incorrect answers in quizzes.

Figure 16. Game over implementation

If players successfully complete three stages, the level complete screen appears as shown in Figure 17. The number of stars earned is accumulated based on remaining lives: five lives earn three stars, three or four lives earn two stars, and one or two lives earn one star. The level complete screen also displays the current time and best time. The current time represents the total time spent completing three stages, while the best time shows the fastest recorded completion time. Both the game over and level complete screens include restart and main menu buttons.

Figure 17. Level complete implementation

Figures 16 and 17 represent the implementation of the end scenes, consisting of winning and losing outcomes. If users lose all lives, the game over screen is displayed. If users win, the level complete screen is shown, which includes the best completion time.

4.4 Testing

Black Box Testing was conducted to evaluate the functionality of each feature in the game without examining the source code. The testing focused on how the system responds to user inputs and whether the outputs produced match the expected results. Table 2 presents the results of the black box testing.

Table 2. Black box testing results

Scene	Input	Output	Result
Main Menu	None	Main menu display	Successful
	Press Start Game	Navigate to instructions	Successful
	Press Exit	Exit confirmation display	Successful
	Press About	About page display	Successful
	Press Book	Book menu display	Successful
Book	Press Back button	Return to main menu	Successful

	Select an item	Display selected item information	Successful
About	Press Back button	Return to main menu	Successful
Exit	Press Yes button	Exit the game	Successful
	Press No button	Return to main menu	Successful
Instructions	Press Start button	Start the game	Successful
Main Character	Press A and D or left and right arrow keys	Character moves left and right	Successful
	Press Space, Up Arrow, or W key	Character jumps	Successful
	Character lives depleted	Character dies and game over	Successful
	Touch the final door	Open inventory and quiz	Successful
	Touch a trap	Character is pushed back	Successful
	Fall into water	Character respawns at the starting point	Successful
Trap	None	Trap pushes the character back	Successful
Water	None	Falling into water returns character to starting point	Successful
Random Stage	None	Stages are randomized at the start of each game	Successful
Random Item	None	Items are randomized throughout the map	Successful
Item	Touch item	Display item information pop-up	Successful
Item Pop-up	Press More Info button	Display book	Successful
	Press Back button	Return to item pop-up	Successful
Gameplay	Press Pause button	Pause display	Successful
Pause	Press Resume button	Resume the game	Successful
	Press Restart button	Restart confirmation display	Successful
	Press Book button	Display book	Successful
	Press Main Menu button	Main menu confirmation display	Successful
Restart	Press Yes button	Restart the game	Successful
	Press No button	Return to pause screen	Successful
Main Menu Confirmation	Press Yes button	Return to main menu	Successful
	Press No button	Return to pause screen	Successful
Door Quiz	Select item	Display selected item information	Successful
	Press Add button on item info	Add item to quiz slot	Successful
	Press Remove button on quiz slot	Remove item and return to item list	Successful
	Enter correct answer	Proceed to next stage or finish the game	Successful
	Enter incorrect answer	Life decreases or game ends	Successful

White Box Testing was conducted to evaluate the internal control structure of the game system, particularly the level randomization mechanism, life reduction logic, item-based quiz validation, and win or lose conditions. The game is designed with the following specifications: the system randomly selects three levels from a total of eight available levels for each gameplay session. Each selected level contains five collectible items that function as quiz components. The player is required to match the collected items with the corresponding kingdom theme. The player starts with five lives. Each incorrect answer reduces one life. If the player's lives reach zero, the game ends in a loss condition. The player wins if three levels are successfully completed with at least one remaining life. The internal logic of the game system is represented in the following pseudocode

```
START
life = 5
completedLevel = 0
selectedLevels = random (3 from 8)

FOR each level in selectedLevels
   IF life == 0 THEN
      status = "Lose"
      STOP
   END IF

   itemCount = 5

   FOR each item in level
      IF answer == correct THEN
         continue
      ELSE
         life = life - 1
      END IF

      IF life == 0 THEN
         status = "Lose"
         STOP
      END IF
   END FOR

   completedLevel = completedLevel + 1
END FOR

IF completedLevel == 3 AND life > 0 THEN
   status = "Win"
ELSE
   status = "Lose"
END IF

END
```

Based on the control flow analysis, five predicate nodes were identified, including the loop structures and conditional branching for answer validation and life checking. The Cyclomatic Complexity was calculated using the formula V(G) = P + 1, where P represents the number of predicate nodes. Since five predicate nodes were identified, the Cyclomatic Complexity value is 6. This indicates that six independent execution paths must be tested to ensure complete path coverage. The obtained complexity value also shows that the system logic is structured and manageable. The identified independent paths include scenarios where the player answers all items correctly, loses all lives during the first level, loses lives during the second level, loses lives during the third level, completes all three levels with mixed answers but remaining lives, and loses the final life at the last item attempt. The results of the path-based testing are presented in table 3.

Table 3. White Box Testing Results

Path	Scenario Description	Expected Result	Result
Path 1	All answers correct in 3 levels	Win	Valid
Path 2	Lives reduced to 0 in Level 1	Lose	Valid
Path 3	Lives reduced to 0 in Level 2	Lose	Valid
Path 4	Lives reduced to 0 in Level 3	Lose	Valid

Path 5	Mixed correct and incorrect answers, life > 0 after Level 3	Win	Valid
Path 6	Last life lost on final item attempt	Lose	Valid

All identified execution paths were tested and produced outputs consistent with the designed game logic. Therefore, the internal control structure of the game system is considered valid.

4.5 Beta

The beta testing phase was conducted using a closed beta method. Testing was carried out with 51 fourth-grade students at MI Muhammadiyah 25 Surabaya. The sample was selected using the Slovin formula applied to all fourth-grade students, resulting in 51 students out of a total population of 104. Beta testing consisted of three evaluations: pre-test, post-test, and the System Usability Scale (SUS).

4.5.1 Pre-Test and Post-Test

The application trial was conducted with 51 fourth-grade students at MI Muhammadiyah 25 Surabaya. Before using the educational game, students were given a pre-test consisting of 10 multiple-choice questions to measure their initial knowledge of the Kerajaan Nusantara material. After completing the game to the final stage, students were given a post-test with the same questions to determine learning improvement after using the game. The test results showed that post-test scores were generally higher than pre-test scores, indicating an improvement in students' understanding of the Kerajaan Nusantara material. However, the degree of improvement varied among students depending on their initial ability and learning process. A comparison of pre-test and post-test scores for each respondent is shown in Figure 18.

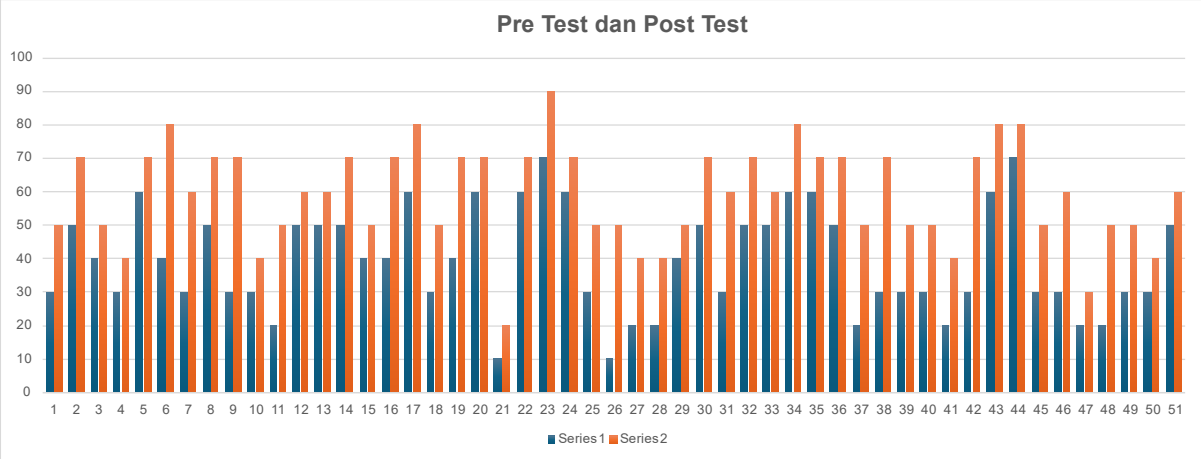

Figure 18. Pre-test and post-test comparison graph

To objectively measure learning improvement, the N-Gain method was applied. N-Gain was used to evaluate the effectiveness of the learning media based on the normalized difference between pre-test and post-test scores. The N-Gain formula used is as follows:

$$\text{N-Gain} = \frac{\text{Post-test Score} - \text{Pre-test Score}}{100 - \text{Pre-test Score}} \quad (2)$$

Based on the test results, the total pre-test score was 2000, and the total post-test score was 3020, indicating an increase of 1020 points after using the educational game. The N-Gain values ranged from 0.1 to 0.7. Of the 51 respondents, 39 students fell into the medium improvement category, while 12 students were in the low category. No students achieved a high category. The average N-Gain value was 0.335 or 34%, which is classified as a medium level of improvement.

4.5.2 System Usability Scale (SUS)

SUS testing was conducted after students finished using the educational game. The respondents consisted of the same 51 fourth-grade students from MI Muhammadiyah 25 Surabaya who participated

in the pre-test and post-test. The SUS instrument consisted of 10 statements (P1–P10) using a Likert scale from 1 to 5, where 1 indicates strongly disagree and 5 indicates strongly agree. Each respondent provided ratings based on their experience using the educational game. The results were calculated to obtain individual SUS scores, which were then analyzed to determine the overall usability level of the application. The total SUS results for each item are shown in Table 4.

Table 4. SUS test results

SUS Items	Mean	Median	Minimum	Maximum
I think that I would like to use this system frequently	3.96	4	1	5
I found the system unnecessarily complex	2.10	2	1	5
I thought the system was easy to use	4.22	5	1	5
I think that I would need the support of a technical person to be able to use this system	2.67	3	1	5
I found the various functions in this system were well integrated	4.08	4	1	5
I thought there was too much inconsistency in this system	1.98	1	1	5
I would imagine that most people would learn to use this system very quickly	4.12	5	1	5
I found the system very cumbersome to use	1.82	1	1	5
I felt very confident using the system	3.80	4	1	5
I needed to learn a lot of things before I could get going with this system	3.37	4	1	5
Total	**3.21**	**4**	**1**	**5**

Based on SUS testing, a total SUS score of 3600 was obtained from 51 respondents, resulting in an average SUS score of 70.59. This score indicates that the developed educational game has a fairly good level of usability and is acceptable to users. According to standard SUS interpretation, a score of 70.59 falls into the Acceptable category, although it has not yet reached the Excellent category. These results indicate that the educational game is sufficiently easy for elementary school students to use and does not cause significant difficulties during usage.

4.6 Release

After completing the design, implementation, and testing stages, the Kerajaan Nusantara educational game entered the release phase. This phase aims to ensure that the developed game can be accessed and used by users in accordance with the research objective, namely as a supporting learning medium for Kerajaan Nusantara material for elementary school students. The game was released through two distribution mechanisms: internal distribution and online distribution. Internal distribution was conducted for students and teachers as the primary target users. At this stage, the game was distributed directly within the school environment to support classroom learning. The results of internal distribution showed that the application ran well on users' devices and could be used as a learning medium without significant technical issues. In addition to internal distribution, the game was also released online through the itch.io platform. This platform was selected because it is easily accessible, supports free distribution of educational games, and allows users to download and play games without complicated installation processes. The game was published in a format compatible with the Windows operating system, which aligns with devices commonly used in school environments.

5. Conclusions

5.1 Conclusion

This study develops a history-based educational game about the Nusantara Kingdoms for fourth-grade students and evaluates its effectiveness and usability. The Game Development Life Cycle (GDLC) method, consisting of initiation, pre-production, production, testing, beta, and release stages, successfully led to a puzzle platformer that integrates historical material with engaging gameplay. Unity was effective in supporting a functional and stable game. Black Box Testing confirmed all features

worked as designed, while White Box Testing ensured the game's internal logic was reliable and structurally sound. A trial with 51 fourth-grade students showed a moderate improvement (34%) in their understanding of history, with post-test scores higher than pre-test scores. Usability evaluation using the System Usability Scale (SUS) resulted in a score of 70.59, indicating the game is easy to use and accessible for students.

5.2 Research Limitation

This study has several limitations that should be acknowledged. First, the historical content included in the educational game is limited to eight Nusantara kingdoms, namely Kutai, Kalingga, Tarumanegara, Mataram, Kediri, Samudra Pasai, Aceh, and Demak. These kingdoms were selected to represent different periods and characteristics of Indonesian history; however, they do not comprehensively cover all Nusantara kingdoms. Therefore, the scope of historical material presented in the game remains limited. Second, the effectiveness and usability testing were conducted only on fourth-grade students from one elementary school, namely MI Muhammadiyah 25 Surabaya. Although the participants were selected randomly from four available fourth-grade classes, the sample does not represent a broader population of elementary school students. Consequently, the generalization of the research findings to other schools or educational contexts should be made with caution.

5.3 Suggestions and Directions for Future Research

Based on the findings and limitations of this study, several suggestions can be proposed for future research. First, future studies are encouraged to expand the historical content of the educational game by incorporating a broader range of Nusantara kingdoms. Including more kingdoms from different historical periods may provide a more comprehensive understanding of Indonesian history and enrich students' learning experiences. Second, further research should involve a larger and more diverse sample of participants from different schools, grade levels, or regions to enhance the generalizability of the findings. Conducting experimental studies with control and experimental groups may also provide stronger evidence regarding the effectiveness of the educational game compared to conventional learning methods. Third, future development can enhance the game features by integrating adaptive difficulty systems, additional interactive elements, or multimedia components such as narration and animated storytelling to increase engagement and learning motivation. Lastly, further studies may explore the long-term impact of using educational games on students' knowledge retention and critical thinking skills in history learning.

Acknowledgement

The author would like to express sincere gratitude to MI Muhammadiyah 25 Surabaya, particularly the teachers and fourth-grade students, for their willingness and cooperation during the data collection and application testing processes. Appreciation is also extended to the academic supervisor for the guidance, suggestions, and support provided throughout the completion of this research. In addition, the author gratefully acknowledges all parties who contributed non-financial support in the form of advice, constructive criticism, and motivation, which greatly assisted in the completion of the research and the development of the Kerajaan Nusantara educational game.

Author Contributions

QAMK was responsible for conceptualization, study design, software development, data collection, formal analysis, and manuscript preparation. APA provided supervision, methodological guidance, manuscript review, and final approval of the submitted version.

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