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Development and Validation of "Merdeka": An Augmented Reality-Based Board Game for Indonesian History Learning

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Abstract: This study aims to develop and evaluate the feasibility of an educational board game, Merdeka, integrated with Augmented Reality (AR) technology as a history learning medium for junior high school students aged 13–15 years. The study employed a development research method using the Game Development Life Cycle (GDLC) model, which consists of six stages: initiation, pre-production, production, alpha testing, beta testing, and release. The feasibility of the product was assessed using a three-pronged evaluation approach: validation by material and media experts, black-box functionality testing of the AR application, and a limited beta trial involving 24 junior high school students. Data were analyzed using descriptive quantitative techniques based on Likert-scale scoring. The expert validation results indicated a "highly feasible" category, with average feasibility scores of 89.44% from material experts and 85.71% from media experts. The user trial results also demonstrated a very high level of acceptance, achieving a feasibility score of 84.8%. These findings indicate that the enjoyable gameplay experience and the integration of AR technology constitute the primary strengths of the product. In conclusion, the Merdeka educational board game is a valid, functional, and well-received learning medium and is therefore suitable for implementation and broader dissemination.

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Introduction

The implementation of the Independent Curriculum requires more creative and innovative learning practices, particularly in history (Fajri et al., 2023). This curriculum emphasizes developing student competencies and character aligned with the Pancasila student profile (Almarisi, 2023). This subject plays a strategic role in shaping the character and national identity of the younger generation, specifically for children aged 13-15 years or junior high school level (Himayati et al., 2024). Through understanding history, children are not only encouraged to recognize a series of past events, but also to understand the noble values of the nation's struggle, such as patriotism, unity, and perseverance (Y. Fitriani & Fatmariza, 2022). Thus, history learning becomes an important foundation in building awareness of national identity and preparing students to become citizens with character (Lisnawati et al., 2022).

Technology is vital in modern, student-centered education (Saiman et al., 2025). For Generation Z, gamification is an innovative approach that uses game elements to increase student motivation, making traditionally monotonous subjects like history more interactive and enjoyable (Nurhayati et al., 2024) (Li et al., 2024). Gamification with the use of game elements has proven effective in increasing student motivation and involvement in the

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learning process (A.A. Wahyudi R, 2025). In history learning, which is often considered monotonous, gamification can change the learning atmosphere to be more fun and interactive so that children are more motivated to understand the material in depth (Smiderle et al., 2020).

Among various types of gaming media, board games offer advantages in training strategic thinking skills, creativity, and social interaction (Aji Nugroho, 2024). Board games can be designed to simulate historical events, so that players can directly experience the dynamics and challenges that exist (Salamoon et al., 2023). Additionally, AR allows students to visualize historical figures in realistic 3D forms, which are often abstract and difficult to imagine through text descriptions alone, making material more vivid and understandable (Suharti et al., 2024). The use of AR in history education can enable the visualization of objects in three-dimensional (3D) format, making the learning materials more vivid and easier to understand (Bunari et al., 2024).

Initial observations indicate that the current learning process remains heavily oriented towards theory mastery and rote memorization, often lacking contextual connection to the students' environment (Nurhayati et al., 2024). Consequently, students struggle to visualize the causal relationships in historical events, leading to low engagement and retention levels in traditional classroom settings. This research proposes a hybrid learning medium that integrates an educational board game with cooperative AR technology. The board game is designed to foster social interaction, collaboration, and strategic thinking, while the AR application delivers educational content through history quizzes. This synergistic approach addresses a key research gap, as studies specifically combining these two technologies in a cooperative game for learning the history of the Indonesian struggle are limited.

The core innovation is the "learn to survive" game design, where mastering educational content by answering AR quizzes is essential for players to survive and win collaboratively. The primary objective is to develop and test the feasibility of the AR-integrated board game "Merdeka," a novel learning tool designed for junior high school students (ages 13-15). The product's feasibility will be comprehensively evaluated based on its material accuracy, pedagogical suitability, media design quality, technical functionality, and usability for the target users.

This research uniquely synergizes cooperative board game mechanics with AR to operationalize the concept of “collective struggle”. Unlike isolating gamification apps, this hybrid model uses AR as a resource-generation tool, where students individually acquire assets through historical quizzes but must socially negotiate and barter them on the physical board to survive. This ensures that digital immersion fosters, rather than replaces, the essential face-to-face teamwork needed to experientially understand the unity behind Indonesian independence.

Research Method

This research employed the Game Development Life Cycle (GDLC) model (Widjaja et al., 2024), which is structured into six main stages: initiation, pre-production, production, testing (alpha), beta testing, and release (Wahyu, 2022). Specifically, the testing phase was conducted through two approaches: expert validation by material and media specialists to assess content and design, and black box testing to ensure the AR application's functionality met specifications (Abdillah et al., 2023). Furthermore, beta testing was carried out with the target audience junior high school students aged 13-15 using observations and questionnaires to evaluate usability and the overall playing experience. GDLC is an adaptation of the

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Software Development Life Cycle (SDLC) principles tailored to the needs of game development by combining game design, asset creation, gameplay mechanics, and interactive testing (Febriyanto et al., 2024). The advantage offered by this methodology is the creation of products that provide an engaging and enjoyable experience. Figure 1 shows the stages of the GDLC (Mustofa et al., 2021).

Figure 1. GDLC

Processing GDLC Stages:

1) Initiation: This stage is the initial step in designing a game, including problem identification, literature review, conceptualization of ideas, and determination of target users.
2) Pre-Production: This stage focuses on the detailed design of the hybrid system (physical board game and an AR application) and the creation of an initial prototype. This stage begins by documenting all game design elements in a Game Design Document (GDD).
3) Production: This stage involves the full creation of game assets, implementation of the code in the AR application program, and the integration of digital assets with the program code. The main output of this phase is a complete prototype that has undergone refinement and formal detailing. This formal detailing includes refining the game structure by incorporating all approved mechanics and complete visual assets, both for the physical components of the board game and the AR application.
4) Testing (Alpha Testing): This alpha testing phase focuses on internal validation of the operational functionality and playability of the complete prototype produced in the production phase. Formal detailed testing is conducted through playtests, specifically aimed at evaluating the functionality of the added features and assessing the level of game balance. Functional testing is also conducted concurrently with playtests.
5) Beta Testing: Following rigorous internal testing, the project moves into the Beta phase. In this stage, the physical components of the complete board game and the AR application are tested by external users: the target audience of children aged 13-15. This beta test uses an approach similar to the previous playtest, measuring the feasibility of the AR based educational board game with a group of 24 junior high students. Beta testers are actively encouraged to identify any bugs in the AR application's functionality and gaps in the board game's mechanics.
6) Release: This release phase marks the end of game development, where the board game and AR application have been refined and launched to the public and used by the target audience. This is followed by comprehensive research documentation and knowledge sharing of the research results.

The data collected from expert validation and user trials were analyzed using descriptive quantitative analysis. The results were then interpreted based on feasibility categories, where a score above 81% is considered “Very Feasible”**.** The scores obtained from the Likert scale questionnaires (ranging from 1 = Strongly Disagree to 5 = Strongly Agree) were converted into percentage feasibility using the formula (Khusna et al., 2024):

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$$Percentage\ Feasibility = \left(\frac{Total\ Score}{Maksimum\ Score}\right) x\ 100\%$$

Results and Discussion

The results of this study are presented according to the GDLC stages that have been implemented. The following is a discussion of each chapter.

Initiation Stage Results and Discussion

This stage involved problem identification, conducted through literature reviews, interviews, and observations in junior high schools. The primary problem identified was low motivation and engagement in subjects like history, which are often taught using conventional and non-interactive methods (Tanama et al., 2023). This is significant because emotional, social, and contextual factors are key determinants of learning engagement (de Carvalho & Veiga, 2023). Furthermore, the characteristics of Generation Z, who are highly responsive to digital media, indicate a need for more immersive and contextual learning experiences (Virtanen et al., 2021) (Singh et al., 2024). These findings formed the basis for designing a cooperative board game integrated with AR to foster a more collaborative and engaging history education. Identification of user needs:

1) Story: The input for this story design was the gap in history education, which often relies on memorization and fails to instill an understanding of underlying values. The process involved establishing the theme of "Collective Struggle" with a fortress defense storyline and mechanics that encourage player collaboration. The resulting output is a narrative concept for a cooperative game where players, as heroes, must work together to defend their fortress, winning or losing as a team.
2) Technology: The input for technology development was the game's cooperative narrative concept. The process focused on evaluating a hybrid model that combines physical media for social interaction with immersive digital media, ultimately choosing AR as a more engaging platform for quizzes. The output is a hybrid educational game concept that uses a physical game board for strategy and an AR application for an immersive educational quiz experience.
3) Mechanic: The input for mechanic development was the potential disconnect between the objective of playing for fun and the objective of learning. The design process involved creating a core gameplay loop where players must master educational content to gain in-game advantages, which was achieved by balancing three types of threats and resources. The output is a mechanics concept where the core of the game is "learning to survive." AR quizzes serve as mandatory gateways to acquiring resources, making learning a crucial part of game progression.
4) Aesthetic: The input for the aesthetic design was the common perception that educational games are often "flat" and lack challenge, whereas the theme of struggle requires strong emotional engagement. The desired output is an aesthetic concept that creates a gameplay experience dominated by tension and urgency, driven by enemy threats, the need for collaboration, the challenge of answering AR quizzes, and the satisfaction of success.

The next step is user identification for this collaborative game. The process involves determining the target audience for the board game and AR app. The target audience is teenagers aged 13-15 or junior high school students. This is, provided these children are capable of operating and own a smartphone.

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Results and Discussion of the Pre-Production Stage

The pre-production stage is the stage before the game is created. This stage determines the game genre, gameplay, scenario and characters, challenges and collaboration, and assets and prototypes. The explanation of the pre-production stage is as follows:

1) Game Genre: The input began with the initial concept of an educational and cooperative game. The process involved defining this as a "Cooperative Fortress Defense Game," where players work together to eliminate threats rather than competing against each other. The final output is a game design tailored for junior high school students, featuring an appropriate quiz difficulty level and a user-friendly interface.
2) Gameplay: The input for the gameplay was the main plot, "Learn to survive," which requires players to answer AR quizzes correctly to gain resources and perform actions. The process focused on balancing the game by determining resource rewards, the damage needed to counter threats, and the speed of enemy movement to ensure a fair challenge. The output includes the finalized, detailed game rules, a clear flowchart for all game phases, and documentation of the game's balance calculations.
3) Scenario and Characters: Based on the input of using national heroes to protect fortresses from three distinct threats (Dutch soldiers, refugees, and spies), the process involved tailoring the gameplay to fit this specific scenario and its characters. The resulting output is a gameplay experience fully integrated with AR quizzes, complete with production-ready narrative text and character descriptions.
4) Interaction design: The input was a desired game atmosphere that is tense, challenging, collaborative, and ultimately satisfying. The process involved designing specific mechanics to evoke these feelings, such as adjusting the speed of "threat cards" for tension and creating bartering rules to foster collaboration. The output consists of the final rules for the bartering mechanism, which encourages interdependence, as well as rules for enemy movement and the emergence of new threats.
5) Assets and Prototypes: The initial input identified the need for both physical board game components and a companion AR application. In the process, an asset list (2D and 3D images) was created, the AR application flow was sketched, and a paper prototype was developed for game testing. The final output is an approved wireframe design for the AR app and a paper prototype that has been playtested and confirmed to be balanced and engaging.

"Merdeka" is a cooperative hybrid educational game designed for 2 to 4 players. Players assume the roles of national heroes with the shared goal of defending Indonesia's independence from various threats (represented by military, ideological, and social crisis cards). The game's unique value lies in its mandatory core mechanic: players can only acquire the resources needed to counter these threats (such as weapons, food, and public morale) by correctly answering history questions in an AR quiz. This quiz is accessed by scanning a QR code, making it the only functional path to progress. As illustrated in Figure 2, this design effectively integrates the motivation to survive directly into the learning process. The game concludes when players collectively achieve victory or suffer defeat in their fight for independence.

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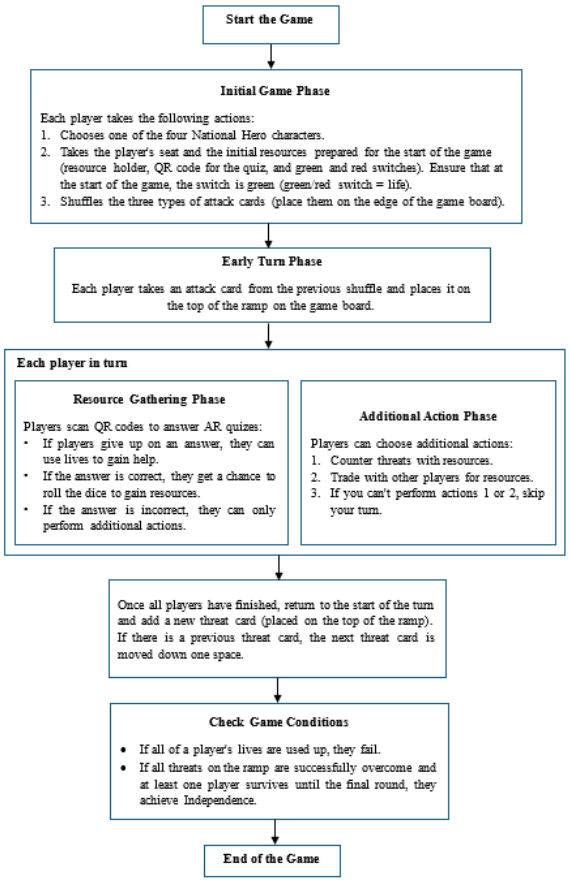

Figure 2. Board Game and AR Game Flow

Results and Discussion of the Production Stage

The results of the production phase demonstrated that combining a cooperative board game with AR elements creates a more engaging and meaningful learning experience. Specifically, the implementation of game mechanics that require player cooperation and AR quiz scans fostered active engagement, helping children understand historical events both visually and narratively. These findings align with existing research showing that game-based learning and immersive technology can enhance student motivation and knowledge retention (de Carvalho & Veiga, 2023) (Singh et al., 2024). Therefore, the production phase not only produced functional game media but also built a strong pedagogical foundation for the testing phase.

Board Game Display Design

Figure 3 illustrates the board game's visual design, which was finalized during the pre-production stage. The game's physical components consist of four playable national hero characters (Imam Bonjol, Cut Nyak Dhien, Patimura, and Diponegoro), four corresponding hero forts, and a central enemy fort. Four 7-step ramps lead from the enemy fort down to each player's fort. The game also includes three types of threat cards (14 each of Dutch soldiers, spies, and refugees) and three types of resource tokens (16 each of weapons, public morale, and food). Each player has a component containing a QR code and a life tracker for their three lives. The set is completed with a rulebook, a carrying case, and decorative elements designed to heighten tension. To ensure durability, the board game is constructed from PVC board and acrylic.

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Figure 3. Visual Design of the Board Game "Merdeka"

AR Application Display Design

The asset design for the game, implemented using Unity 6 (Unity Hub and Unity Editor). This AR application utilizes marker-based principles and the Vuforia Engine SDK as a plugin. This AR game was developed for the Android operating system. Figure 4 shows the AR application's display integrated with the existing board game. There are two selectable menus within the application: the game start menu and the player character biography.

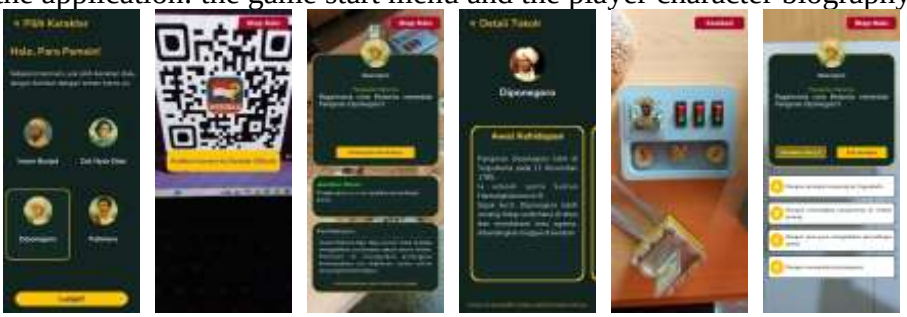

Figure 4. App displays for Augmented Reality Quizzes

Results and Discussion of the Testing Phase (Alpha Testing)

In this alpha testing phase, errors in the game being developed are identified, whether there are bugs or not. If bugs or problems are found, then repairs need to be made so as not to disrupt interaction when users run this game. This alpha testing phase or testing is carried out by the development team. The trials carried out are playtests with 4 players who match the target (trying with 2-4 players), functional trials for AR applications (Abdillah et al., 2023), and validation with experts.

Functional testing of the "Merdeka" game was conducted using the Black box method, yielding successful results across all features. Core application functions performed as expected: Main Menu Navigation was seamless; the Core Gameplay flow from character selection to AR quiz initiation was flawless; Quiz and Biography functionalities worked correctly; and all General Controls, including "Stop Play" and "Back" buttons, were fully operational. Furthermore, the AR application's QR code marker demonstrated robust performance under various conditions. At an optimal distance (20-30 cm) and angle (90 degrees), detection was instantaneous. The system responded as expected when tested beyond its limits (over 30 cm or under 5 cm) by not detecting the marker. While detection was immediate in normal and bright lighting, there was only a minor 3.2-second delay in dim light, with the high-contrast marker still being recognized. The tracking system's robustness was proven as the application successfully displayed the AR object even when 50% of the marker was obstructed.

Additionally, the "Merdeka" educational board game and its AR application were validated by material and media experts. This expert validation was conducted to assess the feasibility of the product's construction and content before it was tested on end-users. Specifically, four material experts evaluated the quality of the historical content, with the

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results shown in Table 1. The validity scores were interpreted using a scale common in Indonesian learning media development research: 0%-40% is considered invalid/not feasible; 41%-60% is fairly valid/feasible (requiring significant revisions); 61%-80% is valid/good (requiring minor revisions); and 81%-100% is very valid/very feasible (ready for implementation) (Khusna et al., 2024).

Table 1. Material Expert Assessment

Main Assessment Aspects	Average (Score)	Category
Accuracy and appropriateness of history material	95%	Highly Feasible
Suitability of learning objectives and critical thinking skills	83%	Highly Feasible
Pedagogical feasibility and learning interest	95%	Highly Feasible
Representation of national values and character	85%	Highly Feasible
Suitability of narrative and game mechanics	90%	Highly Feasible
Language and clarity of instructions	90%	Highly Feasible

This subject matter expert validation instrument consists of 18 items categorized. The results obtained from four subject matter experts indicate that all aspects received an average score above 80%, with a range of 83% to 95%. This range falls into the "Very Appropriate" category based on the validity assessment criteria. The highest score of 95% was awarded for the accuracy of historical material and for pedagogical feasibility, indicating the game's content is both factually sound and engaging for students. This high score of 95% in material accuracy was achieved because the content of the board game and AR quizzes was rigorously curated based on the official Indonesian Junior High School history curriculum and verified against historical records. The inclusion of precise biographical data of national heroes and accurate chronological events in the quiz database ensured no historical distortion occurred. The lowest score was 83% for the appropriateness of its learning objectives and critical thinking skills; while still considered 'very appropriate,' this suggests potential for improvement, such as by adding more varied analytical questions to the history quiz. With an average overall score of 89.44% from the four experts, the results confirm that the "Merdeka" board game meets the criteria for content suitability. It can now be considered a viable alternative history learning medium for the junior high school level and is ready to proceed to a limited trial phase with students to assess its overall feasibility. Next, a discussion of the media expert validation was conducted. This validation measured the media's visual design and aesthetics; technical quality and function; usability for the target user; AR application integration; engagement and stimulation of learning interest; game mechanics and representation of historical concepts. Table 2 presents the results of the media expert assessment from three media experts**.**

Validation of the "Merdeka" board game by three media experts, covering six main aspects and 14 questions, resulted in all aspects being rated as "Very Appropriate," with average scores above 80%. This indicates that the game's visual design, technical functions, AR integration, and mechanics meet the standards for interactive learning media. The highest score was achieved in AR application integration (91.11%), highlighting the synergy between technology and visual display as the media's main strength. The lowest scores were for technical quality and the ability to stimulate learning interest (both at 80%). While still considered appropriate, this feedback suggests a need for future optimization of gameplay and learning variety. With an overall average score of 85.71%, the media expert validation confirms that the "Merdeka" board game has met the necessary design, technical, and

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pedagogical criteria. Therefore, the game is ready for limited trials with junior high school students aged 13-15.

Table 2. Media Expert Assesment

Main Assessment Aspects	Average (Score)	Category
Visual design and media aesthetics	88,89%	Highly Feasible
Technical quality and media functionality	80%	Highly Feasible
Usability for target users	86,67%	Highly Feasible
AR application integration	91,11%	Highly Feasible
Engagement and stimulation of learning interest	80%	Highly Feasible
Game mechanics and representation of historical concepts	83,33%	Highly Feasible

Results and Discussion of the Beta Testing

After receiving input from media and material experts, the product will be tested on the designated target users. The selected target users are children aged 13-15 years or junior high school students. The number of users who tried was 24 junior high school students. The target users were asked to try the educational board game "Merdeka" based on AR. Then after finishing playing, they were asked to fill out a questionnaire to measure the rules and gameplay; playing experience (enjoyment); AR applications; learning; and the feasibility of the media. Figure 5 shows the results of the feasibility test result. This testing was limited to a small class. To calculate the percentage of product feasibility, use the following formula: (Khusna et al., 2024).

$$Assessment\ Percentage = \frac{total\ score\ obtained\ by\ researcher}{number\ of\ questions\ *\ highest\ number\ of\ points\ in\ the\ question} x\ 100\%$$

The feasibility test for the "Merdeka" educational board game yielded a very high score of 84.8%, with overwhelmingly positive feedback from junior high school students (ages 13-15). The analysis revealed that the game's primary strengths are its enjoyable playing experience and technological innovation. Specifically, the statement, "Playing this game is fun, and the AR feature makes it exciting," received a high percentage of "strong agreement," confirming that the core objective of providing an engaging and enjoyable learning experience was successfully achieved. The product's feasibility was further validated by its target users, as evidenced by the complete absence of responses below a neutral score (1-3).

Despite its overall advantages, the game has shortcomings that require improvement. The statement, "The guidebook is easy to understand," was the only one to receive a "disagree" response (8.33%) and a high neutral response (41.67%). This correlates with the finding that many users also felt neutral about "Quickly understands how to play" (45.83%). These results indicate that while the game mechanics are fair and enjoyable, the guidebook's instructions need to be simplified and better illustrated to improve the initial user experience. Nevertheless, the beta test results confirm that the product was well-received by its target audience, with its strengths in fun and technology integration providing a solid foundation. This user feedback on the instructions offers clear direction for product refinement before its final release.

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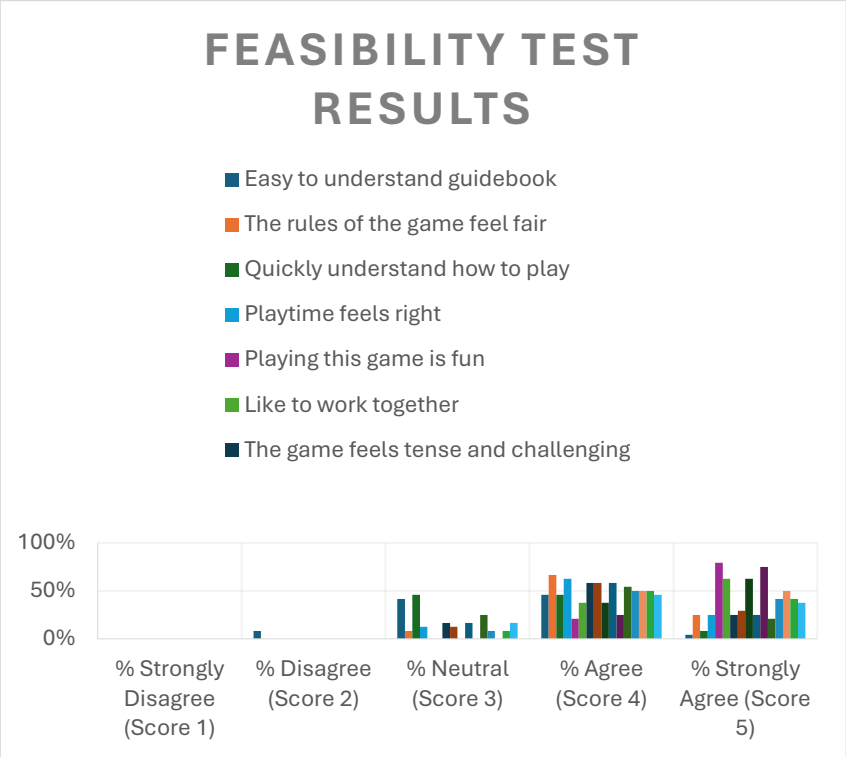

Figure 5. Results of the Suitability Test for Children Aged 13-15 Years

Theoretically, this study contributes to the literature on hybrid game-based learning by demonstrating that integrating cooperative board game mechanics with AR effectively bridges the gap between social interaction and digital immersion. Unlike standalone apps, this model ensures that technological engagement supports rather than replaces face-to-face collaboration. Practically, “Merdeka” provides teachers with a validated tool aligned with the Independent Curriculum (Kurikulum Merdeka). It specifically facilitates the development of the Pancasila Student Profile (Profil Pelajar Pancasila), particularly the dimension of Mutual Cooperation (Gotong Royong). Teachers can utilize this game to transform history lessons from passive memorization into active, student-centered experiences, enabling the simultaneous assessment of historical understanding (cognitive) and collaborative skills (character) as mandated by national education standards.

Conclusion

This research has successfully developed and validated the AR based educational board game "Merdeka" using the GDLC method. The resulting prototype was declared highly feasible based on expert validation, with an average score of 89.44% from material experts and 85.71% from media experts. Furthermore, a beta trial conducted on 24 junior high school students confirmed very positive user acceptance with a feasibility score of 84.8%. Analysis of this trial revealed that the product's main strengths lie in its engaging gameplay experience and the innovative integration of AR technology. This also helps increase students' interest in learning. It was also found that there were parts that needed improvement regarding the clarity of the rules in the game guidebook that needed to be simplified. It can be concluded that the application of the GDLC method proved effective in guiding the production process of the hybrid media educational board game "Merdeka" based on AR that is valid, functional, and ready to be implemented to the release stage after minor improvements.

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Recommendation

Further research is recommended to quantitatively measure the "Merdeka" board game's effectiveness on cognitive outcomes, such as knowledge retention, using a larger and more diverse sample. Comparative studies evaluating this medium against conventional learning methods are also suggested. For educators, this board game can be implemented as a supplementary tool to stimulate classroom discussion and collaboration. However, to optimize the learning experience, it is crucial for facilitators to address the guidebook's usability issues by providing a clear demonstration of the rules before the game begins.

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