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Development of a Turn-Based Mathematics Educational Game for Fourth-Grade Elementary Students Using ADDIE Model

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Abstrak

Matematika sering dipersepsikan sebagai mata pelajaran yang sulit dan abstrak oleh siswa sekolah dasar, yang dapat menyebabkan rendahnya minat dan motivasi belajar. Kondisi ini tercermin dalam hasil Programme for International Student Assessment (PISA) tahun 2022 yang menunjukkan bahwa tingkat kemahiran matematika siswa di Indonesia masih relatif rendah. Penelitian-penelitian sebelumnya telah mengeksplorasi gim edukasi untuk pembelajaran matematika. Namun, masih terbatas penelitian yang secara eksplisit mengintegrasikan mekanisme strategis berbasis giliran dengan tingkat kesulitan matematika bertahap untuk mendorong pengambilan keputusan reflektif pada siswa sekolah dasar. Penelitian ini bertujuan untuk mengembangkan gim edukasi berbasis Android berjudul Petualangan Ksatria sebagai media pembelajaran pendukung untuk pembelajaran matematika kelas IV sekolah dasar. Proses pengembangan gim mengikuti model desain pembelajaran ADDIE (Analysis, Design, Development, Implementation, and Evaluation) dan diimplementasikan menggunakan game engine Unity. Validasi fungsional dilakukan melalui pengujian black-box untuk memastikan seluruh modul dan fitur gim berjalan sesuai dengan spesifikasi yang telah ditetapkan. Selanjutnya, tahap evaluasi menggunakan User Acceptance Testing (UAT) yang melibatkan 31 siswa dan satu guru kelas IV. Hasil penelitian menunjukkan tingkat penerimaan siswa sebesar 85% yang termasuk dalam kategori Sangat Memuaskan, serta penilaian guru sebesar 80% yang termasuk dalam kategori Memuaskan. Temuan ini menunjukkan bahwa Petualangan Ksatria selaras dengan Kurikulum Merdeka di Indonesia dan menunjukkan potensi sebagai media pembelajaran pendukung yang menarik untuk pembelajaran matematika di sekolah dasar.

Kata kunci: berbasis android, game edukasi, matematika, sekolah dasar, model ADDIE, user acceptance testing.

Abstract

Mathematics is often perceived as a difficult and abstract subject by elementary school students, which can lead to low learning interest and motivation. This condition is reflected in the 2022 Programme for International Student Assessment (PISA) results, which indicate relatively low mathematical proficiency among students in Indonesia. Previous studies have explored educational games for mathematics learning. However, limited research explicitly integrates strategic turn-based mechanics with graded mathematical difficulty levels to encourage reflective decision-making among elementary students. This study aims to develop an Android-based educational game entitled Petualangan Ksatria as a supplementary learning medium for fourth-grade elementary mathematics learning. The game development process followed the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design model and was implemented using the Unity game engine. Functional validation was conducted through black-box testing to ensure that all game modules and features operated in accordance with predefined specifications. Furthermore, the evaluation stage employed User Acceptance Testing (UAT), involving 31 students and one fourth-grade teacher. The results indicate a student acceptance score of 85%, classified as Very Satisfactory, and a teacher evaluation score of 80%, categorized as Satisfactory. These findings indicate that Petualangan Ksatria is aligned with the Kurikulum Merdeka in Indonesia and shows potential as an engaging supplementary learning medium for mathematics education in elementary schools.

Keywords: *ADDIE model, android-based, educational game, elementary school, mathematics, user acceptance testing.*

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1. INTRODUCTION

Mathematics is a fundamental subject in elementary education, serving as the basis for developing logical thinking, problem-solving skills, and numerical literacy [1], [2]. However, in practice, mathematics is often perceived by elementary school students as difficult, abstract, and intimidating, which frequently leads to low learning interest and reduced motivation and may negatively affect learning outcomes from an early stage [3], [4].

The challenges in mathematics learning are reflected in international assessment results. According to the 2022 Programme for International Student Assessment (PISA), only around 18% of Indonesian students achieved the minimum level of mathematical proficiency, which is significantly lower than the OECD average [5]. Although PISA targets 15-year-old students, these findings may indicate underlying issues in foundational mathematics education, particularly at the elementary school level where core concepts are initially introduced [6].

One contributing factor to this issue is the dominance of conventional teaching methods that lack interactivity and visual engagement, which can reduce students' interest and motivation [7], [8]. Along with the rapid advancement of digital technology, educational games have emerged as a potential alternative learning medium [9]. Educational games combine learning content with interactive gameplay, enabling students to learn in a more engaging and enjoyable manner [10], [11].

Previous studies have demonstrated that digital game-based learning can enhance students' motivation, engagement, and mathematical understanding at the primary school level, especially for abstract topics [12], [13]. Although numerous educational games have been developed to support numeracy skills and conceptual comprehension through interactive gameplay, many of these studies primarily focus on reporting learning outcomes or motivational improvements while providing limited theoretical justification for specific gameplay mechanics or their direct mapping to structured curriculum content. Furthermore, limited research explicitly integrates strategic turn-based mechanics with graded mathematical difficulty levels to encourage reflective decision-making among elementary students.

Strategic turn-based mechanics refer to gameplay systems in which players take actions sequentially and are given time to consider available options before responding. Unlike real-time gameplay that may create pressure and impulsive reactions, turn-based interaction can encourage deliberate thinking, planning, and reflective decision-making [14], [15]. In the context of mathematics learning, this approach is relevant because students often need sufficient time to calculate, compare answer choices, and select appropriate problem-solving strategies [16], [17]. Therefore, integrating turn-based mechanics with graded mathematical challenges may support both engagement and cognitive processing for elementary learners.

In this study aims to address this gap by developing a curriculum-aligned Android-based educational game that integrates structured mathematical content with a turn-based combat system designed to promote cognitive engagement and strategic problem-solving. This study contributes to the literature by explicitly linking gameplay mechanics with pedagogical rationale and curriculum structure, rather than treating game elements solely as motivational tools. Unlike prior works that emphasize gamification elements alone, this research systematically combines instructional design principles through the ADDIE model with functional validation and user acceptance evaluation to ensure both pedagogical relevance and technical feasibility.

2. RESEARCH METHODOLOGY

This study employs the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model to guide the development of an Android-based educational game for fourth-grade elementary school students. The ADDIE model is a structured and systematic instructional design approach that emphasizes user needs and supports the development of effective educational media [18], [19]. The stages of the ADDIE model applied in this study are illustrated in Figure 1.

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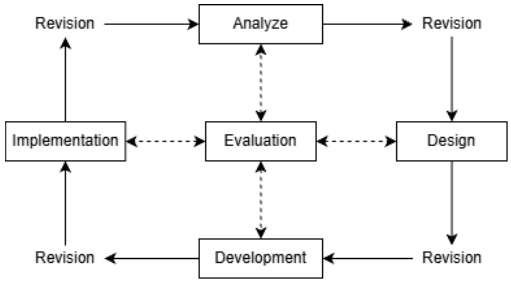

Figure 1. ADDIE Model Stages

2.1. Analyze

At the analysis stage, a comprehensive needs assessment is conducted to identify the characteristics, learning needs, and challenges of the target users [20]. This stage serves as a fundamental basis for the entire game development process. The educational game is designed based on user needs, curriculum alignment, and learning objectives to ensure its relevance and effectiveness as a learning medium. Therefore, a systematic analysis is required to determine appropriate learning content, gameplay mechanics, and user interaction design, enabling the developed game to be well accepted and effectively used by students.

2.1.1. Interview

Data collection at the analysis stage was conducted through an interview with a fourth-grade elementary school teacher to obtain insights into students' learning difficulties, curriculum requirements, and expectations regarding the use of educational games in mathematics learning. The teacher was selected purposively as a fourth-grade homeroom teacher with direct experience in teaching mathematics and understanding students' classroom challenges. The interview was intended as an exploratory needs analysis to gather practical insights for the initial game design rather than to produce statistically generalizable findings. The findings were used as references in designing the educational game to ensure alignment with user needs, learning characteristics, and instructional goals. The interview results are summarized in Table 1. These findings were further translated into decisions regarding game content, gameplay mechanics, and visual design in the subsequent design stage.

Table 1. Interview Result

No.	Questions	Answers
1	How do you usually teach mathematics in fourth-grade classes?	The teacher applies collaborative teaching methods and utilizes concrete learning aids to facilitate students' conceptual understanding.
2	What learning media have been used so far in mathematics lessons?	Concrete objects such as stones and small sticks are commonly used as instructional media for basic arithmetic.
3	Do students show enthusiasm when learning mathematics? If not, what are the main obstacles?	Students' enthusiasm varies, with some students showing high interest while others exhibit low engagement.
4	Which mathematics topics are most difficult for fourth-grade students to understand?	Plane geometry and memorization of formulas are considered challenging, as well as basic concepts of three-dimensional shapes.
5	What factors contribute to students' difficulties in understanding these topics?	Lack of concentration and divided attention are identified as primary factors affecting students' understanding.
6	How do you usually address students who have difficulty understanding mathematics lessons?	The teacher incorporates ice-breaking activities to restore students' focus and learning motivation.

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7	Have you ever used digital media (such as videos, applications, or games) in teaching mathematics? If yes, how effective was it?	Instructional videos have been used however, their effectiveness is perceived as limited.
8	What is your opinion on the use of educational games as a medium for mathematics learning?	Educational games are viewed positively, provided that they support learning objectives and enhance students' understanding.
9	In your opinion, are fourth-grade students ready to use educational games as part of the learning process?	Fourth-grade students are considered ready and are expected to respond enthusiastically to educational games.
10	What features do you think should be included in a mathematics educational game?	The game should include visually appealing colors and engaging characters to increase students' interest.
11	Do you prefer educational games that are played independently by students or guided by the teacher in class?	A guided introduction followed by independent gameplay is preferred.

The interview findings in Table 1 were systematically translated into game design decisions. Students' difficulties in understanding plane geometry, three-dimensional shapes, and mathematical formulas were addressed by integrating curriculum-aligned question modules into each level. The issue of low concentration and divided attention was addressed through interactive turn-based combat mechanics, which were designed not only to maintain engagement but also to support reflective problem-solving by providing structured time for students to analyze and respond to mathematical questions [14], [15]. This approach aligns with pedagogical principles that emphasize deliberate thinking and step-by-step reasoning in mathematics learning [12], [13]. The teacher's recommendation for attractive colors and engaging characters was implemented through child-friendly visual themes and selectable protagonists to enhance motivation and visual appeal. In addition, the preference for guided introduction followed by independent learning was translated into the inclusion of a tutorial provided before gameplay and self-paced progression during the main game, supporting gradual learning and learner autonomy [17], [21].

2.2. Design

At the design stage, the educational game was systematically planned based on the results of the analysis phase. This stage focused on defining learning objectives, structuring game content, designing gameplay mechanics, and developing the user interface to ensure alignment with students' characteristics and learning needs. The learning content was designed in accordance with the current Indonesian fourth-grade mathematics curriculum, covering six primary modules of the fourth-grade mathematics curriculum, including whole numbers up to 10,000, fractions, visual and number patterns, measurement of area and volume, plane figures, and pictograms. Specific subtopics such as Least Common Multiple (LCM), Greatest Common Divisor (GCD), and two- and three-dimensional shapes were embedded within these modules. The overall game structure and interaction flow were also outlined to serve as a reference for the development.

2.3. Development

At the development stage, the designed prototype from the previous design phase is implemented into a concrete and functional educational game. This stage focuses on transforming conceptual design into an operational application that can be used by the target users. The game is developed using the Unity game engine as the primary development tool. All development activities are conducted based on the design specifications and prototype defined in the design stage, ensuring consistency in game features, gameplay mechanics, user interface, and core functionalities.

2.4. Implementation

At the implementation stage, the developed application is deployed as a complete educational game and introduced to the target users. This stage involves the practical use of the game by fourth-grade elementary school students and their teacher, allowing them to interact directly with the system in a real learning context. During implementation, the usability, visual presentation, functionality, and feasibility of the game as an alternative mathematics learning medium are assessed. The primary objective of this stage is to provide users with hands-on experience and to gather initial feedback that supports the subsequent evaluation process, ensuring that the game aligns with its intended educational and interactive objectives.

The implementation phase was conducted at a public elementary school in Sleman, Special Region of Yogyakarta, Indonesia. A total of 31 fourth-grade students and one mathematics teacher participated in this study. The participants were selected using a convenience sampling approach based on school availability and willingness to participate. Prior permission was obtained from the school authorities before conducting the implementation. The game was introduced during a mathematics learning session, where students received guided instructions at the beginning and were subsequently allowed to explore the game independently before completing the evaluation questionnaire.

2.5. Evaluation

The evaluation phase represents the final stage of the ADDIE instructional design model and aims to determine whether the developed educational game meets the intended pedagogical objectives and functional requirements. In this study, evaluation is conducted through User Acceptance Testing (UAT), which focuses on assessing the suitability of the application from the users' perspective [22]. Unlike technical testing that emphasizes system functionality, UAT evaluates how well the game aligns with users' needs and expectations [23]. By emphasizing user experience and educational relevance, this phase validates the effectiveness of the game as an alternative learning medium for fourth-grade mathematics learning. UAT was conducted using a structured assessment scale and evaluation instruments for both students and the teacher. The assessment scale used in this study is presented in Table 2, which serves as the basis for scoring all UAT responses.

Table 2. User Acceptance Testing Assessment Scale

Score	Description
5	Strongly Agree
4	Agree
3	Neutral
2	Disagree
1	Strongly Disagree

The UAT instruments were divided into two forms to capture different evaluation perspectives. The student UAT form, presented in Table 3, focuses on learning interest, motivation, ease of use, enjoyment, and clarity of visuals and instructions. Meanwhile, the teacher UAT form shown in Table 4 emphasizes curriculum alignment, media feasibility, ease of implementation, and pedagogical effectiveness.

The questionnaire instruments were developed based on common indicators used in educational game evaluation studies, including usability, engagement, motivation, and instructional relevance. Prior to implementation, the instruments were reviewed through expert judgment by a fourth-grade teacher to ensure content validity, clarity, and suitability for elementary school students.

Table 3. User Acceptance Testing Form for Students

No.	Question	1	2	3	4	5
1	Do you feel happy learning mathematics using this game?					
2	Does this game make mathematics lessons feel more interesting?					
3	Does this game make you more enthusiastic about learning mathematics?					
4	Do you want to play this game again to learn mathematics?					
5	Is this game easy to play?					

6	Do you have any difficulty using the buttons and menus in the game?					
7	Do you feel happy while playing this game?					
8	Is learning mathematics with this game not boring?					
9	Are the images and colors in this game attractive?					
10	Are the instructions and explanations in the game easy for you to understand?					
Total Score						

Table 4. User Acceptance Testing for Teacher

No.	Question	1	2	3	4	5
1	Does the material in the game align with the 4th-grade mathematics curriculum?					
2	Is the presentation of the material relevant to the core competencies of 4th-grade students?					
3	Is this game feasible to be used as an alternative learning medium?					
4	Can this game be used as a supporting medium for mathematics learning?					
5	Is the game easy for students to use during learning activities?					
6	Does the teacher experience any difficulty in guiding students to use the game?					
7	Can this game increase students' interest in learning mathematics?					
8	Can this game motivate students to be more active in learning mathematics?					
9	Are the visual appearance and animations in the game attractive to students?					
10	Does the interaction within the game support student engagement during learning?					
Total Score						

The collected UAT responses were analyzed using descriptive statistics, including overall percentage scores and mean scores for each questionnaire item. The total UAT score was converted into a percentage value using (1), with a maximum score of 50 per respondent, where n represents the number of respondents

$$UAT\ (\%) = \frac{\Sigma Score}{n \times 50} \times 100\% \quad (1)$$

The percentage results of the UAT were then interpreted using satisfaction level categories presented in Table 5 to determine the overall acceptance level of the developed educational game.

Table 5. UAT Satisfaction Level Categories

Percentage	Category
81% – 100%	Very Satisfactory
61% – 80%	Satisfactory
41% – 60%	Fairly Satisfactory
21% – 40%	Poorly Satisfactory
0% – 20%	Very Unsatisfactory

3. RESULTS AND DISCUSSION

3.1. System Design Results

The developed educational game system integrates fourth-grade mathematics content with turn-based gameplay mechanics as the core learning interaction. The game consists of six sequential levels aligned with the Kurikulum Merdeka curriculum topics: whole numbers, fractions, patterns, measurement, plane figures, and pictograms. In each battle stage, players must answer mathematics

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questions to execute selected actions. Three attack options (light, medium, and heavy) correspond to easy, medium, and difficult question levels, respectively. This design combines learning tasks with strategic decision-making, while the sequential level unlocking system supports mastery learning and progressive skill development.

3.2. User Interface Results

This section presents the user interface design of the developed educational game, including the main menu, gameplay, and supporting interfaces.

3.2.1. Main Menu Interface

The Main Menu Interface of Petualangan Ksatria serves as the initial screen encountered by users upon launching the application. This interface is designed with an emphasis on visual appeal and simplicity to ensure intuitive navigation, thereby preventing confusion for the target users, specifically fourth-grade elementary school students [24]. The layout features the game logo and three primary functional buttons Play, Exit, and Settings each representing its respective function. To enhance the system's reliability and prevent accidental termination of the application, selecting the Exit button triggers a quit confirmation dialog that requires user verification before the application is closed, serving as an error prevention mechanism. The visual layout of the main menu is illustrated in Figure 2.

Figure 2. Main Menu Interface

3.2.2. Settings Interface

The Settings Interface is used to provide players with the ability to modulate music and sound effect volumes according to their individual auditory preferences. By facilitating these adjustments, the application aims to create a personalized and comfortable gaming environment that enhances overall user engagement. This screen features two dedicated sliders for volume control, each distinctly labeled to ensure intuitive operation and seamless navigation. The layout of the settings menu is illustrated in Figure 3.

Figure 3. Settings Interface

3.2.3. Tutorial Interface

The Tutorial Interface automatically appears once the player initiates the game by selecting the Play button. This strategic placement is intended to ensure that users are adequately prepared and to minimize potential confusion regarding the game's core mechanics. The screen features an embedded instructional video demonstrating the primary gameplay of Petualangan Ksatria. Additionally, a dedicated Restart button is provided, allowing players to replay the video to ensure a comprehensive understanding before proceeding to the game. The tutorial layout is illustrated in Figure 4.

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Figure 4. Tutorial Interface

3.2.4. Level Select Interface

The Level Selection Interface functions as the progression hub where players access the game's educational stages. To ensure a structured learning experience, the game utilizes a sequential unlocking mechanism where only the first level is initially accessible, while subsequent levels are gradually unlocked based on the player's successful completion of preceding challenges. This mechanism reflects the principle of mastery learning, in which learners are encouraged to achieve sufficient understanding of foundational concepts before progressing to more advanced topics [25]. By structuring levels in consecutive order, the system supports progressive scaffolding and mirrors the structured flow of classroom instruction under the Kurikulum Merdeka framework. In addition to supporting structured learning progression, the sequential unlocking system reinforces a sense of achievement and goal-oriented progression, which contributes to sustaining students' motivation throughout gameplay. The game features a total of six levels, which are strategically aligned with the six primary modules of the fourth-grade mathematics curriculum (Kurikulum Merdeka): (1) whole numbers up to 10,000, (2) fractions, (3) visual and number patterns, (4) measurement of area and volume, (5) plane figures, and (6) pictograms. Each level represents these topics in consecutive order to maintain consistency with the curriculum sequencing implemented in classroom learning. Furthermore, a level reset button is incorporated in the lower-right corner, which triggers a confirmation dialog before clearing the player's current progress, ensuring that level progress is only reinitialized upon deliberate user verification as an error prevention mechanism suitable for young learners.

Figure 5. Level Select Interface

3.2.5. Character Select Interface

The Character Selection Interface is presented to the user upon selecting a specific level within the game. The inclusion of character selection supports learner autonomy by allowing students to personalize their in-game representation. Providing such choice elements has been associated with increased engagement and intrinsic motivation, particularly in elementary learners. This screen features two distinct playable protagonists available from the start: Arine and Sheryn. By allowing a personalized selection based on player preference, the game aims to foster a more immersive and engaging learning experience [26], [27]. This element of choice is strategically integrated to increase student motivation and enjoyment as they navigate through the challenges. The visual layout of this selection screen is illustrated in Figure 6.

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Figure 6. Character Select Interface

3.2.6. Gameplay Interface

The Gameplay Interface serves as the core interactive environment of Petualangan Ksatria, where players engage in turn-based combat to complete each level. The turn-based combat mechanism was intentionally selected to provide students with sufficient cognitive processing time before responding to mathematical problems [14]. Unlike real-time systems that may increase time pressure and anxiety, turn-based interaction allows learners to reflect on problem-solving strategies and make deliberate decisions [15]. This design aligns with elementary students' cognitive development stage, where structured and paced interaction supports developmentally appropriate cognitive engagement [16]. To maintain engagement and prevent visual monotony, each level features a unique environmental background and a distinct set of enemy assets, ensuring that players encounter a varied and dynamic atmosphere throughout their journey. The screen is equipped with a wave counter to track current progress and a status panel that displays the real-time health points (HP) and character names for both the protagonist and the opponent. Players interact through three distinct action buttons, each clearly labeled with specific damage values to facilitate strategic decision-making. Immediate feedback is provided via a notification panel in the lower-right corner, which confirms the outcome of player actions and signals enemy movements. The combat system incorporates a progressive difficulty mechanic where three enemies appear sequentially for each stage. These opponents feature increasing health values specifically 80, 90, and 100 HP across successive waves to challenge the students' persistence. The gradual increase in enemy health values reflects a progressive challenge structure, which is essential for maintaining optimal engagement without overwhelming learners. Additionally, a pause button is available for users to access the system menu, with the overall gameplay layout illustrated in Figure 7.

Figure 7. Gameplay Interface

3.2.7. Quiz Interface

The Quiz Interface serves as the primary assessment mechanism within Petualangan Ksatria, appearing immediately after a player selects a combat action. To execute the chosen action, the player must successfully validate the action by providing the correct answer to a mathematical problem. Failure to do so, or allowing the time to expire, results in an automatic counter-attack from the opponent with damage proportional to the selected attack level. This interface features a countdown timer at the top of the screen to ensure a focused learning pace, with durations strategically adjusted to the action's difficulty: 15 seconds for light attacks, 20 seconds for medium attacks, and 25 seconds for heavy attacks. The differentiated time allocation is designed to regulate cognitive load by aligning processing time with task complexity, ensuring that increased cognitive demand is accompanied by proportional response time while avoiding excessive time pressure [17]. Problems are presented using a combination of textual descriptions and illustrative imagery, accompanied by four multiple-choice options to support clarity and accessibility for elementary learners. By categorizing questions into easy, medium, and hard tiers

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corresponding to the selected action, the game implements a high-risk, high-reward framework. This structure encourages strategic thinking and prudent decision-making, while also fostering metacognitive awareness as students evaluate their confidence before selecting a challenge level aligned with their perceived ability [28], [29]. Additionally, the opportunity to choose different difficulty levels enhances intrinsic motivation by providing learners with autonomy and a sense of control over their learning experience [21]. The layout of this interface is illustrated in Figure 8.

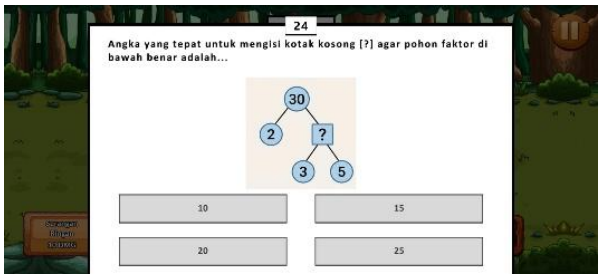

Figure 8. Quiz Interface

3.2.8. Pause Interface

The Pause Menu Interface is accessed when a player selects the pause button within the gameplay interface. This interface features an overlay menu containing four primary functional buttons, each represented by a distinct icon to ensure intuitive navigation for the user. These include the Resume button to continue the current session, the Settings button to access the settings menu, the Restart button to reinitialize the current level from the beginning, and the Home button to return to the main menu. To prevent the accidental loss of progress, selecting the Restart or Home button triggers a confirmation dialog that requires user verification before the system reinitializes the level or exits the session, serving as a safety mechanism. The visual layout of the pause menu is illustrated in Figure 9.

Figure 9. Pause Interface

3.2.9. Victory and Defeat Interface

The Victory and Defeat Interfaces serve as the concluding feedback mechanisms at the end of each level. Both interfaces are designed with motivational messaging to maintain user engagement regardless of the session outcome. The Victory Interface is triggered upon the successful elimination of all enemy waves, providing positive reinforcement and offering three navigational options: returning to the level selection menu, restarting the current level, or proceeding to the next level. Conversely, the Defeat Interface appears if the player's health points are depleted. This interface provides supportive feedback, such as 'Mistakes are part of learning,' to encourage persistence and reduce frustration. It provides two primary functional options: returning to the level selection or retrying the level. The visual layout for these end-state screens is illustrated in Figure 10.

Figure 10. (a) Victory Interface and (b) Defeat Interface

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3.3 Test Results

3.3.1 Black-Box Testing

Black-box testing is a software evaluation technique that focuses on functionality relative to requirements without examining the internal source code. The primary objective of this method is to ensure that the application's features, inputs, and outputs align with the predefined specifications [30]. This approach can be applied to both individual components and integrated systems to verify software behavior regardless of its internal architecture or implementation details. The results of the black-box testing are summarized in Table 6.

Table 6. Black-Box Testing Results

Interface	Input (Action)	Process	Output (Expected Result)	Validity
Main Menu	Click the Play button	Access the tutorial interface	Displays the tutorial screen	Valid
	Click the Settings button	Access the settings interface	Displays the settings menu	Valid
	Click the Exit button	Access the quit confirmation dialog	Displays the quit confirmation dialog	Valid
Settings	Adjust the Music/SFX sliders	Change the audio volume levels	Music and sound effect volumes change	Valid
Tutorial	Click the Play/Restart button	Play the tutorial video.	The tutorial video plays from the beginning	Valid
	Click the Continue button	Access the level selection interface	Displays the level selection screen	Valid
Level Select	Click a Level button	Access the character selection interface	Displays the character selection screen	Valid
	Click the Reset Level button	Access the reset confirmation dialog	Displays the reset confirmation dialog	Valid
Character Select	Select Arine or Sheryn	Set the selected character for battle	Displays the gameplay screen with the chosen hero	Valid
Gameplay	Click an Action button	Access the quiz interface with a specific timer	Displays the math problem and countdown timer	Valid
	Click the Pause button	Stop the game time and show the pause menu	Gameplay stops and the pause menu appears	Valid
	Enemy HP reaches 0	Access the victory interface	Displays the victory panel	Valid
	Hero HP reaches zero	Access the defeat interface	Displays the defeat panel	Valid
Quiz Interface	Select the correct answer	Validate the answer and trigger an attack	Hero attacks and enemy HP decreases	Valid
	Wrong answer or timeout	Trigger the enemy's counter-attack	Enemy attacks and hero HP decreases	Valid
Pause Menu	Click the Resume button	Close the pause menu and resume game time	Menu closes and gameplay continues	Valid
	Click the Restart button	Access the restart confirmation dialog	Displays the restart confirmation dialog	Valid
	Click the Home button	Access the home confirmation dialog	Displays the home confirmation dialog	Valid

3.3.2 User Acceptance Testing (UAT) Results

The results of the User Acceptance Testing (UAT) involving student participants are presented in Table 7 and Table 8. Table 7 presents individual responses, while Table 8 provides the mean score of each evaluation item.

Table 7. Students' User Acceptance Testing (UAT) Results

No.	Respondent ID	Question No.										Total Per Respondent
		1	2	3	4	5	6	7	8	9	10	
1	S01	5	5	5	5	4	5	5	5	4	5	48
2	S02	5	5	4	5	5	5	5	5	5	5	49
3	S03	4	4	5	4	4	5	4	3	3	4	40
4	S04	5	4	5	5	5	5	4	4	5	5	47
5	S05	5	5	5	5	4	5	5	4	5	5	48
6	S06	5	5	5	5	4	5	5	4	5	5	48
7	S07	5	5	5	5	5	5	5	5	5	5	50
8	S08	5	4	3	5	3	4	5	3	4	3	39
9	S09	5	5	5	5	5	5	5	5	5	5	50
10	S10	5	4	3	5	5	5	5	3	4	5	44
11	S11	5	5	5	5	4	4	5	5	1	5	44
12	S12	3	5	3	3	5	5	4	3	5	5	41
13	S13	4	4	5	5	4	5	4	5	4	4	44
14	S14	5	4	5	4	5	4	4	5	5	5	46
15	S15	4	3	2	4	2	3	4	5	4	5	36
16	S16	4	3	5	4	3	2	4	4	5	3	37
17	S17	4	4	5	4	3	5	4	4	5	4	42
18	S18	5	5	5	4	4	5	5	5	4	5	47
19	S19	4	4	5	4	3	5	4	4	5	4	42
20	S20	3	4	4	5	5	5	4	5	4	5	44
21	S21	3	4	5	5	5	4	3	4	5	5	43
22	S22	4	5	3	4	3	5	5	5	5	5	44
23	S23	4	4	5	4	4	5	4	3	3	4	40
24	S24	4	5	4	3	4	3	3	5	3	4	38
25	S25	5	4	5	5	5	4	5	5	4	5	47
26	S26	5	4	5	5	5	4	5	5	4	5	47
27	S27	4	5	4	4	5	5	4	5	5	5	46
28	S28	4	3	5	4	3	4	4	3	4	3	37
29	S29	1	2	1	2	3	1	3	1	3	1	18
30	S30	3	3	2	4	3	2	3	4	3	3	30
31	S31	5	5	5	5	5	5	5	5	4	4	48
	Overall Score											1324
	Percentage											85%

The student responses produced an overall score of 1324 out of the maximum possible score, resulting in an acceptance percentage of 85%, categorized as Very Satisfactory. This finding indicates that the developed educational game was positively received by students as a supplementary mathematics learning medium. Most respondents gave consistently high scores, although several lower responses suggest differences in user experience, gameplay familiarity, or individual learning preferences.

Table 8. Mean Score of Student UAT

Question No.	Mean Score
1	4.26
2	4.23
3	4.29
4	4.39
5	4.10

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6	4.32
7	4.32
8	4.23
9	4.19
10	4.39

Item-level mean scores (i.e., mean scores for each questionnaire item) provide a clearer interpretation of student perceptions toward specific aspects of the game. The highest mean scores were obtained for Question 4 (M = 4.39) and Question 10 (M = 4.39), indicating strong willingness to replay the game and positive perceptions regarding the clarity of instructions. High scores were also recorded for Question 6 (M = 4.32), Question 7 (M = 4.32), and Question 3 (M = 4.29), suggesting that students found the game enjoyable, engaging, and supportive of enthusiasm toward mathematics learning. Meanwhile, the lowest mean score was found in Question 5 (M = 4.10), followed by Question 9 (M = 4.19). Although these scores remain positive, they indicate that gameplay accessibility and visual presentation may still be further improved, possibly due to differences in students' familiarity with digital controls or turn-based mechanics.

The results of the User Acceptance Testing (UAT) involving the teacher participant are presented in Table 9 and reflect the pedagogical evaluation of the developed game.

Table 9. Teacher User Acceptance Testing (UAT) Results

No.	**Respondent ID**	**Question No.**										**Total Per Respondent**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
1	T01	4	4	4	4	4	4	4	5	3	4	40
						Overall Score						40
						Percentage						80%

The teacher evaluation produced a total score of 40 out of the maximum possible score, resulting in an acceptance percentage of 80%, categorized as Satisfactory. This indicates that the developed educational game was considered pedagogically acceptable and appropriate as a supplementary mathematics learning medium. Most evaluation items received a score of 4 (Agree), suggesting positive perceptions regarding curriculum alignment, usability, and instructional relevance. The highest score was recorded for Question 8 (score = 5), indicating positive perception of the game's potential to motivate students to be more active in learning. Meanwhile, the lowest score was found in Question 9 (score = 3), suggesting that the visual appearance and animations may still require further refinement. Overall, the result indicates opportunities for improvement in instructional features and classroom integration.

3.4 Discussion

The functional evaluation conducted through Black-box testing confirmed that all core modules of Petualangan Ksatria operated according to predefined specifications. Navigation flows from the main menu, tutorial sequence, character selection, and core gameplay were consistently valid. Error prevention mechanisms, such as confirmation dialogs for resetting progress, returning to the home screen, or exiting the application, were also successfully implemented. These features are particularly important for fourth-grade students, as they help prevent accidental progress loss and unintended session termination.

The student acceptance evaluation yielded a positive overall score of 85% from 31 respondents, which falls within the Very Satisfactory category. This result indicates that the developed game was well received as a supplementary mathematics learning medium. Similar positive findings were reported by Satriyo *et al.* [31], whose RPG-based mathematics game achieved a UAT score of 90.5%, and by Taufik *et al.* [32], who found that RPG-based mathematics games were feasible for classroom support. Although the acceptance score in this study was slightly lower, the developed game provides a distinctive design contribution by integrating turn-based strategic mechanics with graded mathematical difficulty levels, allowing learning tasks to be directly connected with decision-making during gameplay.

The positive student responses also support previous findings that digital mathematics games can enhance motivation and engagement. Cubillos *et al*. [33] reported improved motivation and learning performance through digital math games among primary students. In the present study, high scores related to willingness to replay the game and enjoyment during play similarly suggest positive engagement and interest toward mathematics learning. These findings indicate that combining learning content with interactive gameplay may help create a more engaging learning environment.

Although the overall acceptance result was highly positive, individual responses revealed some variability. Several respondents, such as S29 and S30, recorded noticeably lower scores than the majority of participants. This suggests that not all students experienced the same level of engagement or usability. Differences in prior learning interest, digital familiarity, or personal learning preferences may have influenced these perceptions. Therefore, future improvements may include stronger tutorial reinforcement, simplified interaction cues, and adaptive support mechanisms to better accommodate diverse learner characteristics.

From a pedagogical perspective, the teacher evaluation reached 80%, categorized as Satisfactory. This indicates that the game was considered acceptable in terms of curriculum relevance, usability, and classroom feasibility. The teacher's responses suggest that the game content was generally aligned with the Indonesian Kurikulum Merdeka, particularly for topics such as whole numbers, fractions, and measurement. In addition, supportive motivational feedback integrated into the Victory and Defeat interfaces may help maintain learner persistence and positive emotional responses during gameplay [34].

This study has several limitations. First, the user acceptance evaluation involved a limited student sample and only one teacher respondent, which may restrict generalizability. Second, the study focused on acceptance and perceived engagement rather than measuring learning improvement through pre-test and post-test instruments. Third, the implementation was conducted in a short-term setting, so long-term effects on motivation and achievement remain uncertain.

Future studies may involve larger participant groups, multiple teacher evaluators, and experimental designs using pre-test and post-test measurements to assess learning outcomes more objectively. Additional development may also include adaptive difficulty systems, teacher dashboards, and learning analytics to strengthen classroom integration and personalized learning support.

4. CONCLUSION

The development of Petualangan Ksatria using the ADDIE model and the Unity game engine resulted in a functional mathematics learning game tailored for fourth-grade elementary students. The systematic application of the ADDIE stages helped ensure that the game was designed in accordance with user needs, curriculum requirements, and instructional objectives. Black-box testing verified that all functional specifications operated as intended, while User Acceptance Testing (UAT) yielded scores of 85% from students and 80% from the teacher, indicating positive user acceptance and satisfactory pedagogical perceptions. These findings suggest that the developed game has potential as a supplementary mathematics learning medium that may support students' interest and engagement in learning mathematics. Future research may extend this work by evaluating learning outcomes, motivation changes, and long-term implementation across broader educational settings.

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