

**DEVELOPMENT OF AN ANDROID-BASED EDUCATIONAL
MATHEMATICS GAME FOR FOURTH-GRADE
ELEMENTARY SCHOOL STUDENTS TO
SUPPORT LEARNING INTEREST
AND MOTIVATION**



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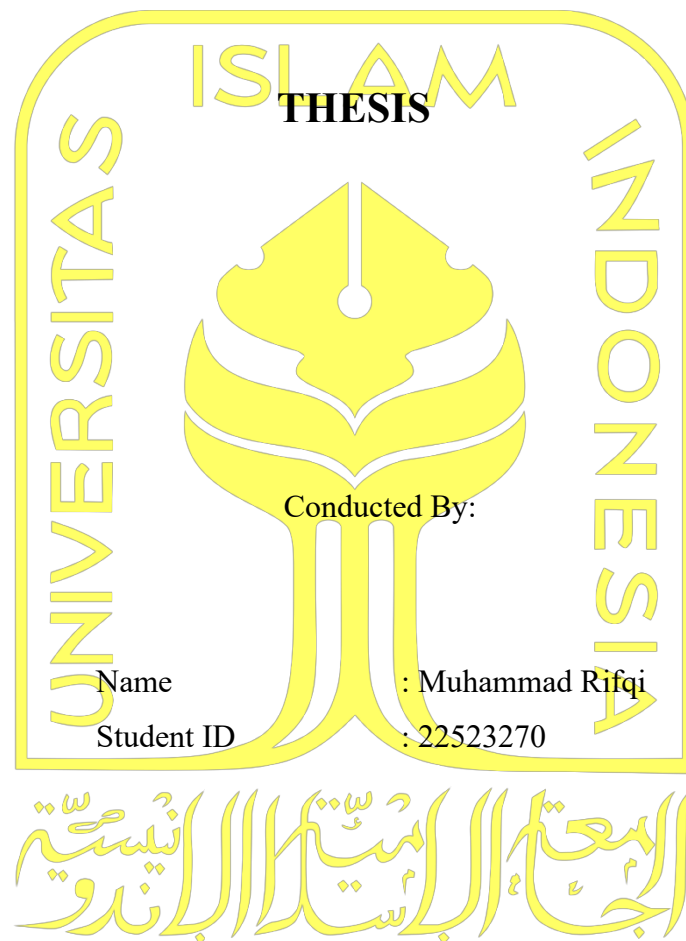
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**INFORMATICS STUDY PROGRAM – UNDERGRADUATE PROGRAM
FACULTY OF INDUSTRIAL TECHNOLOGY
UNIVERSITAS ISLAM INDONESIA**

2026

SUPERVISOR ENDORSEMENT PAGE

**DEVELOPMENT OF AN ANDROID-BASED EDUCATIONAL
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ELEMENTARY SCHOOL STUDENTS TO
SUPPORT LEARNING INTEREST
AND MOTIVATION**



Yogyakarta, April 22nd, 2026

Advisor,

(Kurniawan Dwi Irianto, S.T., M.Sc.)

EXAMINER ENDORSEMENT PAGE

**DEVELOPMENT OF AN ANDROID-BASED EDUCATIONAL
MATHEMATICS GAME FOR FOURTH-GRADE
ELEMENTARY SCHOOL STUDENTS TO
SUPPORT LEARNING INTEREST
AND MOTIVATION**

THESIS

Has been defended in front of the examiners as one of the requirements to obtain a
Bachelor of Informatics degree from the Undergraduate Program in Informatics at the Faculty
of Industrial Technology, Universitas Islam Indonesia

Yogyakarta, May 25th, 2026

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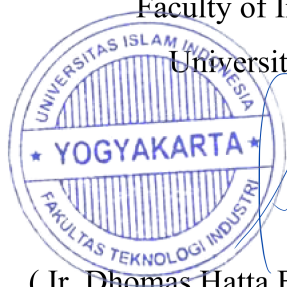
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**Development of an Android-Based Educational Mathematics
Game for Fourth-Grade Elementary School Students to
Support Learning Interest and Motivation**

Stating that all components and contents in this final project are my own work. If in the future it is proven that some parts of this work are not my own work, the final project submitted as my own work is ready to be withdrawn and ready to bear any risks and consequences.

Thus this statement letter is made, hopefully it can be used properly.

Yogyakarta, April 22nd, 2026



(Muhammad Rifqi)

DEDICATION

Alhamdulillah rabbil ‘alamin, all praise be to Allah SWT for His mercy and guidance, by which this thesis has been completed smoothly and successfully. With deepest respect, this work is dedicated to the author’s beloved parents, sister, and entire family, who have continuously provided prayers, support, and encouragement throughout the completion of this thesis. The author would also like to express sincere gratitude to my thesis supervisor, Kurniawan Dwi Irianto, S.T., M.Sc., as well as all lecturers of the Informatics Study Program at Universitas Islam Indonesia, who with patience and understanding have given valuable guidance, knowledge, and time to the author. May Allah SWT always bestow His mercy, blessings, sustenance, and good health upon them and upon us all.

MOTTO

“Allah does not burden a soul beyond that it can bear. “

(QS. Al-Baqarah: 286)

FOREWORD

Assalamu'alaikum Warahmatullahi Wabarakatuh.

Alhamdulillah rabbil 'alamin, all praise and gratitude are devoted to Allah SWT for His blessings, mercy, and guidance, which have enabled the author to complete this thesis entitled “Development of an Android-Based Educational Mathematics Game for Fourth-Grade Elementary School Students to Support Learning Interest and Motivation” successfully. The preparation of this thesis was carried out as one of the requirements to obtain a bachelor's degree in informatics from the Informatics Study Program, Undergraduate Program, Faculty of Industrial Technology, Universitas Islam Indonesia. During the process of completing this thesis, the author received considerable assistance, support, prayers, and motivation from many parties. Therefore, on this occasion, the author would like to express sincere gratitude to:

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The author realizes that this thesis is still far from perfect and may contain various shortcomings. Therefore, the author sincerely welcomes any constructive criticism and suggestions for future improvement. May Allah SWT bestow His guidance, mercy, and blessings upon us all. Aamiin.

Wassalamu'alaikum Warahmatullahi Wabarakatuh.

Yogyakarta, April 22nd, 2026



(Muhammad Rifqi)

ABSTRACT

Mathematics is frequently perceived as a difficult and abstract subject by elementary school students, which may reduce their interest and motivation to learn. This issue is reflected in the 2022 Programme for International Student Assessment (PISA) results, which show that Indonesian students' mathematical proficiency remains relatively low. Previous studies have demonstrated that educational games can support mathematics learning. However, most studies primarily focus on feasibility, usability, or general effectiveness, while relatively limited attention has been given to the design of specific gameplay mechanics that support students' learning interest and motivation, particularly in educational games tailored for fourth-grade elementary students. Therefore, this study aims to develop an Android-based educational mathematics game entitled *Petualangan Ksatria* as an alternative learning medium for fourth-grade elementary school students. The game was designed to provide a more interactive and engaging learning experience while supporting students' interest and motivation in mathematics learning. This research applied the Research and Development (R&D) approach using the ADDIE instructional design model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. The application was developed using the Unity game engine and integrates mathematics materials based on the Grade IV Merdeka Curriculum into gameplay that adopts turn-based mechanics. Functional testing was conducted using Black Box Testing to verify whether all system features operated according to the intended specifications. In addition, User Acceptance Testing (UAT) was carried out involving 31 students and one fourth-grade teacher at SD Negeri Ngemplak 2. The results of Black Box Testing showed that all major functions of the application operated properly. Furthermore, the UAT results indicated a student acceptance score of 85%, categorized as Very Satisfactory, and a teacher evaluation score of 80%, categorized as Satisfactory. These findings indicate that *Petualangan Ksatria* is feasible as an alternative and engaging supplementary learning medium for mathematics learning at the elementary school level and has the potential to support students' learning interest and motivation.

Keywords: ADDIE model, Android-based application, educational game, elementary school mathematics, learning motivation, user acceptance testing.

GLOSSARY

ADDIE	an instructional design model consisting of Analysis, Design, Development, Implementation, and Evaluation stages.
Android	a mobile operating system used as the target platform for the developed application.
Black Box Testing	a software testing method that evaluates system functions based on inputs and outputs without examining internal code.
Educational Game	a game designed to combine entertainment elements with learning objectives.
Game Engine	software used to develop games and interactive applications.
Gameplay	the mechanics, rules, and interactions experienced by players during the game.
HIPO Diagram	Hierarchy Input Process Output diagram used to describe system structure and module relationships.
HUD (Hheads-Up Display)	an interface element displaying important in-game information such as HP, names, or status.
JSON (JavaScript Object Notation)	a lightweight data format used to store and exchange structured data.
Kurikulum Merdeka	the current Indonesian national curriculum used as the learning content reference.
PISA (Programme for International Student Assessment)	an international assessment measuring student competencies in mathematics, reading, and science.
R&D (Research and Development)	a research method focused on designing, developing, and evaluating a product.
Turn-Based Game	a type of game in which actions are performed sequentially by taking turns.
UAT (User Acceptance Testing)	a testing method used to measure user acceptance and satisfaction toward a developed system.
Unity	a game engine used to develop the application in this study.
Wireframe	a basic visual layout used to plan interface structure before implementation.

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CHAPTER I

INTRODUCTION

1.1 Background

Mathematics is one of the fundamental subjects taught at the elementary school level. This subject serves as a foundation for students to develop problem-solving and critical thinking skills, both in academic contexts and in everyday life applications (Solikhah et al., 2024). Therefore, a strong and effective foundation in basic mathematics education is essential to support the future development of students' abilities (Lestari et al., 2024).

However, in practice, many students perceive mathematics as complex, confusing, and even intimidating. This perception is supported by the findings of Yabashiru et al. (2025), which indicate that students often experience difficulties in understanding problem language, connecting information, and visualizing mathematical concepts. These learning difficulties frequently lead to frustration, reduced interest, and low motivation to engage actively in mathematics learning, causing students to view mathematics as an unappealing subject.

The low level of students' interest and motivation in learning mathematics may contribute to broader issues in mathematics education, as reflected in the results of the 2022 Programme for International Student Assessment (PISA). According to the report, only around 18% of Indonesian students achieved at least the minimum level of mathematical proficiency, which is significantly lower than the OECD average of 69% (OECD, 2023). Although PISA assesses 15-year-old students, these results highlight the importance of fostering students' interest and motivation in learning mathematics from the elementary school level, as learning attitudes developed early can influence academic performance in later stages (Gashaj et al., 2023).

This condition is further exacerbated by the use of conventional teaching methods and learning media that lack interactivity and visual appeal, which tend to reduce students' interest and motivation in learning mathematics (Mujahadah et al., 2021). In contrast, rapid technological advancements have opened opportunities for the use of innovative learning media. One such alternative is educational games, which integrate elements of play and learning to create enjoyable, interactive, and engaging learning experiences that can increase students' interest and motivation to participate in mathematics learning activities (Chen & Tu, 2021).

Several previous studies have demonstrated the potential of educational games in elementary mathematics learning. Gontah et al. (2021) developed a mobile-based educational

mathematics game for elementary school students, demonstrating that mobile platforms can be effectively utilized to create interactive and engaging learning environments. Meanwhile, Amanda & Prihatin (2025) developed an interactive educational game Math Adventure, which was proven to be feasible and effective in increasing students' learning motivation in mathematics. The findings of these studies indicate that educational games are able to attract students' attention, enhance learning motivation, and encourage more active involvement in mathematics learning. However, relatively few studies specifically focus on the development of mobile-based educational games intended to support learning interest and motivation among fourth-grade elementary school students.

This study focuses on fourth-grade elementary school students, as this grade represents a transitional stage in which students begin to encounter more abstract mathematical concepts. Based on interviews conducted with a fourth-grade teacher at SD Negeri Ngemplak 2, it was found that students often show low enthusiasm when learning topics such as two-dimensional and three-dimensional shapes as well as Least Common Multiple (LCM) and Greatest Common Divisor (GCD) using conventional teaching methods. The teacher also noted that students' motivation and interest in classroom learning tend to vary, indicating the need for a more engaging and interactive learning medium.

The selection of fourth-grade students as the subject of this study is based on several academic considerations. At the age of approximately 9-10 years, students are in the concrete operational stage according to Piaget's theory of cognitive development, where they are able to think logically about concrete objects but still require visual and interactive learning support to maintain interest and motivation when dealing with abstract concepts (Fahma & Purwaningrum, 2021). According to the Merdeka Curriculum, fourth-grade students learn topics such as whole numbers up to 10,000, basic arithmetic operations, factors and multiples, fractions, number patterns, measurement of area and volume, plane figures, and three-dimensional shapes. Many of these topics are abstract in nature, thus requiring learning approaches that are visually engaging and motivating for students.

To address these challenges, this study aims to develop an educational game in the form of a mobile application as an alternative learning medium for fourth-grade mathematics. The developed game is intended to support students' interest and motivation in learning mathematics through an enjoyable, interactive, and engaging learning experience aligned with the characteristics and needs of elementary school students.

1.2 Problem Formulation

Based on the background described above, the problems to be addressed in this research can be formulated as follows:

- a. How is a fourth-grade elementary school mathematics educational game developed as an alternative learning medium to support students' interest and motivation in learning mathematics?
- b. How feasible is the mathematics educational game as an alternative learning medium in supporting students' interest and motivation in learning mathematics?

1.3 Research Objective

The objectives of this research are as follows:

- a. To develop a fourth-grade elementary school mathematics educational game as an alternative learning medium to support students' interest and motivation in learning mathematics.
- b. To determine the feasibility of the mathematics educational game as an alternative learning medium in supporting students' interest and motivation in learning mathematics.

1.4 Research Limitation

To ensure that the research remains focused and manageable, this study is limited to the following scope:

- a. The educational game developed in this study is designed specifically for fourth-grade elementary school students.
- b. The mathematical material implemented in the game is limited to selected topics from the current fourth-grade elementary school mathematics curriculum in Indonesia (Kurikulum Merdeka), including whole numbers up to 10,000, fractions, picture and number patterns, measurement of area and volume, plane figures, and basic data representation using pictograms and bar charts.
- c. The game is developed in the form of a mobile application with basic gameplay mechanics appropriate for the cognitive level of elementary school students.
- d. User testing is conducted on a limited group of students and teachers to evaluate the usability, functionality, and acceptance of the game.

1.5 Research Significance

This research is expected to provide several benefits, including:

- a. For students: Providing an engaging, interactive, and accessible learning medium that can support students' interest and motivation in learning mathematics and encourage positive learning experiences.
- b. For teachers: Offering an alternative learning medium that can be integrated into classroom activities to support student engagement and learning motivation in mathematics learning.
- c. For future researchers and developers: Providing reference materials, design considerations, and implementation insights for the development of educational games or technology-based learning media in mathematics and related fields.
- d. For the education field: Supporting the adoption of innovative and technology-based learning media that align with the characteristics, needs, and learning styles of elementary school students.

1.6 Writing System

To ensure that this thesis report is organized systematically and clearly, the writing is structured as follows:

a. CHAPTER 1 Introduction

This chapter provides a general overview of the background of the research, outlines the problem formulation, research objectives, significance of the research, scope and limitations, and the structure of the thesis.

b. CHAPTER 2 Theoretical Basis

This chapter presents a review of relevant theories and previous studies that support the development of the educational mathematics game.

c. CHAPTER 3 Research Methodology

This chapter explains the research methods used in designing and developing the educational game.

d. CHAPTER 4 Result and Discussion

This chapter presents the results of the game development process, from the initial analysis phase to the final evaluation.

e. CHAPTER 5 Conclusion

This final chapter provides conclusions drawn from the entire development process and research findings.

CHAPTER II

THEORETICAL BASIS

2.1 Mathematics Learning in Elementary School

Mathematics learning at the elementary school level plays a fundamental role in developing students' basic numeracy skills, logical reasoning, and problem-solving abilities. These competencies serve as an essential foundation for students' future learning in both academic and everyday contexts (Torres-Peña et al., 2025). At this stage, students are gradually introduced to fundamental mathematical concepts, such as numbers, patterns, measurements, and shapes, which are closely related to real-life situations and daily experiences (Rahmawati et al., 2025).

Elementary school students are generally in a developmental phase where concrete thinking dominates their cognitive processes. As a result, mathematics learning at this level often requires the use of concrete examples, visual representations, and meaningful activities to help students understand concepts that may later become more abstract. When learning materials are presented in an abstract or monotonous manner, students may experience difficulties in grasping mathematical ideas, which can lead to confusion and reduced engagement in learning activities (Siller & Ahmad, 2024).

To address these challenges, mathematics learning in elementary schools needs to be supported by appropriate learning media that can facilitate concept understanding and maintain students' attention. Learning media that incorporate visual elements, interaction, and contextual examples can help bridge the gap between abstract mathematical concepts and students' concrete thinking abilities (Hidayati et al., 2026). The use of suitable learning media is therefore considered an important component in creating meaningful and effective mathematics learning experiences for elementary school students (Rino, 2025).

In addition, well-designed learning media can support teachers in presenting mathematical content more systematically and engagingly. By providing structured learning experiences that align with students' developmental characteristics, mathematics learning at the elementary school level can be conducted in a way that is more accessible, enjoyable, and supportive of students' learning needs (Sari et al., 2024).

2.2 Students' Learning Interest and Motivation

Learning interest refers to students' tendency to feel attracted to and engaged in learning activities, which encourages active participation in the learning process. Students who

demonstrate a high level of learning interest tend to show greater attention, curiosity, and enjoyment during learning activities (Thiel & Hanssen, 2025). In elementary education, learning interest plays a crucial role in shaping students' attitudes toward learning, particularly in subjects that are often perceived as challenging, such as mathematics (Wakhata et al., 2024).

Learning motivation can be defined as the internal and external factors that drive students to initiate, sustain, and persist in learning activities in order to achieve learning goals. Motivation influences students' willingness to invest effort, overcome learning difficulties, and maintain consistency throughout the learning process (Huang et al., 2025). For elementary school students, learning motivation is strongly influenced by external factors, including the learning environment, instructional strategies, and the learning media used by teachers (Feng & Xiao, 2024).

Learning interest and motivation are closely related and mutually reinforcing. When students are interested in learning activities, their motivation to participate and engage in learning tends to increase (Fitri & Hasbi, 2025). Conversely, motivated students are more likely to develop sustained interest in learning. In mathematics learning, insufficient interest and motivation may lead to passive learning behaviors, reduced engagement, and difficulties in understanding concepts, which can negatively affect learning outcomes (Wang, 2022).

To support students' learning interest and motivation, learning approaches that are interactive, enjoyable, and aligned with students' developmental characteristics are needed. The use of appropriate learning media can help create a more engaging learning atmosphere, encourage active participation, and reduce feelings of boredom or anxiety toward learning mathematics (Ningsi et al., 2025). Therefore, learning media play an important role in fostering positive learning attitudes and supporting students' interest and motivation in elementary school mathematics learning (Wahyuni et al., 2025).

2.3 Educational Games

Educational games are games designed with the primary objective of supporting learning activities by integrating educational content into gameplay. These games combine learning elements with game mechanics such as rules, challenges, rewards, and feedback, allowing learners to acquire knowledge and skills through interactive experiences (Nurhikmah et al., 2024). By embedding learning objectives within game structures, educational games aim to create learning environments that are both engaging and meaningful (Nadeem et al., 2023).

One of the main characteristics of educational games is their interactive nature, which encourages active learner participation during the learning process (Nurfalah et al., 2025). Educational games provide opportunities for learners to engage in problem-solving activities, make decisions, and receive immediate feedback on their actions. These features support repeated practice and help learners understand learning materials more effectively, particularly when dealing with abstract concepts (Sihombing et al., 2025).

In the context of elementary school learning, educational games can play an important role in supporting students' interest and motivation. The integration of gameplay elements into learning activities can help create a more enjoyable learning atmosphere and reduce feelings of boredom or anxiety toward academic subjects such as mathematics. Therefore, educational games are considered a learning medium that has the potential to support positive learning experiences for elementary school students (Nurhaliza et al., 2025).

2.4 Android

Android is an open-source mobile operating system developed by Google for mobile devices such as smartphones and tablets. As an open-source platform, Android allows developers to design and develop various types of applications, including educational applications, with a high level of flexibility (Susila et al., 2023). Applications developed on the Android platform can be distributed through digital application stores such as Google Play Store, making them easily accessible to users (Alkinoon et al., 2025).

In the context of education, Android supports mobile learning by enabling learning activities to be carried out using portable devices that can be used anytime and anywhere (Galimova et al., 2025). The widespread use of Android-based smartphones and tablets contributes to the accessibility of educational applications, allowing learning materials to be accessed beyond the classroom environment and supporting more flexible learning experiences (Firdausi, 2025).

Android is one of several platforms that can be used for developing educational applications. Compared to other mobile operating systems such as iOS by Apple, Android is available on a wider range of devices produced by different manufacturers (Eliza et al., 2024). In contrast to desktop-based platforms such as Windows by Microsoft, which are commonly used in fixed learning environments, Android emphasizes mobility and portability through handheld devices (Eom, 2023).

2.5 Turn-Based Game

Turn-based game is a type of game in which players perform actions in a sequential manner, with each participant taking turns according to predefined rules. In this gameplay system, the game state changes only after a player has completed their turn, allowing actions to be processed step by step rather than simultaneously (Leong et al., 2022). Turn-based mechanics emphasize structured interaction and rule-based progression, making them distinct from real-time gameplay systems (Qaffas, 2020).

Turn-based games are characterized by clearly defined turns, orderly action sequences, and decision-making processes that do not rely on speed or reflex-based input. This type of gameplay allows players to focus on planning, evaluating options, and considering the consequences of their decisions without time pressure. As a result, turn-based mechanics often support thoughtful interaction and logical reasoning during gameplay (Reynaldo et al., 2021).

In game design, turn-based mechanics can be contrasted with real-time game mechanics, where players must react quickly and perform actions continuously within limited time constraints. Real-time games often emphasize speed, reflexes, and immediate responses, while turn-based games prioritize deliberation and structured decision-making (Lewandowska et al., 2022). These differences result in distinct player experiences and interaction patterns (Domingues et al., 2024).

Due to their structured nature, turn-based mechanics are frequently applied in games that require strategic thinking, logic, and step-by-step problem-solving (Smith & Basak, 2023). In learning-oriented contexts, this gameplay structure can support activities that involve careful reasoning and decision-making, making turn-based mechanics suitable for applications that aim to encourage thoughtful engagement rather than fast-paced reactions (Czuderna & Budke, 2020).

2.6 Unity Game Engine

Unity is a game engine that provides an integrated development environment for creating digital games and interactive applications. It supports the development of both two-dimensional and three-dimensional content, allowing developers to design interactive systems within a single development framework (Widjaja et al., 2024). Unity is widely used in the development of games and interactive digital applications across various domains due to its flexibility and comprehensive toolset (Liu et al., 2025).

Unity enables developers to deploy applications across multiple platforms using a unified development environment. This cross-platform capability allows a single project to be adapted for different target platforms without requiring significant changes to the core development process (Coronado et al., 2023). As a result, Unity is commonly utilized in the development of interactive applications that are intended to reach diverse user environments (Komianos et al., 2024).

In the field of game development, Unity can be compared with other game engines such as Unreal Engine and Godot (Mohd et al., 2023). Unreal Engine is widely recognized for its advanced visual capabilities and realistic rendering features, which are often applied in games that prioritize high-quality graphics (Silva Jasau et al., 2024). In contrast, Unity emphasizes flexibility and broad platform support, making it suitable for a wide range of interactive applications (Haces-Garcia & Zhu, 2024). Godot, as an open-source game engine, offers an alternative development environment with a growing community, though it differs from Unity in terms of ecosystem size and development support (Kaarlela et al., 2023).

Based on these characteristics, Unity is positioned as a game engine that balances visual capability, flexibility, and accessibility, making it widely applied in the development of games and interactive digital applications across various fields.

2.7 ADDIE Development Model

The ADDIE development model is a systematic instructional design framework that is widely used in the development of educational products, learning media, and instructional systems (Tias & Saprudin, 2025). ADDIE is an acronym that represents five main stages: Analyze, Design, Development, Implementation, and Evaluation. This model provides a structured and logical process for developing learning materials by ensuring that each stage is based on clearly defined objectives and supported by continuous evaluation (Rosyanto et al., 2025).

One of the main strengths of the ADDIE model lies in its clear and sequential structure, which allows developers to identify learning needs before designing and developing instructional solutions (Ni Luh Putu Gautami et al., 2025). The iterative nature of ADDIE enables revisions and improvements at each stage based on feedback and evaluation results (Kalonde et al., 2025). This characteristic makes ADDIE flexible and adaptable to different educational contexts, particularly in the development of learning media that require alignment between learning objectives, content, and user characteristics.

In the context of educational media development, ADDIE plays an important role in ensuring that learning products are designed systematically and pedagogically sound (Uktolseja et al., 2025). The analysis stage supports the identification of learner needs and learning objectives, while the design and development stages focus on translating these needs into structured learning content and interactive media (Alfa & Astuti, 2025). The implementation and evaluation stages allow learning products to be applied in real learning environments and assessed in terms of usability and suitability (Trihantoyo et al., 2026). As a result, ADDIE is commonly applied in research and development studies related to instructional media and technology-based learning (Imam Sa'id Nurfrendi et al., 2025). The ADDIE development model is illustrated in Figure 2.1.

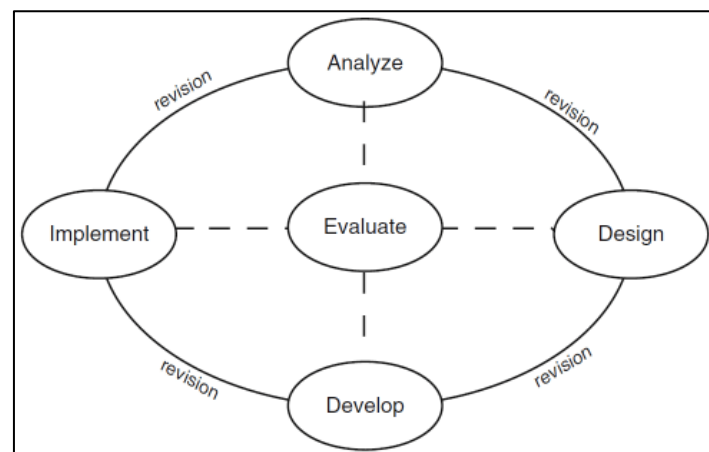


Figure 2.1 ADDIE Model Stages.

Source: (Branch, 2009)

The explanation of each stage in the ADDIE development model is presented as follows.

a. Analyze

The Analyze stage focuses on identifying learning needs, objectives, and characteristics of the target users. This stage involves examining existing problems, determining learning goals, and understanding the context in which the learning product will be used (Putri et al., 2025). The results of the analyze stage serve as the foundation for subsequent development stages.

b. Design

The design stage involves planning the structure and content of the learning product based on the results of the analyze stage. This includes defining learning objectives, selecting

appropriate learning strategies, and designing the overall layout, flow, and interaction of the learning media (Fadilla et al., 2025). The design stage aims to ensure that the product aligns with educational goals before development begins.

c. Development

The development stage is the process of producing and assembling the learning product according to the design specifications. During this stage, learning materials, media elements, and system components are created and integrated. The focus of this stage is to ensure that the product functions as intended and meets the predefined design requirements (Dwinanto et al., 2024).

d. Implementation

The implementation stage involves delivering or deploying the developed product to the intended users. During this phase, the system is introduced to the target users so that they can interact with the learning product in a real learning environment (Yusupa et al., 2025). This stage allows developers and educators to observe user interaction and identify potential issues before the evaluation stage.

e. Evaluation

The evaluation stage focuses on assessing the effectiveness and quality of the learning product. Evaluation can be conducted both during the development process (formative evaluation) and after implementation (summative evaluation) (Listiqowati et al., 2026). The results of the evaluation stage are used to identify areas for improvement and to determine whether the learning objectives have been achieved.

When compared to other development models, ADDIE demonstrates several distinguishing characteristics. The Game Development Life Cycle (GDLC), for example, is specifically designed for game production and focuses on stages such as concept development, production, testing, and release. While GDLC is effective for managing technical and production aspects of game development, it does not explicitly emphasize instructional analysis and learning objectives (Fahlefi et al., 2026). Similarly, the Waterfall model follows a linear and rigid sequence of stages, where each phase must be completed before moving to the next. Although suitable for software development with fixed requirements, the Waterfall model offers limited flexibility for revision and continuous evaluation during the development process (Kirpitsas & Pachidis, 2022).

Compared to these models, ADDIE places stronger emphasis on instructional analysis, learner-centered design, and continuous evaluation. These characteristics make ADDIE

particularly suitable for the development of educational media, where alignment between learning objectives, content, and user needs is essential. Therefore, ADDIE is widely recognized as an appropriate development model for research that focuses on the design and development of learning media and educational applications (Adelowo et al., 2024).

2.8 Black Box Testing

Black box testing is a software testing method that focuses on evaluating the functionality of a system based on predefined requirements without examining its internal structure or source code. In this approach, the tester interacts with the system by providing various input scenarios and observing the resulting outputs to determine whether the system behaves as expected (Tyanafisya et al., 2025). The main objective of black box testing is to ensure that system functions operate correctly according to user and system requirements.

This testing method emphasizes verification from the user's perspective, as it assesses how the system responds to inputs without considering how the processes are implemented internally. Black box testing is commonly used to identify functional issues such as incorrect outputs, missing features, or interface-related errors. Due to its focus on observable system behavior, this method is widely applied in testing interactive applications before they are evaluated directly by end users (Setyoko et al., 2026).

In software testing, black box testing can be contrasted with other testing approaches such as white box testing and gray box testing. White box testing examines the internal logic, structure, and source code of a system, requiring detailed knowledge of the implementation (Avdeenko & Serdyukov, 2021). Gray box testing combines aspects of both black box and white box testing by considering limited internal information while still focusing on functional behavior (Zhang et al., 2025). Compared to these approaches, black box testing does not require access to internal system details and instead prioritizes functional correctness and usability from the user's point of view (Encep et al., 2025).

Because of its emphasis on functional validation and user-oriented evaluation, black box testing is particularly suitable for verifying whether an application meets its specified requirements before proceeding to acceptance testing. This makes black box testing an important method in the development and evaluation of interactive software applications.

2.9 User Acceptance Testing (UAT)

User Acceptance Testing (UAT) is a testing method conducted to evaluate whether a system meets user needs and expectations. This testing method focuses on assessing the system from the perspective of end users by examining aspects such as usability, functionality, and overall user experience (Aliyah et al., 2024). UAT is typically performed after functional testing to ensure that the system is suitable and acceptable for actual use in real-world conditions.

Unlike technical testing methods that focus on internal system performance, UAT emphasizes user satisfaction and acceptance. Through direct interaction with the system, users provide feedback regarding ease of use, clarity of features, content suitability, and overall system comfort (Dwiyanto & Irianto, 2024). In educational applications, UAT is particularly important because the success of the system is closely related to how well users can understand, operate, and benefit from the application during learning activities (Anwary Adzirudin et al., 2025).

In software evaluation, UAT can be distinguished from other testing methods such as system testing and usability testing. System testing focuses on verifying whether the system meets specified technical and functional requirements (Agh et al., 2024). Usability testing, on the other hand, examines specific aspects of user interaction, such as interface design and navigation efficiency (Akhsin & Irianto, 2025). In contrast, UAT evaluates the system holistically from the user's perspective, focusing on whether the system is acceptable and appropriate for its intended purpose and users.

Due to its emphasis on real user interaction and acceptance, User Acceptance Testing is widely used in the evaluation of educational media and learning applications. UAT allows developers and researchers to obtain direct feedback from target users regarding the suitability of the system for learning activities (Vanesha et al., 2024). Therefore, UAT is considered an appropriate testing method for determining whether an educational application is ready for implementation and use by its intended users.

2.10 Reference Textbook (Kurikulum Merdeka)

The reference textbook used in this study is the fourth-grade elementary school mathematics textbook published by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia. This textbook is officially developed as part of the Kurikulum Merdeka and is intended to serve as a primary learning resource in mathematics

instruction at the elementary school level. As an official government-issued textbook, it is widely used in schools as a standard reference for mathematics learning.

The mathematics textbook for grade IV covers various fundamental mathematical topics appropriate to students' developmental levels, including whole numbers up to 10,000, fractions, picture and number patterns, measurement of area and volume, plane figures, and basic data representation such as pictograms and bar charts. The materials presented in the textbook are structured to support conceptual understanding and learning progression in accordance with the objectives of the Kurikulum Merdeka. Figure 2.2 shows the cover of the Grade IV Mathematics textbook used as the reference textbook in this study.

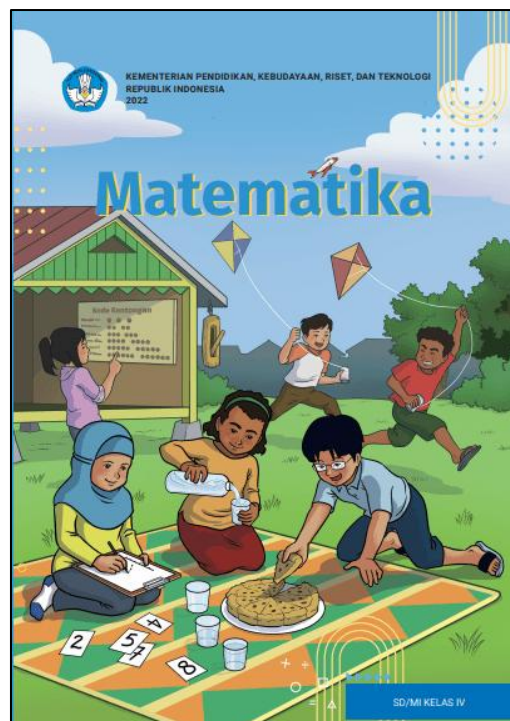


Figure 2.2 Cover of the Grade IV Mathematics Textbook (Kurikulum Merdeka).

Source: Ministry of Education, Culture, Research, and Technology (2022)

2.11 Related Works / Previous Studies

Several previous studies related to mathematics educational games and game-based learning were reviewed to identify relevant problems, development approaches, and research findings. The comparison of these studies is summarized in Table 2.1.

Table 2.1 Previous Studies.

Title	Author	Problem	Objective	Methodology	Result
Developing Educational Game of Mathematics Calculating Concept for Elementary School	(Chamsudin & Asih, 2021)	Conventional lecture-based mathematics learning makes it difficult for elementary students to understand abstract mathematical concepts.	To develop an educational mathematics game to support students' understanding of calculation concepts.	Research and Development using ADDIE with expert validation and student testing.	The developed educational game was considered valid and reliable and was accepted by students as an alternative mathematics learning medium
Development of RPG-Based Mathematics Educational Games with the Waterfall Method on Fraction Material for Elementary School Students	(Satriyo et al., 2025)	Fraction concepts are often considered difficult by elementary school students due to their abstract nature.	To develop an RPG-based mathematics educational game for fraction learning.	R&D using Waterfall with interviews, questionnaires, Blackbox Testing, and UAT.	The developed game achieved a UAT score of 90.5%, indicating high user acceptance and effectiveness in supporting fraction learning.
Designing a Learning Game for Elementary	(Wandri et al., 2024)	Mathematics is often perceived as a difficult	To design and develop a mobile-based	Game Development Life Cycle (GDLC) with	The developed mobile game functioned

School Students in Learning Mathematics using a Mobile Platform		and monotonous subject due to the lack of interactive learning media.	mathematics learning game for elementary students.	Unity 3D implementation .	properly and was suitable as an interactive mathematics learning medium.
Development of an Interactive Tiered Mobile-Based Crossword Puzzle Game to Improve Elementary School Students' Arithmetic Skills	(Taramita & Qisthiano, 2025)	Low student motivation and arithmetic ability are often caused by conventional teaching approaches.	To develop a mobile-based arithmetic crossword puzzle educational game.	R&D using ADDIE with expert validation and limited student trials.	The game obtained a feasibility score of 88.8% and was considered engaging and suitable for supporting arithmetic learning.
Development of Edugame-Based "MathQuest" Learning Media to Improve Elementary School Students'	(Putra et al., 2025)	Students experience difficulties in learning fractions due to memorization-based teaching methods.	To develop edugame-based learning media for fraction materials.	R&D using ADDIE with expert validation and student testing.	The developed media showed high validity, practicality, and effectiveness in improving students' learning outcomes.

Mathematical Skills					
Role-Playing Game (RPG): Educational Game for Learning Mathematics	(Taufik et al., 2024)	Traditional mathematics learning methods often fail to create engaging learning environments.	To develop an RPG-based mathematics educational game as an alternative learning medium.	ADDIE development model with expert validation and student evaluation.	The RPG-based educational game was considered feasible and effective in supporting students' understanding of mathematical concepts.
Game-Based Learning Experiences in Primary Mathematics Education	(Debrenti, 2024)	Mathematics learning requires engaging learning strategies to improve students' participation and understanding.	To investigate the effectiveness of game-based learning in primary mathematics education.	Quasi-experimental study comparing game-based learning experiences.	The results showed that game-based learning increased student engagement and supported better mathematical understanding.
A Digital Math Game and Multiple-Try Use with Primary	(Cubillos et al., 2024)	Students often show low motivation in mathematics	To examine the impact of a digital math game on students' motivation	Experimental study involving primary students using digital math games.	The results showed that the use of digital math games improved

Students: A Sex Analysis on Motivation and Learning		learning using traditional instructional approaches.	and learning outcomes.		students' motivation and learning performance.
Developing Adaptive Serious Games for Children With Specific Learning Difficulties	(Yildirim & Surer, 2021)	Children with learning difficulties require adaptive learning tools to support their educational needs.	To develop serious games with adaptive difficulty systems for learning support.	Two-phase study with usability testing, System Usability Scale (SUS), and Technology Acceptance Model (TAM).	The developed serious games received positive feedback from both educators and students, demonstrating good usability and acceptance.

Previous studies on mathematics educational games generally demonstrate the positive potential of game-based learning in supporting mathematics education at the elementary school level. However, these studies differ in terms of their objectives, gameplay approaches, and evaluation focus.

Several studies focused primarily on the development and feasibility of mathematics educational games as learning media. Chamsudin & Asih (2021), Wandri et al. (2024), Taramita & Qisthiano (2025), and Putra et al. (2025) developed educational games or interactive mathematics learning media using approaches such as ADDIE and GDLC. These studies consistently reported positive findings related to validity, usability, and student acceptance, suggesting that educational games can function as feasible and engaging learning tools. Nevertheless, their primary focus remained on media development and implementation feasibility.

Some studies specifically incorporated RPG elements into mathematics learning. Satriyo et al. (2025) and Taufik et al. (2024) developed RPG-based mathematics educational games and reported positive outcomes in terms of engagement and user acceptance. Compared with

non-RPG educational games, these studies introduced more interactive and immersive learning environments through role-playing mechanics. However, their implementations mainly focused on content delivery and general game feasibility.

In contrast, other studies emphasized the educational effectiveness of game-based learning. Debreñti (2024) and Cubillos et al. (2024) examined how game-based learning environments influence student motivation and learning outcomes through experimental approaches. Their findings showed that mathematics games may increase engagement, motivation, and conceptual understanding, supporting the broader educational value of game-based learning.

Furthermore, Yildirim & Surer (2021) highlighted the importance of adaptive gameplay through the development of adaptive serious games. Unlike most previous studies that focused on general educational games, this study emphasized adaptive systems and usability to support learners with different educational needs.

Based on the reviewed studies, it can be concluded that educational game-based learning media have significant potential to support mathematics learning at the elementary school level. Previous research has demonstrated that educational games can enhance student engagement, improve conceptual understanding, and provide more interactive learning experiences. Various types of educational games have been developed, including mobile-based learning games, puzzle-based games, and digital game-based learning environments.

However, most previous studies primarily focus on the development and feasibility evaluation of educational games, including expert validation, usability testing, and user acceptance measurement. While these studies confirm that educational games are generally well received and feasible for instructional use, they often treat gameplay as a medium for content delivery rather than as a structured learning interaction system.

More specifically, relatively few studies explicitly examine how specific gameplay mechanics such as turn-based interaction systems, progression flow, difficulty scaling, and feedback mechanisms can be systematically designed to support students' learning interest and motivation in mathematics learning activities. In many existing studies, gameplay mechanics are implemented only as supporting features, without a detailed explanation of how turn-based interaction structures influence students' engagement during learning processes.

In addition, most previous studies in mathematics educational games are designed for elementary school students in general without considering the specific cognitive and learning characteristics of particular grade levels. Limited research has focused on the design of

educational games specifically tailored to fourth-grade elementary school students, despite the importance of aligning game difficulty, content scope, and interaction design with students' developmental stage.

Therefore, this study addresses this gap by developing a turn-based mathematics educational game in which learning activities are embedded directly into the core interaction system, aiming to provide a structured learning experience where students continuously engage in problem-solving through game progression. In this design, students solve mathematics problems to perform actions within a turn-based system, making problem-solving an integral part of gameplay progression and learning flow. The game also incorporates structured features such as wave-based challenge progression, difficulty adjustment, and immediate feedback to support student engagement and learning motivation.

Unlike previous studies that primarily evaluate educational games based on feasibility, usability, or general effectiveness, this research emphasizes the role of turn-based interaction design as a structured learning mechanism to support student engagement and motivation in elementary mathematics learning, specifically targeting fourth-grade elementary school students.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research Methodology

In this study, a Research and Development (R&D) approach is employed to design and develop an interactive educational mathematics game for fourth-grade elementary school students. The purpose of this approach is to produce a functional learning media that can support students' learning interest and motivation through an engaging game-based environment.

The development process follows the ADDIE model, which consists of five main phases: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). This model is selected because it provides a systematic and structured framework for developing educational media, ensuring that the final product aligns with user needs, learning objectives, and system functionality. This approach ensures both pedagogical relevance and technical feasibility of the developed system. During the development process, each phase of the ADDIE model is carried out sequentially while allowing iterative refinement, particularly in the design and development stages. The analysis phase focuses on identifying user needs and learning problems, the design phase focuses on planning the game structure and learning content, the development phase involves implementing the system using appropriate tools, the implementation phase delivers the application to users, and the evaluation phase assesses the usability and acceptance of the developed game. To provide a clear overview of the research process, the overall methodology applied in this study is illustrated in Figure 3.1.

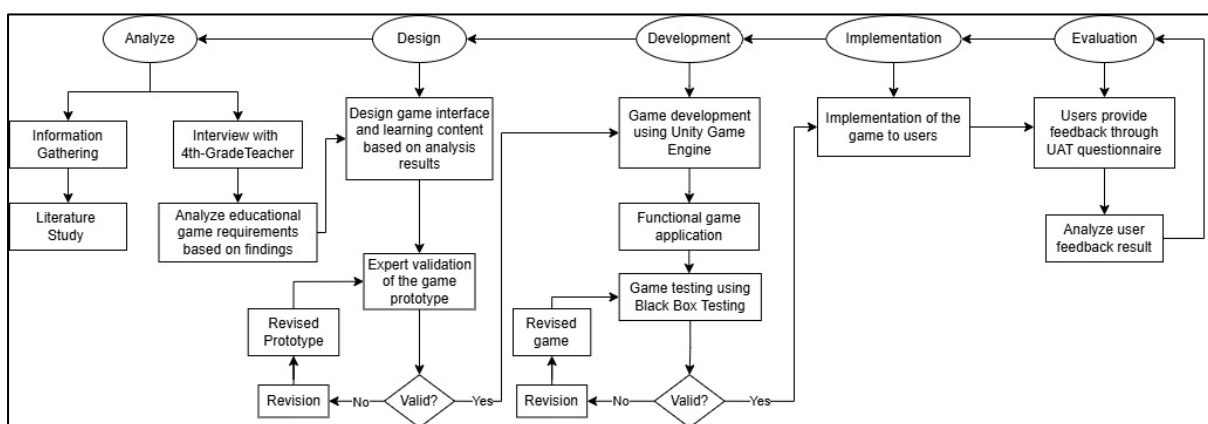


Figure 3.1 Research Methodology Based on the ADDIE Model.

Figure 3.1 illustrates the overall research methodology based on the ADDIE model. The process begins with the analysis phase, which involves gathering information through literature

study and interviews to identify user needs and learning problems. In the design phase, the game interface and learning content are planned based on the analysis results and validated by an expert to ensure their suitability for fourth-grade elementary school students and alignment with learning objectives. The development phase involves implementing the game into a functional application, followed by system testing to ensure proper functionality. The implementation phase introduces the developed game to the target users, allowing them to interact with the application. Finally, the evaluation phase collects and analyzes user feedback through User Acceptance Testing (UAT) to determine the acceptance and feasibility of the developed game.

3.2 Research Procedure

The research procedure in this study follows the ADDIE model, which consists of five main phases: Analysis, Design, Development, Implementation, and Evaluation. Each phase is conducted systematically to ensure that the developed educational game meets both learning objectives and user requirements. The detailed explanation of each phase is presented as follows.

3.2.1 Analysis

The analysis phase aims to identify the needs, characteristics, and learning challenges of the target users. This stage serves as the foundation for the development of the educational game, ensuring that the designed system aligns with students' learning conditions and curriculum requirements.

In this study, the analysis phase focuses on collecting information related to students' difficulties in mathematics learning, current teaching methods, and the potential use of educational games as a learning medium. The results obtained from this phase are used to determine the game concept, learning content, and gameplay design.

Data collection in the analysis phase was conducted through interviews. Prior to conducting the interview, formal permission was obtained from the school to ensure that the research activities were carried out appropriately. The interview was conducted with a fourth-grade elementary school teacher at SD Negeri Ngemplak 2 to obtain in-depth information regarding students' learning conditions, difficulties in understanding mathematical concepts, and expectations toward the use of educational games in the learning process.

The teacher was selected as the primary interview source because the teacher directly observes and understands classroom learning conditions, students' learning difficulties, engagement levels, and learning behaviors during mathematics lessons. In addition, the

interviewed teacher was the only fourth-grade teacher responsible for mathematics instruction at SD Negeri Ngemplak 2 and was selected as the source of information because the school served as the implementation site of this study. Therefore, the information obtained was considered relevant to the target users and learning context of the developed game.

The interview aimed to explore several key aspects, including teaching methods, learning media, student engagement, difficult learning materials, and the potential implementation of digital learning tools. The information obtained from the interview was used as a reference in designing the educational game, particularly in determining the learning content, gameplay mechanics, and visual design elements to ensure that the game is appropriate and relevant to students' needs.

Student surveys and classroom observations were not conducted during the analysis phase. Teacher interviews were considered more appropriate and efficient for the initial needs analysis because teachers possess broader and more consistent observations across multiple students and classroom situations. In addition, collecting individual responses from elementary school students would require additional time, communication approaches, and procedures due to variations in students' ability to express their learning experiences clearly. Nevertheless, since the needs analysis relied on information obtained from a single teacher within one school context, the findings primarily represent the learning conditions and instructional context of SD Negeri Ngemplak 2 and may not be generalized to broader student populations. The list of interview questions used in this study is presented in Table 3.1.

Table 3.1 Interview Questions.

No.	Questions
1	How do you usually teach mathematics in fourth-grade classes?
2	What learning media have been used so far in mathematics lessons?
3	Do students show enthusiasm when learning mathematics? If not, what are the main obstacles?
4	Which mathematics topics are most difficult for fourth-grade students to understand?
5	What factors contribute to students' difficulties in understanding these topics?
6	How do you usually address students who have difficulty understanding mathematics lessons?
7	Have you ever used digital media (such as videos, applications, or games) in teaching mathematics? If yes, how effective was it?
8	What is your opinion on the use of educational games as a medium for mathematics learning?
9	In your opinion, are fourth-grade students ready to use educational games as part of the learning process?

10	What features do you think should be included in a mathematics educational game?
11	Do you prefer educational games that are played independently by students or guided by the teacher in class?

3.2.2 Design

The design phase focuses on transforming the results obtained from the analysis phase into a structured plan for developing the educational game. This stage aims to define the overall system design, including the learning content, user interface, and system structure, before proceeding to the implementation stage. The design is carried out to ensure that the developed application is aligned with user needs, learning objectives, and the characteristics of fourth-grade elementary school students.

In this study, the design phase consists of three main components: learning content design, interface design, and system design using the HIPO diagram. The learning content design focuses on preparing mathematical materials and questions based on the elementary school curriculum and the findings from the analysis phase. The interface design involves creating wireframes that represent the initial layout, navigation structure, and user interaction within the game. These wireframes serve as a guideline for the development process. Meanwhile, the HIPO diagram is used to describe the system structure and illustrate the relationship between input, process, and output within the application. Through this design phase, a clear and systematic blueprint of the educational game is established, which will guide the implementation process in the development stage.

Prior to the development phase, the proposed design was reviewed and validated by the same fourth-grade teacher involved in the analysis phase, who served as the expert validator in this study. The teacher was selected as the validator due to direct involvement in mathematics instruction and familiarity with students' learning characteristics and classroom conditions at SD Negeri Ngemplak 2, which also served as the implementation site of this study. The validation aimed to ensure that the proposed design was suitable for fourth-grade elementary school students and aligned with learning objectives. The review focused on several aspects, including the suitability of mathematics materials with the Grade IV curriculum, the appropriateness of visual design and characters, the clarity of interface layout and navigation, and the suitability of gameplay concepts to support students' engagement and learning experience. Feedback obtained from this validation process was used as a reference for refining the design before proceeding to the development stage.

A. Learning Content Design

The learning content in this study is developed based on the fourth-grade elementary school mathematics curriculum, specifically referring to the student textbook from the Merdeka Curriculum issued by the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek). The questions are organized according to six main chapters taught at this level and are designed to align with the learning objectives of each chapter to ensure that the content supports the intended educational outcomes.

The question set consists of approximately 600 multiple-choice questions, each with four answer options. The questions are distributed across multiple levels, where each level contains 100 questions. These questions are categorized into three levels of difficulty: easy, medium, and hard. The distribution within each level includes 45 easy questions, 30 medium questions, and 25 hard questions. The classification of difficulty levels is based on the concept of Higher-Order Thinking Skills (HOTS), where the questions are structured progressively from lower-order to higher-order thinking levels. In addition, some questions are presented with visual elements, such as images, to support students' understanding and enhance engagement.

The development of the questions involved an AI-assisted drafting process using Gemini as a supporting tool. The Grade IV mathematics textbook and the learning objectives of each chapter were used as the primary references during question development. The researcher first identified the relevant materials and learning objectives from the textbook and then used prompts in Gemini to generate draft questions aligned with the selected topics and intended learning outcomes. The use of AI in this study was intended to support the initial drafting process rather than replace curriculum-based instructional design. AI-generated questions were not used directly without review but instead served as draft materials requiring further refinement and validation.

The question development process involved two stages of review. The first stage was conducted by the researcher as the game developer and content author through an iterative prompt–reprompt and self-review process. Questions considered unclear, linguistically difficult, or insufficiently aligned with the intended material were revised through additional prompting and refinement. This process focused on improving question clarity, language appropriateness, and alignment with the learning objectives of each chapter.

The second stage involved validation by the fourth-grade elementary school teacher involved in the analysis phase. The teacher reviewed the questions to evaluate their suitability with the curriculum, students' learning levels, and classroom learning conditions. Validation

and consultation were conducted through WhatsApp communication due to accessibility and scheduling considerations, allowing the researcher and teacher to discuss, review, and revise the questions efficiently throughout the development process.

The learning content is integrated into the gameplay mechanics, where players must answer the questions correctly in order to perform actions and progress within the game. This integration aims to create an interactive learning experience that combines educational content with game-based engagement.

B. Interface Design

The interface design in this study is developed to be simple, intuitive, and suitable for fourth-grade elementary school students. The design emphasizes ease of use by applying clear layouts and straightforward navigation to ensure that users can interact with the system without difficulty. The interface is designed using Figma to produce wireframes that represent the initial layout and structure of the application. These wireframes serve as a guideline for the development process before implementation. Each interface design is validated by a teacher to obtain feedback and suggestions for improvement. This validation process aims to ensure that the design is appropriate and aligned with the characteristics of elementary school students.

The designed interfaces include the main menu, settings, tutorial, level selection, character selection, gameplay, pause menu, and result screens (victory and defeat), all of which are arranged to support usability and consistency within the game.

a. Main Menu Interface

The main menu interface is the first screen displayed when the game starts. This screen presents the game title “*Petualangan Ksatria*” along with several main menu options. On this interface, there are three main buttons: Play, Exit, and Settings. The Play button directs the player to tutorial interface. The Exit button is used to close the game. Meanwhile, the Settings button allows users to access game configuration options. The detailed appearance of the main menu interface is shown in Figure 3.2.

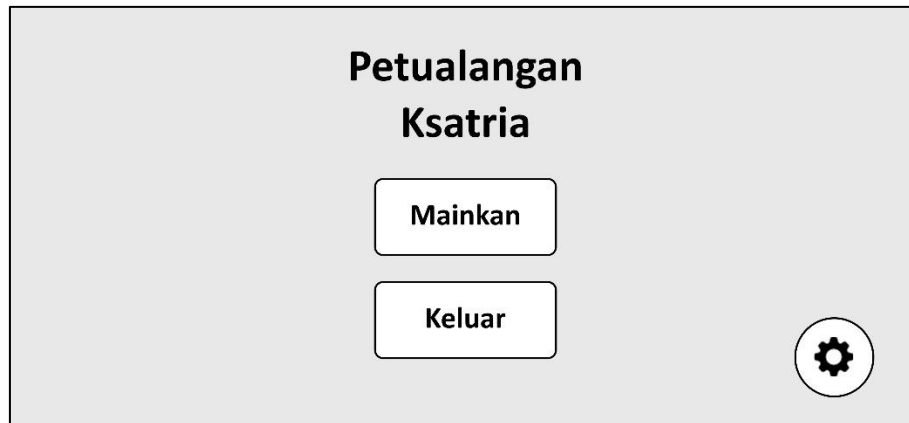


Figure 3.2 Main Menu.

b. Settings Interface

The settings interface is displayed when the user selects the settings option from the main menu. This screen allows players to adjust audio preferences according to their needs. In this interface, there are two sliders used to control the volume of background music and sound effects. These controls enable players to customize the audio level to create a more comfortable gaming experience. Additionally, a Back button is provided to return to the main menu. The detailed appearance of the settings interface is shown in Figure 3.3.

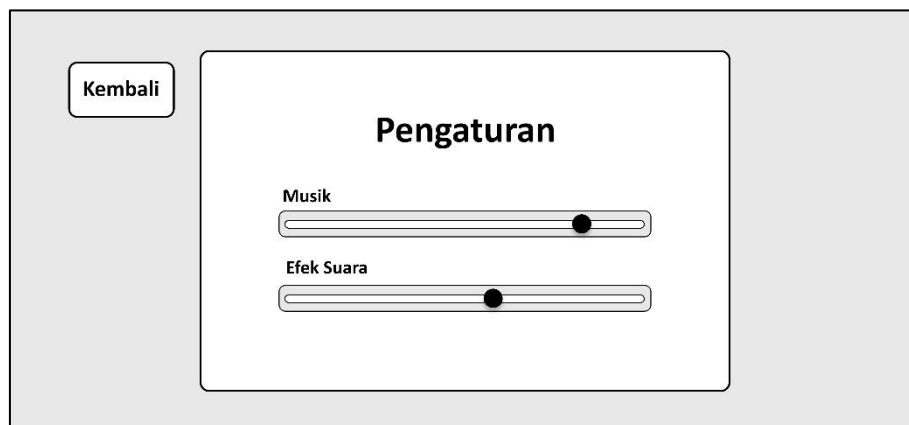


Figure 3.3 Settings.

c. Tutorial Interface

The tutorial interface is displayed before the gameplay begins to introduce players to the game mechanics. This screen contains a video player that explains how the gameplay mechanics work. Several control buttons are provided, including a Play button to start the video, a Replay button to restart the tutorial from the beginning, and a Next button to proceed to the level selection screen.

The placement of the tutorial at this stage is intended to ensure that players understand the gameplay mechanics before starting the game, thereby reducing confusion during gameplay. The detailed appearance of the tutorial interface is shown in Figure 3.4.

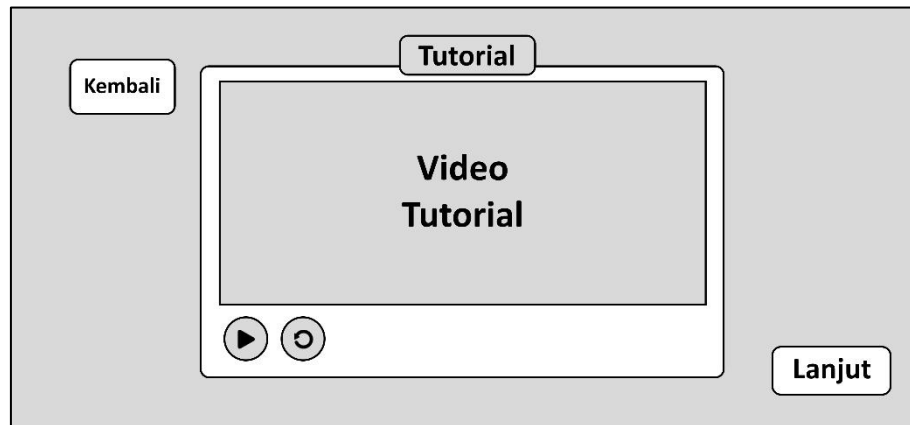


Figure 3.4 Tutorial.

d. Level Select Interface

The level selection interface is displayed after the tutorial and allows players to choose the level they want to play at. This screen contains six level buttons representing different stages in the game. At the beginning of the game, only the first level is available. The remaining levels are locked and can be accessed only after the player successfully completes the previous level.

In addition, a Reset button is provided to reset the player's progress, allowing all levels to return to their initial locked state. The detailed appearance of the level selection interface is shown in Figure 3.5.

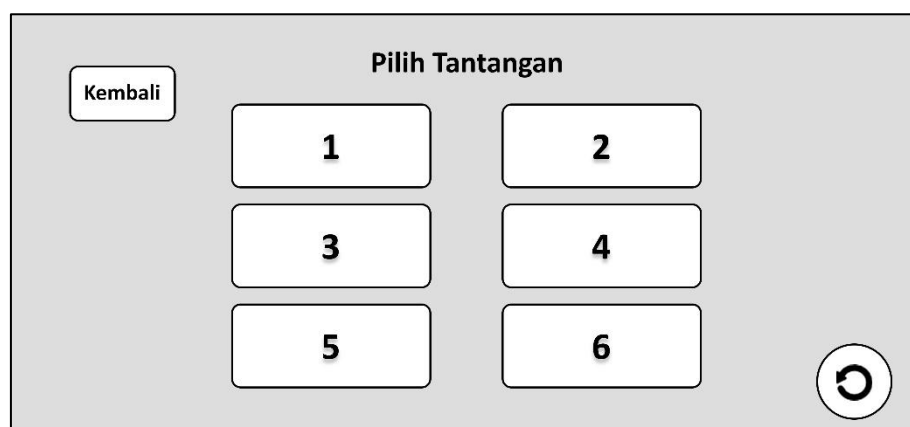


Figure 3.5 Level Select.

e. Character Select Interface

The character selection interface is displayed after the player selects a level. This screen allows players to choose a character before starting the game. In this interface, two character options are available, each accompanied by a name and visual representation to help users easily recognize their selection. The detailed appearance of the character selection interface is shown in Figure 3.6.

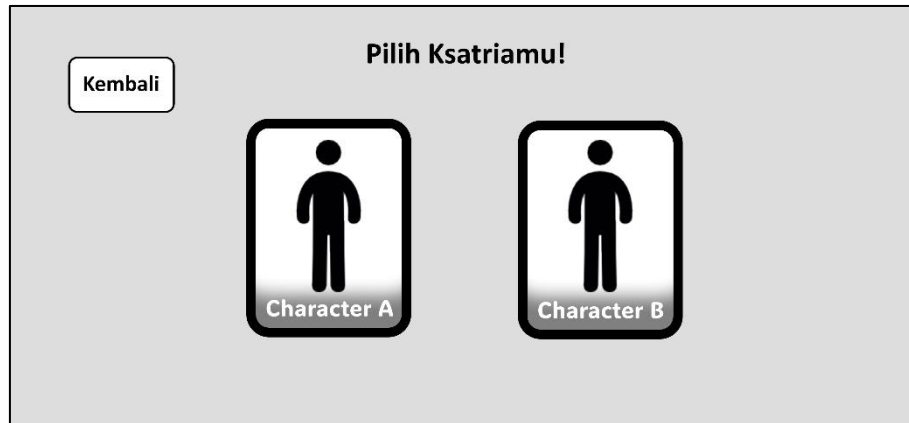


Figure 3.6 Character Select.

f. Gameplay Interface

The gameplay interface is displayed when the player starts the game after selecting a character. This screen represents the main interaction area where the game is played. In this interface, two characters are presented, namely the player and the enemy. Below each character, a Heads-Up Display (HUD) is provided, showing the character's name, health bar, and remaining HP value. The interface also includes three action buttons, each representing different types of attacks with varying damage levels. Additionally, a wave counter is displayed to indicate the current wave. A Pause button is also available, allowing players to temporarily stop the game and access the pause menu. Furthermore, a dialogue box is located at the bottom-right corner of the screen, which displays text feedback related to the player's actions, such as whether an action is successful or not. This feature helps players understand the outcome of their actions during gameplay. The detailed appearance of the gameplay interface is shown in Figure 3.7.

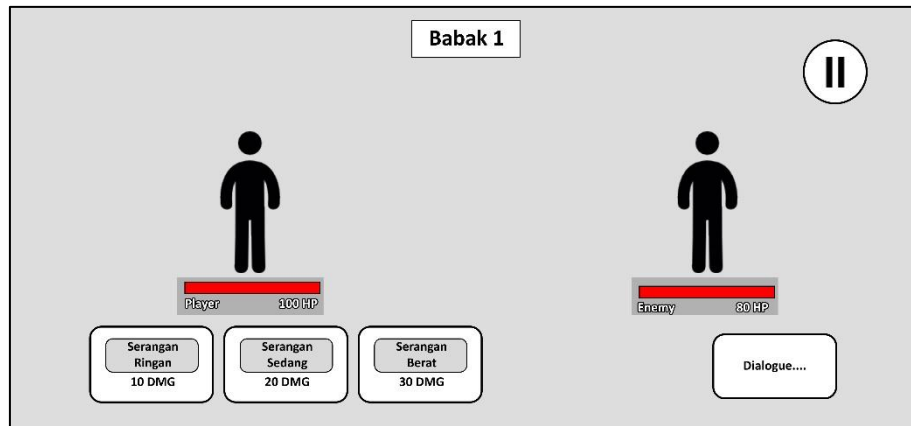


Figure 3.7 Gameplay.

g. Quiz Interface

The quiz interface is displayed when the player selects an action during gameplay. This screen presents a question that must be answered before the action is executed. The question is shown in text form, and in some cases, it is accompanied by an image to support understanding. Four answer options are provided as buttons for the player to choose from. In addition, a timer is displayed at the top of the screen to limit the time available for answering. This interface is designed to integrate learning activities into the gameplay, requiring players to answer correctly in order to perform actions. The detailed appearance of the quiz interface is shown in Figure 3.8.

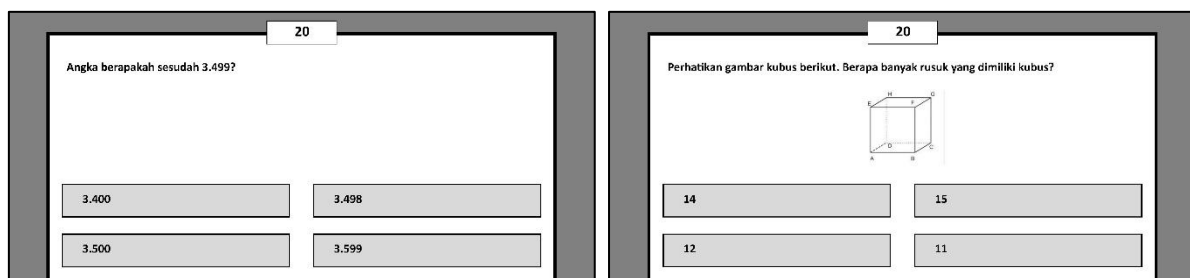


Figure 3.8 (a) Quiz (b) Quiz with image.

h. Pause Interface

The pause interface is displayed when the player presses the pause button during gameplay. This screen allows players to temporarily stop the game and access several additional options. In this interface, four main buttons are provided. The Home button is used to return to the main menu, the Restart button allows the player to restart the current level from the beginning, the Settings button provides access to the settings menu, and the Play button is used to resume the game. The detailed appearance of the pause interface is shown in Figure 3.9.

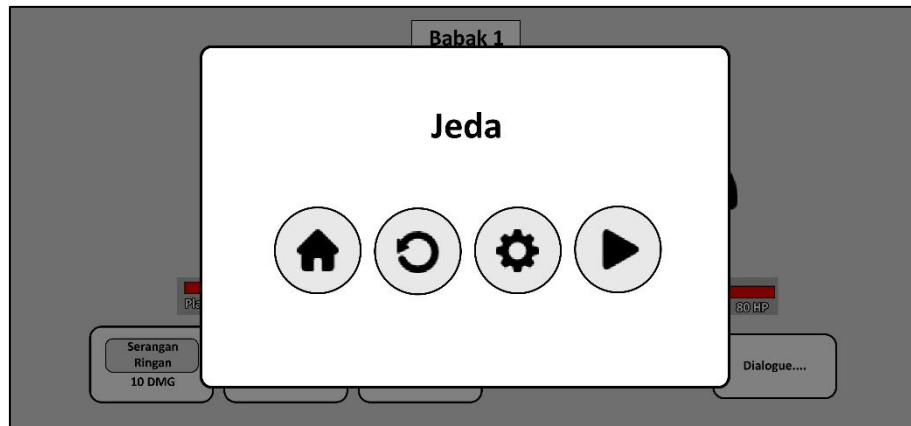


Figure 3.9 Pause Menu.

i. Victory and Defeat Interface

The victory interface is displayed when the player successfully completes a level. This screen provides feedback indicating that the player has won the game. In this interface, three main buttons are available: a button to return to the level selection screen, a Restart button to replay the current level, and a Next Level button to proceed to the next level.

On the other hand, the defeat interface appears when the player fails to complete the level. This screen provides feedback encouraging the player to try again. Two main buttons are available: a button to return to the level selection screen and a Restart button to restart the level from the beginning. The detailed appearance of the victory and defeat interfaces is shown in Figure 3.10.

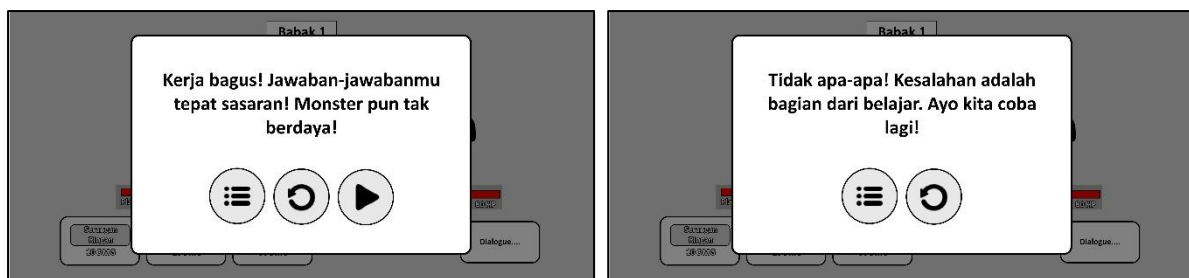


Figure 3.10 (a) Victory (b) Defeat.

C. HIPO Diagram

The HIPO (Hierarchy plus Input-Process-Output) diagram is used in this study to describe the structure and functionality of the developed system in a hierarchical manner. This diagram helps illustrate how each component of the game is organized and how the overall system is structured, making it easier to understand the relationship between different modules within the application.

a. Visual Table of Content (VTOC)

The Visual Table of Content (VTOC) diagram presents a hierarchical representation of the system structure, showing the main components and their relationships. It provides an overview of how the game is organized, starting from the main menu and branching into several functional modules such as tutorial, settings, level selection, character selection, and gameplay. Furthermore, the gameplay module is divided into several sub-components, including quiz interaction, pause functionality, and game outcomes such as victory and defeat. This hierarchical structure helps to clearly illustrate the flow and organization of the system, ensuring that each component is well-defined and logically connected. The VTOC diagram used in this study is shown in Figure 3.11.

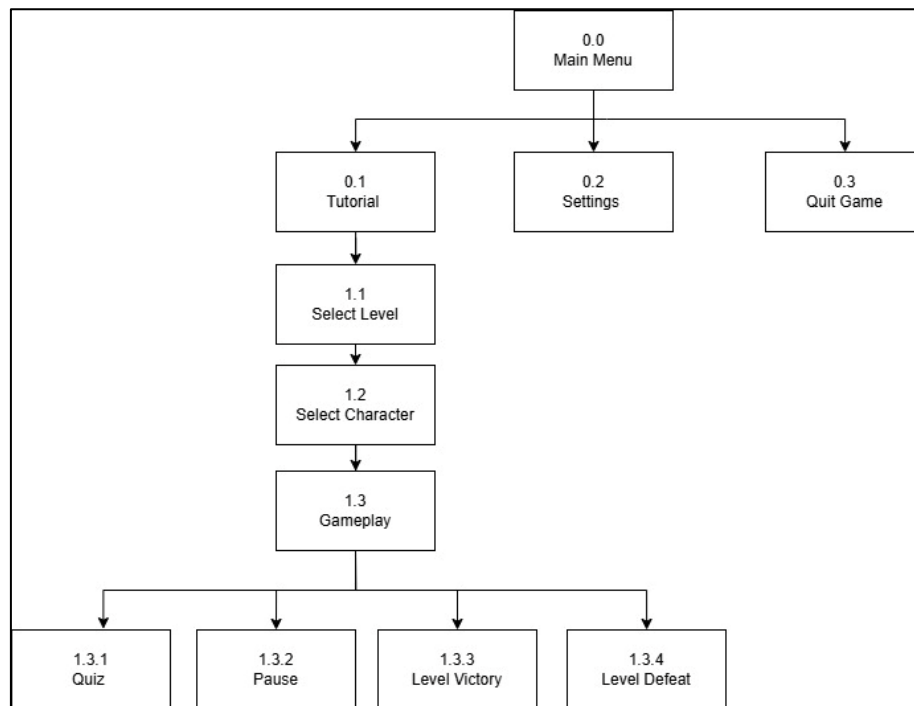


Figure 3.11 Visual Table of Content (VTOC) Diagram.

The following explanation describes each module presented in the VTOC diagram:

12. Main Menu (0.0): The Main Menu serves as the initial interface displayed when the game is launched. This menu provides access to the main features of the game, including the tutorial, settings, and exit options.
13. Tutorial (0.1): The Tutorial menu provides guidance to players regarding the gameplay mechanics. It presents instructional content in the form of a video tutorial to help users understand how to play the game before starting.

14. Settings (0.2): The Settings menu allows players to adjust audio preferences, including background music and sound effects, according to their individual preferences.
15. Quit Game (0.3): The Quit Game menu enables users to exit the game application.
16. Select Level (1.1): The Select Level menu allows players to choose the level they want to play. Initially, only the first level is unlocked, while subsequent levels are unlocked progressively after completing previous levels.
17. Select Character (1.2): The Select Character menu allows players to choose a character before entering the gameplay. Each character is visually represented to assist users in making their selection.
18. Gameplay (1.3): The Gameplay module represents the core part of the game where the player interacts with the system. In this stage, players engage in turn-based battles by selecting actions that trigger quiz questions.
19. Quiz (1.3.1): The Quiz module appears when the player selects an action. It presents a question in the form of text or images along with multiple-choice answers. The player must answer correctly to execute the selected action.
20. Pause (1.3.2): The Pause menu allows players to temporarily stop the game. It provides options such as resume, restart, access settings, or return to the main menu.
21. Level Victory (1.3.3): The Level Victory screen is displayed when the player successfully completes a level. It provides options to proceed to the next level, restart the current level, or return to level selection.
22. Level Defeat (1.3.4): The Level Defeat screen appears when the player fails to complete a level. It provides options to retry the level or return to the level selection menu.

This hierarchical representation provides a clear understanding of the system structure and supports the design and development of the educational game.

b. Overview

The Overview diagram is used to describe the functional behavior of each module in the system based on the Input-Process-Output (IPO) concept. This diagram provides a more detailed explanation of how the system operates by illustrating how user inputs are processed by the system to produce specific outputs.

In this study, the overview diagram focuses on the main modules of the educational game, including the main menu, level selection, character selection, gameplay, and supporting

features such as quiz interaction, pause functionality, and game outcomes. Each module is described in terms of its input, process, and output to provide a clear understanding of how user interactions influence the system behavior. By using the overview diagram, the system functionality can be systematically analyzed, ensuring that each module operates according to the intended design and supports the overall gameplay experience. The overview diagrams for each game module are presented in Table 3.2-Table 3.11.

Table 3.2 Overview Diagram Main Menu Module.

Module	Page	Input	Process	Output
Main Menu	Main Menu	Play button clicked	Navigate to tutorial interface	Tutorial screen displayed
	Main Menu	Settings button clicked	Navigate to settings interface	Settings menu displayed
	Main Menu	Exit button clicked	Open exit confirmation dialog	Exit confirmation dialog displayed

Table 3.3 Overview Diagram Settings Module.

Module	Page	Input	Process	Output
Settings	Settings Menu	Adjust music slider	Update background music volume	Music volume changes
	Settings Menu	Adjust SFX slider	Update sound effect volume	Sound effect volume changes
	Settings Menu	Back button clicked	Return to main menu	Main menu displayed

Table 3.4 Overview Diagram Quit Game Module.

Module	Page	Input	Process	Output
Quit Game	Confirmation Dialog	Yes button clicked	Close application	Application terminated
	Confirmation Dialog	No button clicked	Return to main menu	Main menu displayed

Table 3.5 Overview Diagram Tutorial Module.

Module	Page	Input	Process	Output
Tutorial	Tutorial Screen	Play button clicked	Play tutorial video	Video starts playing
	Tutorial Screen	Restart button clicked	Replay tutorial video	Video restarts
	Tutorial Screen	Continue button clicked	Navigate to level selection	Level selection screen displayed
	Tutorial Screen	Back button clicked	Return to main menu	Main menu displayed

Table 3.6 Overview Diagram Level Select Module.

Module	Page	Input	Process	Output
Level Select	Select Level	Level button clicked	Navigate to character selection	Character selection screen displayed
	Select Level	Reset button clicked	Open reset confirmation dialog	Reset confirmation displayed
	Select Level	Back button clicked	Return to main menu	Main menu displayed

Table 3.7 Overview Diagram Character Select Module.

Module	Page	Input	Process	Output
Character Select	Character Screen	Character selected	Store selected character and start game	Gameplay screen displayed with corresponded character
	Character Screen	Back button clicked	Return to level selection	Level selection screen displayed

Table 3.8 Overview Diagram Gameplay Module.

Module	Page	Input	Process	Output
Gameplay	Gameplay Screen	Action button clicked	Trigger quiz with timer	Quiz interface displayed
	Gameplay Screen	Pause button clicked	Pause game and open menu	Pause menu displayed
	Gameplay Screen	Enemy HP reaches 0	Trigger victory condition	Victory screen displayed
	Gameplay Screen	Player HP reaches 0	Trigger defeat condition	Defeat screen displayed

Table 3.9 Overview Diagram Quiz Module.

Module	Page	Input	Process	Output
Quiz	Quiz Screen	Correct answer selected	Validate answer and execute attack	Enemy HP decreases
	Quiz Screen	Wrong answer selected	Trigger enemy counterattack	Player HP decreases
	Quiz Screen	Timer runs out	Trigger enemy counterattack	Player HP decreases

Table 3.10 Overview Diagram Pause Module.

Module	Page	Input	Process	Output
Pause Menu	Pause Screen	Resume button clicked	Close pause menu	Gameplay resumes
	Pause Screen	Restart button clicked	Open restart confirmation dialog	Restart confirmation displayed
	Pause Screen	Home button clicked	Open home confirmation dialog	Home confirmation displayed
	Pause Screen	Settings button clicked	Open settings menu	Settings menu displayed

Table 3.11 Overview Diagram Result Module (Victory & Defeat).

Module	Page	Input	Process	Output
Victory	Victory Screen	Next button clicked	Load next level	Next level displayed
	Victory Screen	Restart button clicked	Restart current level	Gameplay restarted
	Victory Screen	Level button clicked	Return to level selection	Level selection displayed
Defeat	Defeat Screen	Retry button clicked	Restart level	Gameplay restarted
	Defeat Screen	Level button clicked	Return to level selection	Level selection displayed

3.2.3 Development

The development phase focuses on transforming the validated design from the design stage into a concrete and functional educational game application. At this stage, all design components, including game mechanics, user interface, and learning content, are implemented based on the approved design specifications.

The development process is carried out using the Unity game engine as the primary development tool. Unity is utilized to integrate various game elements such as user interface layouts, character assets, sound effects, gameplay logic, and question systems into a cohesive and interactive application. All features are developed in accordance with the design results to ensure consistency between the planned system and the implemented application.

During the development process, functional testing is conducted using the black-box testing approach to verify that each feature operates according to its intended functionality. This testing ensures that all user interactions, system processes, and outputs are aligned with the predefined system requirements before the application proceeds to the implementation stage. The result of this phase is a fully functional educational game application that is ready to be deployed and evaluated by the target users in the implementation phase.

3.2.4 Implementation

At the implementation stage, the developed application is delivered as a complete educational game and introduced to the intended users. This phase involves the direct use of the game by fourth-grade elementary school students and their teacher, enabling them to interact with the system within an actual learning environment. During this stage, several aspects are observed, including usability, visual design, system functionality, and the feasibility

of the game as an alternative medium for learning mathematics. The main objective of this phase is to provide users with hands-on experience while collecting initial feedback to support the evaluation stage, ensuring that the developed game meets its educational and interactive goals.

The implementation was carried out at SD Negeri Ngemplak 2, a public elementary school located in Sleman, Special Region of Yogyakarta, Indonesia. The participants consisted of 31 fourth-grade students and one mathematics teacher. A convenience sampling technique was applied, considering the availability and willingness of the school to participate in the study. This sampling approach was selected because the school served as the implementation site and provided practical access to the target users during the development study. Prior to the implementation, permission was obtained from the school authorities. The activity was conducted during a mathematics lesson, where students were first given guided instructions on how to use the game. Afterward, they were allowed to explore the game independently before completing the evaluation questionnaire.

3.2.5 Evaluation

The evaluation phase represents the final stage of the ADDIE model and aims to assess whether the developed educational game meets the intended learning objectives and user requirements. In this study, the evaluation is conducted using the User Acceptance Testing (UAT) method, which focuses on measuring user acceptance and overall satisfaction with the developed application. This phase involves 31 fourth-grade elementary school students and a mathematics teacher as the respondents, allowing the evaluation to capture both user experience and pedagogical perspectives. The evaluation is conducted using a questionnaire to collect feedback regarding usability, learning experience, and the effectiveness of the game as a learning medium.

The results obtained from this evaluation are used to measure user acceptance of the developed application, as well as to assess whether the game meets user expectations and contributes to supporting students' interest and motivation in learning mathematics.

3.3 Testing Method

3.3.1 Black box testing

Black-box testing is a software testing method that focuses on evaluating the functionality of a system based on its input and output without considering the internal structure or source

code of the application. This method is used to ensure that each feature of the developed system operates according to the predefined specifications and requirements.

In this study, black-box testing is conducted during the development phase to verify that all game functionalities, including navigation, user interactions, and system responses, work correctly. The testing process involves providing specific inputs to the system and observing the resulting outputs to determine whether they match the expected results. The components tested in this study include the main menu, settings, tutorial, level selection, character selection, gameplay, quiz interaction, pause menu, and game result interfaces. Each function is tested to ensure that it performs as intended and does not produce errors during operation. The results of the black-box testing are used to confirm that the developed educational game meets the functional requirements and is ready to proceed to the implementation stage.

3.3.2 User Acceptance Testing (UAT)

User Acceptance Testing (UAT) is a testing method used to evaluate the developed system from the users' perspective by measuring its suitability, usability, and overall acceptance. Unlike technical testing that focuses on system functionality, UAT emphasizes how well the application meets user needs and expectations in real usage scenarios.

In this study, UAT is conducted to assess the feasibility of the developed educational game as an alternative learning medium for fourth-grade elementary school students. The evaluation focuses on measuring whether the game aligns with user expectations and can support students' learning interest and motivation in mathematics learning.

The UAT process involves two types of respondents, namely fourth-grade elementary school students and a mathematics teacher. The inclusion of both groups aims to capture different perspectives, where students represent user experience and engagement, while the teacher represents pedagogical relevance and curriculum alignment.

Data collection is carried out using a structured questionnaire based on a Likert scale consisting of five levels. Each level represents the degree of agreement toward the given statements, ranging from "Strongly Disagree" to "Strongly Agree." The assessment scale used in this study is presented in Table 3.12.

Table 3.12 User Acceptance Testing Assessment Scale.

Score	Description
5	Strongly Agree
4	Agree

3	Neutral
2	Disagree
1	Strongly Disagree

The UAT instrument is divided into two different forms to accommodate the perspectives of both students and the teacher. The student questionnaire is designed to evaluate aspects related to user experience, such as learning interest, motivation, ease of use, enjoyment, and clarity of visual elements and instructions. The list of questions used in the student UAT is presented in Table 3.13.

Table 3.13 UAT Questionnaire for Students.

Indicator	No.	Question	1	2	3	4	5
Interest	1	Do you feel happy learning mathematics using this game?					
	2	Does this game make mathematics lessons feel more interesting?					
Learning Motivation	3	Does this game make you more enthusiastic about learning mathematics?					
	4	Do you want to play this game again to learn mathematics?					
Ease of Use	5	Is this game easy to play?					
	6	Do you have any difficulty using the buttons and menus in the game?					
Enjoyment	7	Do you feel happy while playing this game?					
	8	Is learning mathematics with this game not boring?					
Visual & Instruction Clarity	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							

Meanwhile, the teacher questionnaire is designed to evaluate the application from a pedagogical perspective. This includes assessing the suitability of the content with the curriculum, feasibility as a learning medium, ease of implementation in classroom settings, and its effectiveness in supporting mathematics learning. The teacher UAT instrument is presented in Table 3.14.

Table 3.14 UAT Questionnaire for Teacher.

Indicator	No.	Question	1	2	3	4	5
Curriculum Suitability	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?					
Media Feasibility	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?					
Ease of Implementation	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?					
Interest & Motivation Potential	7	Can this game increase students' interest in learning mathematics?					
	8	Can this game motivate students to be more active in learning mathematics?					
Visual & Interactivity	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							

Prior to its use during the implementation stage, the UAT instrument underwent a validation process. The UAT instrument used in this study was developed specifically to align with the research objectives and intended evaluation outcomes. Therefore, each questionnaire item was designed to evaluate aspects directly related to the developed educational game and the purpose of the study. The questionnaire was reviewed by the research supervisor and a fourth-grade elementary school teacher through qualitative content validation to ensure that the items were relevant to the research objectives, appropriately constructed, and understandable for the target users. This validation process also aimed to confirm that elementary school students would be able to comprehend and respond to the questionnaire properly. Accordingly,

the validation emphasized content relevance, clarity, and appropriateness of the questionnaire items for the target users.

The total score obtained from the UAT responses is then calculated and converted into a percentage value using (3.1). Each respondent has a maximum possible score of 50, while n represents the total number of respondents.

$$\text{UAT Percentage} = \frac{\sum \text{Score}}{n \times 50} \times 100\% \quad (3.1)$$

The percentage results are then interpreted using predefined satisfaction level categories to determine the level of user acceptance of the developed educational game. The classification of acceptance levels is presented in Table 3.15.

Table 3.15 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

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Analysis Result

The analysis phase was conducted to identify user needs and learning problems that would serve as the foundation for developing the educational game. Data collection was carried out through an interview with a fourth-grade elementary school teacher at SD Negeri Ngemplak 2. The interview was conducted on 19 May 2025. The purpose of the interview was to obtain detailed information regarding teaching methods, learning media, student engagement, learning difficulties, and the teacher's perspective on the use of educational games. The detailed results of the interview are presented in Table 4.1.

Table 4.1 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.
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.

Based on the interview results, several important findings were identified to support the development of the educational game. First, students tend to experience low engagement due to lack of concentration and monotonous learning methods. This indicates the need for an interactive learning medium that can maintain students' attention and motivation.

Second, several mathematical topics such as plane geometry, three-dimensional shapes, and formula memorization were identified as challenging. Therefore, the game should focus on these topics and present them in a more engaging and interactive format.

Third, the teacher emphasized the importance of using visually appealing elements, such as bright colors and engaging characters, to attract students' interest. This finding supports the use of child-friendly visual design in the game.

Additionally, the teacher suggested that the game should include a guided introduction before allowing students to play independently. This implies that the game should provide a tutorial or guidance system to help students understand how to use the application.

Overall, these findings indicate that the developed game should be interactive, visually engaging, easy to use, and aligned with learning objectives in order to support students' interest and motivation in learning mathematics. Figure 4.1 shows the interview activity conducted with the fourth-grade elementary school teacher.



Figure 4.1 Interview with a fourth-grade elementary school teacher.

4.2 Design Result

4.2.1 Design Assets

The selection of design assets is a crucial aspect in the development of educational games, particularly for elementary school students. Visual elements play an important role in attracting students' attention, enhancing engagement, and supporting the overall learning experience. Therefore, the design assets used in this study were carefully selected to ensure they are visually appealing, child-friendly, and suitable for the cognitive characteristics of fourth-grade students.

The selection of these assets is based on the results of the analysis phase, which indicated that students prefer learning media that incorporate attractive colors, engaging characters, and interactive visual elements. In addition, the teacher emphasized the importance of using visual components that are not only entertaining but also supportive of the learning objectives. As a result, the assets were designed and chosen to create a fun, immersive, and motivating learning environment.

The assets used in this game include character designs, background environments, user interface elements, icons, and visual effects. Each asset is designed to enhance the aesthetic quality of the game while maintaining clarity and usability. Bright color schemes and simple visual styles are applied to ensure that the interface remains easy to understand and does not overwhelm the students.

Furthermore, consistency in visual design is maintained throughout the game to provide a cohesive user experience. The combination of these assets contributes to making the game more engaging, interactive, and suitable as an educational medium. These design

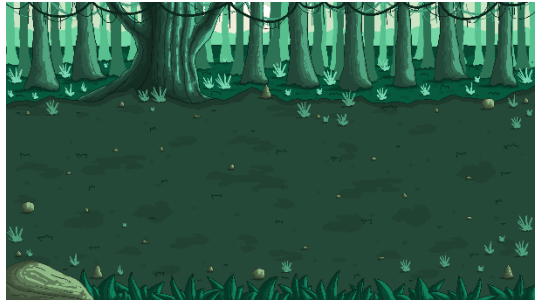
considerations aim to support both visual engagement and cognitive accessibility, ensuring that the game remains enjoyable without compromising its educational purpose.

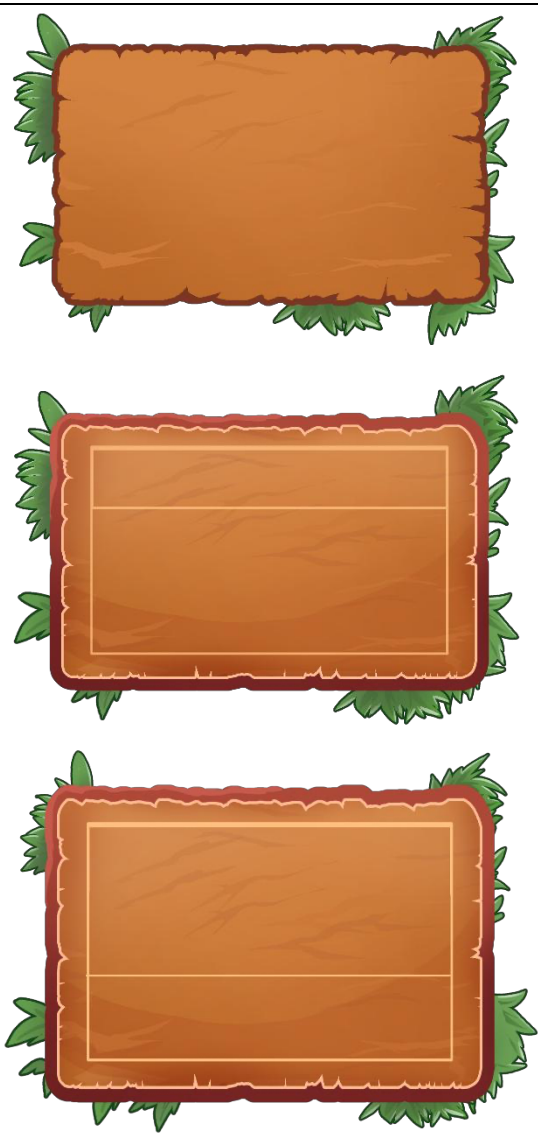
Before proceeding to the development stage, proposed design consisting of learning content, design assets, and interface concepts were reviewed by the fourth-grade teacher involved in the analysis phase. Based on the review, the overall design was considered suitable for further development. The teacher suggested the use of attractive colors, engaging characters, and guidance elements to help students understand how to use the game. In addition, since the game adopts turn-based battle mechanics, the teacher recommended that battle scenes and game interactions should be presented in a non-violent and child-friendly manner to ensure that the gameplay remains suitable for elementary school students and aligned with the educational purpose of the game. These suggestions were incorporated into the final design implemented during the development phase. The detailed list of design assets used in the game is presented in Table 4.2.

Table 4.2 Design Assets Used in the Game.

No.	Asset Type	Asset Image	Description
1	Main Character		The main playable character used throughout the game
2	Enemy Character	<p>Level 1</p> 	Various enemy characters are designed to appear across six levels with different visual appearances. This variation is intended to create a sense of progression for players, where

		<p>Level 2</p>  <p>Level 3</p>  <p>Level 4</p>  <p>Level 5</p>  <p>Level 6</p> 	<p>each level introduces enemies with increasing difficulty. Despite this progression, the enemy designs remain visually appealing and child-friendly to ensure suitability for fourth-grade elementary school students.</p>
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3	Gameplay Background	    	<p>Six different background environments are designed to represent each level in the game. This variation aims to maintain students' engagement by providing a different visual atmosphere in every level, preventing monotony during gameplay. In addition, the use of distinct environments helps create a sense of progression, where each level introduces a new setting. The background design is also aligned with the corresponding enemy characters to ensure visual consistency, where enemies are designed to match the theme of each environment. Despite these variations, all backgrounds maintain a colorful and child-friendly visual style suitable for elementary school students.</p>
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4	Menu Background		Background used in menu interfaces to create an engaging visual atmosphere while maintaining consistency with the game's theme.
5	Overlay Panel		Overlay panels used to display important information such as menus, settings, Tutorial, win/lose panel, and quiz panel while maintaining visual consistency and readability.

			
6	Icon		Icons used as interactive elements for navigation and game control, designed to be intuitive and easily recognizable for elementary school students.
7	Logo		The game logo represents the identity of the game and is designed to be visually appealing and memorable to attract students' interest.

4.3 Development Result

4.3.1 Main Menu Interface

The Main Menu Interface is the first screen displayed when the player launches the game *Petualangan Ksatria*, as shown in Figure 4.2. This interface presents the game logo along with three main buttons: Play, Settings, and Quit, each represented by icons corresponding to their respective functions.

This interface functions as the primary navigation hub that allows players to access the main features of the game. The Play button directs the player to the tutorial interface before entering the gameplay, the Settings button provides access to audio configuration options, and the Quit button displays a confirmation panel to prevent unintended application closure.

From a user experience perspective, the interface is designed to be simple and intuitive, considering the characteristics of fourth-grade elementary school students. The use of clear button labels, minimal menu options, and consistent layout aims to reduce cognitive load and

ensure that users can easily understand how to navigate the game without confusion. This design is aligned with the findings from the analysis phase, which indicate that students prefer straightforward and visually clear interaction when using digital learning media.

The navigation system in this interface is implemented using a panel-based structure, where each menu is represented as a separate panel within a single scene. This approach allows the system to manage different interfaces efficiently while maintaining a consistent user experience. When the application starts, only the main menu panel is displayed, while other panels remain hidden to avoid overlapping elements, as illustrated in Figure 4.3.

To support smooth navigation between interfaces, the system dynamically switches between panels based on user interaction. This mechanism ensures that only one interface is visible at a time, as shown in Figure 4.4, allowing users to focus on a single task without distraction. User interactions are handled through button-based input, where each button triggers a specific navigation response, such as opening the tutorial or settings panel, as illustrated in Figure 4.5.

In addition to panel-based navigation within a single scene, the system also supports navigation across different scenes. This enables the game to maintain continuity when transitioning between gameplay and menu interfaces, ensuring a seamless user experience.

Overall, the design of the Main Menu Interface not only supports functional navigation but also contributes to creating a comfortable and engaging initial interaction. A clear and accessible main menu is important in maintaining students' interest and encouraging them to continue exploring the game as a learning medium.



Figure 4.2 Main Menu Interface.

```
private void HideAllPanels()
{
    mainMenuPanel.SetActive(false);
    settingsPanel.SetActive(false);
    tutorialPanel.SetActive(false);
    levelPanel.SetActive(false);
    quitPanel.SetActive(false);
}
```

Figure 4.3 HideAllPanels () Function Script.

```
private void ShowPanel(GameObject panel)
{
    HideAllPanels();
    panel.SetActive(true);
}
```

Figure 4.4 ShowPanel () Function Script.

```
private void OnStartClicked()
{
    ShowPanel(tutorialPanel);
}

private void OnSettingsClicked()
{
    ShowPanel(settingsPanel);
}
```

Figure 4.5 Button Interaction Functions.

4.3.2 Settings Interface

The Settings Interface provides users with the ability to adjust audio preferences, including background music and sound effects volume, as shown in Figure 4.6. This interface is designed to enhance user comfort by allowing players to customize the audio environment according to their individual preferences.

The interface consists of two main slider components, namely the music slider and the sound effects (SFX) slider. These controls enable users to regulate the intensity of audio output, which is particularly important in maintaining concentration during gameplay. For elementary school students, excessive or inappropriate audio levels may reduce focus or cause distraction, while properly adjusted audio can create a more enjoyable and supportive learning atmosphere.

When the settings interface is accessed, the system automatically applies previously selected audio preferences to ensure consistency in user experience. This allows users to continue interacting with the game without needing to reconfigure settings repeatedly. The synchronization between stored preferences and the user interface ensures that the displayed values accurately represent the current audio configuration.

User interaction with the sliders triggers real-time adjustments to the audio output, enabling immediate feedback as users modify the settings. This direct interaction supports intuitive control and helps users quickly find their preferred audio levels. The system also ensures that these preferences are retained for future sessions, allowing for a more personalized and seamless experience.

The mechanism used to update and store audio preferences is implemented through slider-based input, as illustrated in Figure 4.7. This mechanism allows the system to dynamically adjust audio levels while maintaining user preferences across sessions.

From a learning perspective, the availability of audio control contributes to a more adaptive learning environment. Students can adjust the sound according to their comfort level, which supports better concentration and reduces potential distractions during problem-solving activities. This flexibility aligns with the goal of creating an engaging and student-centered learning medium.

Overall, the Settings Interface not only serves a functional role in system configuration but also plays an important part in supporting usability, comfort, and sustained engagement during the learning process.



Figure 4.6 Settings Interface.

```
// Methods to be called by UI sliders
public void SetSoundFXVolume(float level)
{
    ApplySFXVolume(level);
    PlayerPrefs.SetFloat(SFX_KEY, level);
}
// Methods to be called by UI sliders
public void SetMusicVolume(float level)
{
    ApplyMusicVolume(level);
}
```

```
PlayerPrefs.SetFloat(MUSIC_KEY, level);  
}
```

Figure 4.7 `SetSoundFXVolume()` and `SetMusicVolume()` Function Script.

4.3.3 Tutorial Interface

The Tutorial Interface is designed to provide initial guidance to players on how to play the game, as shown in Figure 4.8. This interface serves as an introductory stage before entering the main gameplay, ensuring that players understand the basic mechanics of the game.

The tutorial is presented in the form of a video-based explanation combined with interactive controls. This approach allows students to learn through visual and auditory elements, which are more suitable for elementary school learners. The use of video helps simplify complex instructions and makes the learning process more engaging and easier to understand.

The interface consists of several components, including a tutorial panel, a video display area, and navigation buttons such as Back and Next. Additional control buttons, including Play and Restart, are provided to allow users to manage the video playback according to their needs. Before the video starts, a thumbnail image is displayed to provide a visual preview and to avoid an empty screen.

From a learning perspective, this interface functions as a scaffolding mechanism, where students are guided step by step before engaging in independent gameplay. This is important because the turn-based gameplay mechanics may be unfamiliar to some students. By providing clear instructions at the beginning, the system helps reduce confusion and increases students' confidence when starting the game.

During video playback, the system adjusts the audio environment to ensure that instructional content can be heard clearly. Background music is temporarily reduced so that the tutorial narration remains the main focus. Once the video is completed, the audio returns to its previous state, ensuring consistency with user preferences.

User interaction with the tutorial is designed to be flexible. Players can replay the video if needed, or skip to the next stage once they feel confident. Navigation buttons allow users to return to the main menu or proceed directly to the level selection interface, supporting smooth transitions between learning and gameplay stages.

The mechanism for controlling video playback and user interaction is implemented through event-driven functions, as illustrated in Figure 4.9. This mechanism ensures that the tutorial operates responsively according to user input.

Overall, the Tutorial Interface plays a crucial role in bridging the gap between introduction and gameplay. By combining visual instruction, interactive control, and adaptive audio, this feature supports an effective and engaging learning experience for elementary school students.



Figure 4.8 Tutorial Interface.

```
[SerializeField] private float tutorialMusicVolume = 0.05f;

private void OnPlayVideoClicked()
{
    ShowThumbnail(false);
    mixerManager.LowerMusicTemporarily(tutorialMusicVolume);
    VideoPlayer.Play();
    PlaySound();
}

private void OnRestartVideoClicked()
{
    ShowThumbnail(false);
    mixerManager.LowerMusicTemporarily(tutorialMusicVolume);
    VideoPlayer.frame = 0;
    VideoPlayer.Play();
    PlaySound();
}
```

Figure 4.9 OnPlayVideoClicked() and OnRestartVideoClicked() Function Script.

4.3.4 Level Select Interface

The Level Select Interface allows players to choose the level they want to play based on their progression in the game, as shown in Figure 4.10. This interface is designed to provide a structured learning pathway by organizing challenges into sequential levels.

The interface displays multiple level options arranged in a grid layout, where each level is represented by a button. At the beginning of the game, only Level 1 is accessible, while the

remaining levels are locked. Locked levels are visually indicated using a lock icon, as shown in Figure 4.10, to clearly communicate progression status to the player.

From a learning perspective, this level-based structure supports progressive learning. Students are required to complete earlier levels before advancing to more complex challenges. This approach ensures that learners build foundational understanding before encountering more difficult material, which aligns with the principles of gradual learning and mastery.

The unlocking mechanism is designed to motivate students by providing a sense of achievement. When a player successfully completes a level, the next level becomes available. This creates a reward-based progression system that encourages continued engagement and reinforces learning through repeated practice.

In addition to level selection, this interface also provides a reset feature that allows players to restart their progress. This feature supports repeated learning, enabling students to revisit earlier levels and reinforce their understanding of previously learned material.

Navigation within this interface is designed to be simple and intuitive. A Back button allows users to return to the previous interface, ensuring smooth transitions between different stages of the game.

The mechanism for updating level availability based on player progress is handled dynamically by the system, as illustrated in Figure 4.11. This ensures that the interface always reflects the current learning progress of the player.

Overall, the Level Select Interface not only functions as a navigation component but also plays an important role in structuring the learning experience. By combining visual feedback, progressive challenges, and motivational elements, this interface supports student engagement and sustained learning throughout the game.



Figure 4.10 Level Select Interface.

```
private void UpdateLevelButtons()
{
    int unlockedLevel = GameManager.Instance.unlockedLevel;

    for (int i = 0; i < levelButtons.Length; i++)
    {
        bool unlocked = (i + 1) <= unlockedLevel;
        levelButtons[i].interactable = unlocked;
    }
}
```

Figure 4.11 UpdateLevelButtons() Function Script.

4.3.5 Character Select Interface

The Character Select Interface is designed to allow players to choose a character before entering the gameplay, as shown in Figure 4.12. This interface serves as a transition stage between the level selection and the gameplay, where the system prepares the player for the upcoming learning activity.

The interface consists of two character options, each represented by a visual illustration and a character name, namely Sven and Sheryn. In addition, a Back button is provided to allow users to return to the previous interface. The use of visual character representations aims to make the interface more engaging and appealing to elementary school students.

From a learning and engagement perspective, this feature incorporates elements of gamification by allowing players to select their preferred character. Giving students the freedom to choose a character creates a sense of ownership and personal connection to the game. This emotional engagement can support motivation and encourage students to participate more actively in the learning process.

The selection process is designed to be simple and intuitive. Players can select a character through a single interaction, after which the system prepares the necessary data and transitions to the gameplay stage. This ensures a smooth and uninterrupted flow between interfaces.

The mechanism for handling character selection and transitioning to the gameplay scene is implemented through a centralized system, as illustrated in Figure 4.13. This mechanism ensures that the selected character and previously chosen level are correctly applied when entering the gameplay.

Navigation within this interface is also designed to be consistent with other parts of the game. The Back button allows users to return to the Level Select Interface, ensuring a clear and predictable navigation flow.

Overall, the Character Select Interface not only functions as a technical preparation stage but also enhances user engagement through personalization. By allowing players to choose their character, this feature contributes to a more immersive and motivating learning experience.



Figure 4.12 Character Select Interface.

```
public void Choose()
{
    // Save the selected character
    GameManager.Instance.selectedCharacter = characterID;

    Debug.Log("Clicked Button Character ID = " + characterID);

    // Take the target level scene
    string targetScene = GameManager.Instance.selectedLevelSceneName;

    Debug.Log("GameManager saved selectedCharacter = " +
    GameManager.Instance.selectedCharacter);

    // Enter gameplay scene
    SceneManager.LoadScene(targetScene);
}
```

Figure 4.13 Choose () Function Script.

4.3.6 Gameplay Interface

The gameplay in this study is designed by integrating educational content with turn-based combat mechanics, forming an interactive learning experience. This system ensures that every player action is directly influenced by their ability to answer mathematical questions correctly.

As shown in Figure 4.14, the Gameplay Interface serves as the main interaction area. It displays both the player character and the enemy, each equipped with a health bar (HP), character name, and visual indicators of their current state. Additional elements such as the wave counter, action buttons, and dialogue box are provided to guide the player throughout the game.

The learning content is managed using a data-driven approach, where questions are stored externally and dynamically loaded into the system. As illustrated in Figure 4.15, this structure allows questions to be organized based on difficulty levels and retrieved efficiently during gameplay. This approach provides flexibility in updating and expanding educational material without modifying the core system.

The core learning mechanism is implemented through a quiz-based interaction system. When the player selects an action, the system presents a mathematical question based on a selected difficulty level. The question is displayed interactively, as shown in Figure 4.16, allowing players to read and select their answers directly within the game interface.

The player's answer determines the outcome of the action. A correct answer triggers the player's attack, while an incorrect answer or failure to respond within the given time results in an enemy counterattack. This mechanism is handled programmatically, as illustrated in Figure 4.17, ensuring that learning performance is directly linked to gameplay consequences.

To further support structured learning, the game provides three levels of difficulty: easy, medium, and hard. Each level represents different levels of question complexity and gameplay challenge. In addition, a time limit is applied to each question to train students' speed and accuracy in problem-solving without creating excessive pressure.

Feedback plays a crucial role in maintaining engagement and supporting learning. The system provides immediate responses through visual, textual, and audio feedback. Correct answers are reinforced with positive messages and successful attacks, while incorrect answers are followed by corrective feedback and enemy responses. This feedback mechanism helps students understand their mistakes and encourages continuous improvement.

The gameplay is structured in a wave-based system, where players must defeat a sequence of enemies to complete a level. This structure introduces a sense of progression and achievement, motivating players to continue learning and improving their performance.

Overall, the gameplay design successfully integrates educational content with interactive mechanics, creating a balanced experience between learning and entertainment. By linking problem-solving activities with game outcomes, the system encourages active participation and enhances students' motivation to learn mathematics.



Figure 4.14 Gameplay Interface.

```
{
  "difficulty": "easy",
  "questions": [
    {
      "id": 42,
      "question": "Berdasarkan gambar balok di atas, bilangan yang
      terbentuk adalah...",
      "options": ["3.424", "3.254", "5.324", "4.253"],
      "answer": "3.424",
      "imagePath": "images/Level1/gambareasy1"
    }
  ]
}
```

```
public enum DifficultyType { Easy, Medium, Hard }

[System.Serializable]
public class Question
{
    public string questionText;
    public string[] options;
    public Sprite questionImage; // Optional image
    public string imagePath; // Path to image in Resources
    public int correctOptionIndex;
}
```

```

[System.Serializable]
public class QuizData
{
    public string difficulty;
    public JsonQuestion[] questions;
}

[System.Serializable]
public class JsonQuestion
{
    public int id;
    public string question;
    public string[] options;
    public string answer;
    public string imagePath; // Path to image in Resources folder
}

```

Figure 4.15 JSON Data Structure and Serializable Classes.



Figure 4.16 Quiz and Quiz with Image Interface.

```

private void OnAnswerReceived(bool isCorrect)
{
    if (isCorrect)
    {
        if (TurnBasedManager.Instance != null)
        TurnBasedManager.Instance.SetCorrectAnswerState();

        switch (selectedDifficulty)
        {
            case DifficultyType.Easy:
                TurnBasedManager.Instance.PlayerAttackWithDamage(10); break;
            case DifficultyType.Medium:
                TurnBasedManager.Instance.PlayerAttackWithDamage(20); break;
            case DifficultyType.Hard:
                TurnBasedManager.Instance.PlayerAttackWithDamage(30); break;
        }
    }
    else
    {
        if (TurnBasedManager.Instance != null)
        TurnBasedManager.Instance.SetWrongAnswerState();

        switch (selectedDifficulty)
        {

```

```

        case DifficultyType.Easy:
TurnBasedManager.Instance.EnemyAttackWithDamage(5); break;
        case DifficultyType.Medium:
TurnBasedManager.Instance.EnemyAttackWithDamage(15); break;
        case DifficultyType.Hard:
TurnBasedManager.Instance.EnemyAttackWithDamage(25); break;
    }
}
}

```

Figure 4.17 OnAnswerReceived() Callback Script.

4.3.7 Victory and Defeat Panel Interface

The Victory and Defeat Panel Interface serves as the final feedback mechanism at the end of the gameplay, as shown in Figure 4.18. This interface is displayed when the game reaches an end condition, either when the player successfully completes all enemy waves or when the player's health points are depleted.

The interface dynamically presents two different panels based on the player's performance. The Victory panel is displayed when the player successfully completes the level. It shows a congratulatory message to reinforce positive learning outcomes and provides navigation options such as proceeding to the next level, restarting the level, or returning to the level selection menu. In contrast, the Defeat panel is displayed when the player fails to complete the level. Instead of presenting negative feedback, the interface provides encouraging messages to motivate students to try again, along with options to retry or return to the level selection.

From a learning perspective, this interface functions as a form of formative feedback. Positive reinforcement in the Victory panel helps increase students' confidence, while the encouraging tone in the Defeat panel supports resilience and reduces frustration. This approach aligns with educational principles where feedback is used to support learning rather than penalize mistakes.

The system determines which panel to display based on the gameplay outcome, as illustrated in Figure 4.19. When the player successfully completes the level, the system activates the Victory panel. Conversely, when the player loses, the Defeat panel is displayed. This mechanism ensures that feedback is delivered immediately after the learning activity.

In addition to feedback, the interface also provides navigation controls that allow players to continue their learning process. These controls include options to restart the level, proceed to the next level, or return to the level selection interface. The navigation mechanism is implemented through button-based interactions, as illustrated in Figure 4.20, ensuring that players can easily decide their next action after receiving feedback.

Overall, the Victory and Defeat Panel Interface not only indicates the end of gameplay but also plays a significant role in supporting the learning process. By providing immediate, meaningful, and motivating feedback, this interface encourages students to reflect on their mistakes and continue improving their mathematical understanding through repeated gameplay.



Figure 4.18 Victory and Defeat Panel Interface.

```
private void GameComplete()
{
    if (winPanel != null) winPanel.SetActive(true);
    if (losePanel != null) losePanel.SetActive(false);
}

private void EnemyWins()
{
    if (winPanel != null) winPanel.SetActive(false);
    if (losePanel != null) losePanel.SetActive(true);
}
```

Figure 4.19 Panel Trigger Mechanism in TurnBasedManager Script.

```
public void RestartGame()
{
    SceneManager.LoadScene(SceneManager.GetActiveScene().name);
}

public void GoToNextLevel()
{
    SceneManager.LoadScene(nextLevelIndex);
}
```

Figure 4.20 RestartGame() and GoToNextLevel() Functions.

4.3.8 Pause Panel Interface

The Pause Panel Interface provides users with control over the gameplay flow by allowing them to temporarily stop the game, as shown in Figure 4.21. This feature is designed to support user comfort by enabling players to take a break, adjust their decisions, or navigate to other menus without losing their current progress.

The interface is displayed as an overlay on the gameplay screen and contains several navigation buttons represented by intuitive icons, including Home, Restart, Settings, and Resume. These controls allow users to either continue the game, restart the current level, or exit to another menu.

From a learning perspective, the pause feature plays an important role in supporting cognitive breaks. Elementary school students may require time to rest or rethink their strategies when facing mathematical problems. By allowing players to pause the game, the system helps reduce cognitive overload and provides a more flexible learning experience.

The system manages the pause state by temporarily halting the gameplay and displaying the pause interface, as illustrated in Figure 4.22. This mechanism ensures that the game state remains unchanged while the player is not actively interacting with the game.

In addition to pausing the game, the interface also provides navigation options such as restarting the level or returning to the main menu. These actions are executed through button-based interactions, as illustrated in Figure 4.23, allowing players to easily control their gameplay flow.

To prevent accidental actions that may result in loss of progress, the system implements confirmation panels, as shown in Figure 4.24. The activation logic of these panels is illustrated in Figure 4.25. These panels require users to confirm their choice before executing actions such as restarting the level or returning to the main menu.

Overall, the Pause Panel Interface not only functions as a control feature but also enhances the learning experience by providing flexibility, reducing cognitive pressure, and preventing unintended actions. This contributes to a more user-friendly and supportive learning environment for students.



Figure 4.21 Pause Panel Interface

```

public void TogglePause()
{
    if (isPaused) ResumeGame();
    else PauseGame();
}

public void PauseGame()
{
    isPaused = true;
    pausePanel.SetActive(true);
    Time.timeScale = 0f;
}

public void ResumeGame()
{
    isPaused = false;
    pausePanel.SetActive(false);
    Time.timeScale = 1f;
}

```

Figure 4.22 Pause Control Mechanism.

```

public void RestartGame()
{
    SceneManager.LoadScene(SceneManager.GetActiveScene().name);
}

public void GoHome()
{
    SceneManager.LoadScene("MainMenu");
}

```

Figure 4.23 Navigation Mechanism.



Figure 4.24 Restart and Home Confirmation Panel Interfaces.

```

public void OnclickRestart()
{
    restartPanel.SetActive(true);
}

public void OnclickGoHome()
{
    goHomePanel.SetActive(true);
}

```

Figure 4.25 Confirmation Panel Mechanism.

4.3.9 Black box Testing Result

Black box testing was conducted to evaluate the functionality of the developed game system by focusing on input-output behavior without examining the internal code structure. This testing aims to ensure that each feature operates according to its intended function and produces the expected output based on user interactions.

The testing process was performed on all main modules of the game, including the main menu, settings, tutorial, level selection, gameplay, quiz, and other supporting interfaces. Each test case consists of user input, system process, expected output, and validation results. The results of the black box testing are presented in Table 4.3.

Table 4.3 Black box Testing Result.

Module	Interface	Input	Process	Output	Validity
Main Menu	Main Menu	Play button clicked	Navigate to tutorial interface	Tutorial screen displayed	Valid
	Main Menu	Settings button clicked	Navigate to settings interface	Settings menu displayed	Valid
	Main Menu	Exit button clicked	Open exit confirmation dialog	Exit confirmation dialog displayed	Valid
Settings	Settings Menu	Adjust music slider	Update background music volume	Music volume changes	Valid
	Settings Menu	Adjust SFX slider	Update sound effect volume	Sound effect volume changes	Valid
	Settings Menu	Back button clicked	Return to main menu	Main menu displayed	Valid
Quit Game	Confirmation Dialog	Yes button clicked	Close application	Application terminated	Valid
	Confirmation Dialog	No button clicked	Return to main menu	Main menu displayed	Valid
Tutorial	Tutorial Screen	Play button clicked	Play tutorial video	Video starts playing	Valid

	Tutorial Screen	Restart button clicked	Replay tutorial video	Video restarts	Valid
	Tutorial Screen	Continue button clicked	Navigate to level selection	Level selection screen displayed	Valid
	Tutorial Screen	Back button clicked	Return to main menu	Main menu displayed	Valid
Level Select	Select Level	Level button clicked	Navigate to character selection	Character selection screen displayed	Valid
	Select Level	Reset button clicked	Open reset confirmation dialog	Reset confirmation displayed	Valid
	Select Level	Back button clicked	Return to main menu	Main menu displayed	Valid
Character Select	Character Screen	Character selected	Store selected character and start game	Gameplay screen displayed with corresponding character	Valid
	Character Screen	Back button clicked	Return to level selection	Level selection screen displayed	Valid
Gameplay	Gameplay Screen	Action button clicked	Trigger quiz with timer	Quiz interface displayed	Valid
	Gameplay Screen	Pause button clicked	Pause game and open menu	Pause menu displayed	Valid
	Gameplay Screen	Enemy HP reaches 0	Trigger victory condition	Victory screen displayed	Valid
	Gameplay Screen	Player HP reaches 0	Trigger defeat condition	Defeat screen displayed	Valid
Quiz	Quiz Screen	Correct answer selected	Validate answer and execute attack	Enemy HP decreases	Valid
	Quiz Screen	Wrong answer selected	Trigger enemy counterattack	Player HP decreases	Valid

	Quiz Screen	Timer runs out	Trigger enemy counterattack	Player HP decreases	Valid
Pause Menu	Pause Screen	Resume button clicked	Close pause menu	Gameplay resumes	Valid
	Pause Screen	Restart button clicked	Open restart confirmation dialog	Restart confirmation displayed	Valid
	Pause Screen	Home button clicked	Open home confirmation dialog	Home confirmation displayed	Valid
Victory	Victory Screen	Next button clicked	Load next level	Next level displayed	Valid
	Victory Screen	Restart button clicked	Restart current level	Gameplay restarted	Valid
	Victory Screen	Level button clicked	Return to level selection	Level selection displayed	Valid
Defeat	Defeat Screen	Retry button clicked	Restart level	Gameplay restarted	Valid
	Defeat Screen	Level button clicked	Return to level selection	Level selection displayed	Valid

Based on the results presented in Table 4.3, all tested modules and features functioned as expected. Each input provided by the user successfully triggered the corresponding process and produced the intended output. This indicates that the system has been implemented correctly and is able to operate according to its designed functionality. Therefore, the developed game can be considered functionally valid and ready to be used in the implementation phase.

4.4 Implementation Result

The implementation phase was conducted on 8 January 2026, at SD Negeri Ngemplak 2 during a mathematics learning session, involving 31 fourth-grade students and one teacher. This phase aimed to introduce the developed educational game to the target users and allow them to directly interact with the system in a real classroom environment.

The implementation was carried out using four Android devices, which were shared among students in small groups. Each session lasted approximately 10 minutes, allowing students to

explore the game and experience its features. At the beginning of the activity, students were given guided instructions on how to use the application, including how to navigate the menu, select levels, and interact with the gameplay mechanics, as shown in Figure 4.26. After the initial guidance, students were allowed to play the game independently, as shown in Figure 4.27. During the implementation process, students interacted with various features of the game, including level selection, character selection, gameplay, and quiz-based challenges. The game was designed to encourage active participation through interactive elements and visual feedback. Most students showed enthusiasm while playing the game, particularly when engaging with the quiz system and character progression features. Several aspects were observed during this phase, including students' engagement, ease of use, clarity of instructions, and system functionality. In general, the application was able to run properly on the devices used, and students were able to understand how to interact with the game after initial guidance.

At the end of the session, students and the teacher were asked to complete a User Acceptance Test (UAT) questionnaire to provide feedback regarding the usability, visual design, and overall effectiveness of the game as a learning medium, as shown in Figure 4.28. The data collected from this phase were then analyzed in the evaluation stage.



Figure 4.26 Students observing the game demonstration.



Figure 4.27 Students interacting with the game independently.



Figure 4.28 Students completing the UAT questionnaire.

4.5 Evaluation Result

The evaluation phase aims to assess the usability and effectiveness of the developed educational game based on user feedback. This evaluation was conducted using the User Acceptance Testing (UAT) method, involving students and the teacher who participated in the implementation phase. The collected data were analyzed to determine whether the developed game meets user expectations and supports the learning process.

4.5.1 User Acceptance Testing Result

The User Acceptance Testing (UAT) was conducted by distributing questionnaires to 31 students and one teacher after the implementation session. The questionnaire consists of 10

statements evaluated using a Likert scale ranging from 1 to 5, where a higher score indicates a more positive response. The results of the student responses are presented in Table 4.4

Table 4.4 Student UAT Result.

No.	Respondent ID	Question No.										Total Per Respondend
		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%

Based on Table 4.4, the total score obtained from all student responses is 1324, resulting in a percentage of 85%. This indicates that most students provided positive feedback regarding the usability, visual design, and overall experience of the game. The results suggest that the game is generally well accepted by students as an interactive learning medium. However, some variations in responses were observed among several participants, indicating that not all students experienced the game in the same way. These variations will be further discussed in the next section.

The teacher's response was also collected to evaluate the effectiveness of the game from an educational perspective. The results of the teacher's evaluation are presented in Table 4.5.

Table 4.5 Teacher UAT Result.

No.	Respondent ID	Question No.										Total Per Respondend
		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%

Based on Table 4.5, the total score obtained from the teacher's response is 40, resulting in a percentage of 80%. This indicates that the teacher has a positive perception of the developed game as a learning medium. The teacher considers that the game is suitable for supporting mathematics learning and student engagement.

4.6 Discussion

This section discusses the development results, technical evaluation, and implementation of the *Petualangan Ksatria* educational game as a mathematics learning medium. The discussion is presented to answer the research questions, evaluate how the developed system addresses the identified research gap, and analyze the feasibility, user acceptance, and limitations of the application based on the findings obtained in this study.

4.6.1 System Development and Addressing the Research Gap

The development of *Petualangan Ksatria* using the ADDIE instructional design model was successfully carried out to address the needs of fourth-grade elementary school students. Referring to the research gap identified in Chapter II, several previous studies mainly focused on the feasibility, usability, or general effectiveness of educational games, while relatively limited studies discussed the pedagogical suitability of specific gameplay mechanics for mathematics learning. This research contributes by integrating mathematics materials with a turn-based combat system designed to support cognitive engagement during learning activities.

The selection of turn-based mechanics provides students with sufficient processing time before responding to mathematical questions. Unlike real-time games that may create excessive time pressure, the turn-based system encourages reflective decision-making and step-by-step problem solving. In this study, the timer system was adjusted according to attack categories, namely 15 seconds for light attacks, 20 seconds for medium attacks, and 25 seconds for heavy attacks. This design was intended to balance question difficulty with available response time, thereby helping students' complete tasks without unnecessary pressure.

The use of the ADDIE model also supported systematic development. The analysis phase identified students' difficulties in several mathematics topics and the need for more engaging learning media. The design phase translated these needs into interface structures, gameplay flow, and learning content. The development phase implemented the system into a functional Android application, while the implementation and evaluation phases enabled direct testing with users. Therefore, the first research question regarding how the educational game was developed has been successfully answered through a structured development process.

4.6.2 System Feasibility and Functional Evaluation

From a technical perspective, the Black Box Testing results indicate that the main system functions operated according to their intended purposes. Features such as interface navigation, settings adjustment, tutorial access, level progression, character selection, gameplay interaction, pause menu, and result panels functioned properly during testing. This suggests that the developed application met its functional requirements and was technically ready for user implementation.

The presence of error-prevention mechanisms, such as confirmation panels when restarting or exiting a level, is also important for elementary school users who may accidentally press

certain buttons. These features help maintain user progress and improve the overall usability of the application.

From an educational perspective, the teacher evaluation reached 80%, which falls within the satisfactory category. This result indicates that the teacher considered the learning materials, level structure, and game flow to be appropriate for fourth-grade mathematics learning. The division of materials into six sequential levels covering whole numbers, fractions, number patterns, measurement, two-dimensional figures, and pictograms also reflects alignment with the Merdeka Curriculum. Therefore, the developed game can be considered feasible as an alternative learning medium from both technical and educational perspectives.

4.6.3 User Acceptance Analysis and Motivation Perspective

The User Acceptance Testing (UAT) results showed that the student acceptance rate reached 85%, which is categorized as highly satisfactory. This indicates that most students positively accepted the application in terms of usability, attractiveness, and overall learning experience. The result supports the conclusion that *Petualangan Ksatria* is feasible for use as an alternative mathematics learning medium for fourth-grade students.

From a motivational perspective, the developed game contains several design elements that may support student engagement, as discussed in Chapter II. Character selection provides a sense of autonomy, which can increase user involvement. Level progression creates clear goals and achievement targets, while rewards after victory may strengthen external motivation. In addition, immediate feedback during gameplay can help maintain persistence and encourage students to continue participating in learning activities. These elements indicate that the developed game has potential to support students' interest and motivation in mathematics learning.

Observations during the implementation phase also showed that students demonstrated curiosity and enthusiasm while trying the game. This positive response suggests that integrating mathematics questions into gameplay may create a more enjoyable learning atmosphere compared to conventional approaches.

4.6.4 Error Analysis and Areas for Improvement

Although the overall UAT result was high, several respondents gave comparatively lower ratings than the majority of participants. For example, respondents S29 and S30 obtained lower

total scores compared to other students. These responses indicate that while the system was positively accepted in general, certain users may have experienced difficulties during use.

These lower scores may be influenced by several possible factors. First, some students may still experience cognitive overload when solving mathematics questions while simultaneously understanding gameplay mechanics. Second, unfamiliarity with mobile-based interactive applications or turn-based game systems may reduce comfort for some users. Third, differences in learning preferences may affect how students respond to battle-based game mechanics, as some learners may prefer simpler or more collaborative learning media.

These findings indicate that the current tutorial feature may not fully accommodate all student characteristics, especially users who require more gradual guidance. Therefore, future development is recommended to include interactive tutorials, adaptive difficulty systems, additional hints, or simplified beginner modes to better support diverse learners.

From the teacher's perspective, the system could also be improved by adding classroom-support features such as progress tracking, score summaries, or topic-based reports. These additions would increase the usefulness of the application not only as an independent learning medium but also as a supporting tool for teachers during mathematics instruction.

4.6.5 Comparison with Previous Studies and Research Contribution

The findings of this study are consistent with previous research stating that educational games can positively support student engagement and motivation in mathematics learning. Similar to prior studies, this research found that interactive gameplay was well accepted by users and considered feasible as a learning medium.

However, this study provides a specific contribution by integrating fourth-grade mathematics content based on the Merdeka Curriculum into an Android-based turn-based format. In addition, this research not only evaluates general feasibility but also discusses how gameplay mechanics may support cognitive processing and motivation in elementary school learners.

4.6.6 Limitations of the Study

This study has several limitations. First, the evaluation focused on feasibility and user acceptance rather than direct measurement of long-term learning outcomes and academic performance.

Second, the implementation involved a limited number of participants from a single school, so the findings may not fully represent wider student populations. In addition, a convenience sampling technique was used based on the availability and willingness of the school to participate. While this approach was considered appropriate for the implementation stage of a development study, it may introduce sampling bias because the participants were not selected through random sampling procedures. Therefore, the findings primarily reflect the learning context and user responses of SD Negeri Ngemplak 2 and should not be generalized to broader populations without further investigation.

Third, user responses were collected within a relatively short implementation period. In addition, the implementation involved 31 students using four Android devices shared in small groups during a 10-minute session. Although this arrangement allowed students to experience the developed game within the available classroom setting, the limited duration and device availability may have limited the amount of hands-on interaction experienced by some students. Consequently, some responses may have been influenced by limited gameplay exposure or peer interaction during the activity, which may have influenced the consistency and reliability of the UAT responses.

Therefore, future studies are recommended to involve larger and more diverse samples, longer usage periods, sufficient device availability, and experimental comparisons to measure the impact of the game on mathematics learning outcomes more comprehensively.

Overall, the results of this study indicate that *Petualangan Ksatria* is feasible as an alternative mathematics learning medium for fourth-grade elementary school students. The game functioned properly, received positive responses from users, and demonstrated potential to support students' interest and motivation in learning mathematics based on acceptance results and implementation observations.

CHAPTER V

CONCLUSION

5.1 Conclusion

Based on the results of this study, it can be concluded that the development of an educational mathematics game for fourth-grade elementary school students was successfully carried out using the ADDIE development model, which consists of the Analysis, Design, Development, Implementation, and Evaluation stages. The developed game was designed as an alternative learning medium to support students' interest and motivation in learning mathematics through interactive and engaging gameplay.

The game integrates mathematics learning materials based on the Grade IV Merdeka Curriculum into a game system that adopts turn-based mechanics, where players are required to answer questions correctly in order to perform actions and progress through the game. The system includes several main features such as the main menu, settings, tutorial, level selection, character selection, gameplay battle system, pause menu, and result panels. These features were developed to provide a structured, enjoyable, and accessible learning experience for elementary school students.

Based on Black Box Testing results, all major system functions operated properly according to the intended design. This indicates that the developed application met its functional requirements and was technically feasible for implementation.

Furthermore, based on User Acceptance Testing (UAT) involving 31 students and 1 teacher at SD Negeri Ngemplak 2, the developed game, *Petualangan Ksatria*, received highly positive responses. The evaluation resulted in a student acceptance rate of 85% (Very Satisfactory) and a teacher evaluation rate of 80% (Satisfactory) in terms of usability, attractiveness, and suitability as a learning medium. The findings indicate that the game has good acceptance among users and shows potential to support students' learning interest and motivation in mathematics.

Therefore, it can be concluded that the developed educational mathematics game is feasible to be used as an alternative learning medium for fourth-grade elementary school students and can contribute positively to creating a more interactive and enjoyable mathematics learning experience.

5.2 Recommendations

Based on the results of this study, several recommendations are proposed for future development and implementation:

1. Future versions of the game may include additional gameplay features such as more playable characters, new enemies or bosses, scoring systems, leaderboards, trophies, player progression systems, character levels, and more varied attack or skill mechanics in order to increase engagement and replay value.
2. The game difficulty and learning support system may be improved by implementing adaptive difficulty levels, additional hints, simplified beginner modes, and more interactive tutorials to better accommodate students with different learning abilities.
3. Future development could incorporate classroom-support features for teachers, such as progress tracking, score summaries, and topic-based reports, to increase the game's usefulness as a monitored learning medium.
4. Future development may expand the learning materials to cover broader mathematics topics and other grade levels, so that the game can be utilized by a wider range of elementary school students.
5. Future studies are recommended to involve a larger number of participants and longer implementation periods in order to evaluate the long-term impact of the game on students' motivation, learning interest, and academic achievement.
6. Teachers and schools may consider integrating educational games such as this application into classroom learning activities as a complementary learning medium to support more engaging mathematics instruction.

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APPENDIX

APPENDIX A. Research Permission Request Letter to the School



FAKULTAS
TEKNOLOGI INDUSTRI

Gedung 04, 4th Floor
Kampus Depok-Sleman Indonesia
Jl. Kalirejo No. 13 Yogyakarta 55584
T. (0274) 898888 ext. 4108, 4101
F. (0274) 898887
E. info@uii.ac.id
www.uui.ac.id

Nomor : 78/Kaprodi.IF.S1/20/IF-V/2025
Lamp : -
Hal : Permohonan Penelitian Tugas Akhir

Kepada Yth.
Kepala Sekolah SD Negeri Ngemplak 2
di Jl. Ngemplak No.2, Ngemplak, Umbulmartani, Kec. Ngemplak, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55584

Assalamu'alaikum Warahmatullahi Wabarakatuh

Melalui surat ini Program Studi Informatika – Program Sarjana Universitas Islam Indonesia memohon kepada Bapak/Ibu agar dapat mengizinkan mahasiswa kami untuk melaksanakan penelitian Tugas Akhir (TA) di institusi yang Bapak/Ibu pimpin. Pelaksanaan penelitian TA ini merupakan salah satu syarat lulus di program studi kami.

Mahasiswa yang akan melaksanakan penelitian adalah :

Nama : Muhammad Rifqi
No. Mhs : 22523270

Kami berharap mahasiswa kami dapat melaksanakan penelitian di institusi Bapak/Ibu antara bulan Mei 2025 sampai dengan Januari 2026. Namun demikian, kepastian jadwal pelaksanaan kami serahkan sepenuhnya kepada institusi Bapak/Ibu.

Demikian permohonan kami, atas perhatian serta terkabulnya permohonan ini kami ucapkan terima kasih.

Wassalamu'alaikum Warahmatullahi Wabarakatuh

Yogyakarta, 5 Mei 2025



Ketua Program Studi Informatika - Program Sarjana Fakultas Teknologi Industri
R. Rhoma Hatta Fudholi, S.T., M.Eng., Ph.D.

APPENDIX B. Documentation of Interface Design Validation



APPENDIX C. Documentation of the Implementation Phase



APPENDIX D. Documentation of the UAT Form Completion



APPENDIX E. Sample of Teacher UAT Questionnaire Form

Form User Acceptance Test (UAT) Guru
Game Edukasi "Petualangan Ksatria"

Nama : Indarto
Instansi : SDN Hogeplau 2

Mohon berikan tanda centang (✓) pada kolom yang tersedia.

No.	Pernyataan	1	2	3	4	5
1	Materi dalam game sesuai dengan kurikulum matematika kelas 4				✓	
2	Penyajian materi dalam game relevan dengan kompetensi dasar kelas 4				✓	
3	Game ini layak digunakan sebagai media pembelajaran alternatif				✓	
4	Game ini dapat digunakan sebagai media pendukung pembelajaran matematika				✓	
5	Game mudah digunakan oleh siswa dalam kegiatan pembelajaran				✓	
6	Guru tidak mengalami kesulitan dalam mengarahkan siswa menggunakan game				✓	
7	Game ini dapat meningkatkan minat belajar siswa terhadap matematika				✓	
8	Game ini dapat memotivasi siswa untuk lebih aktif dalam belajar matematika					✓
9	Tampilan visual dan animasi dalam game menarik bagi siswa			✓		
10	Interaksi dalam game mendukung keterlibatan siswa saat belajar				✓	
Total Nilai						

Skor	Keterangan
5	Sangat Setuju
4	Setuju
3	Cukup Setuju
2	Tidak Setuju
1	Sangat Tidak Setuju

Sloman, 8 Januari 2026

Indarto

APPENDIX F. Sample of Student UAT Questionnaire Form

Form User Acceptance Test (UAT) Siswa
Game Edukasi "Petualangan Ksatria"

Nama : Arjuna Mahadika A.
Kelas : 4

Berikan tanda centang (✓) pada kolom yang paling sesuai dengan perasaanmu ya!

No.	Pernyataan	1	2	3	4	5
1	Saya merasa senang belajar matematika menggunakan game ini					✓
2	Game ini membuat pelajaran matematika terasa lebih menarik					✓
3	Game ini membuat saya lebih semangat belajar matematika					✓
4	Saya ingin bermain game ini lagi untuk belajar matematika					✓
5	Game ini mudah dimainkan				✓	
6	Saya tidak kesulitan menggunakan tombol dan menu dalam game					✓
7	Saya merasa senang saat memainkan game ini					✓
8	Belajar matematika dengan game ini tidak membosankan					✓
9	Tampilan gambar dan warna dalam game ini menarik				✓	
10	Petunjuk dan penjelasan dalam game mudah saya pahami					✓
Total Nilai						

Skor	Keterangan
5	Sangat Setuju
4	Setuju
3	Cukup Setuju
2	Tidak Setuju
1	Sangat Tidak Setuju

Sloman, 8 Januari 2026

Arjuna Mahadika A.

Form User Acceptance Test (UAT) Siswa
Game Edukasi "Petualangan Ksatria"

Nama : Reponia ellenda Syaputri (Ellen)
Kelas : 4 Cempati

Berikan tanda centang (✓) pada kolom yang paling sesuai dengan perasaanmu ya!

No.	Pernyataan	1	2	3	4	5
1	Saya merasa senang belajar matematika menggunakan game ini				✓	
2	Game ini membuat pelajaran matematika terasa lebih menarik				✓	
3	Game ini membuat saya lebih semangat belajar matematika					✓
4	Saya ingin bermain game ini lagi untuk belajar matematika				✓	
5	Game ini mudah dimainkan				✓	
6	Saya tidak kesulitan menggunakan tombol dan menu dalam game					✓
7	Saya merasa senang saat memainkan game ini					✓
8	Belajar matematika dengan game ini tidak membosankan				✓	
9	Tampilan gambar dan warna dalam game ini menarik				✓	
10	Petunjuk dan penjelasan dalam game mudah saya pahami					✓
Total Nilai						

Skor	Keterangan
5	Sangat Setuju
4	Setuju
3	Cukup Setuju
2	Tidak Setuju
1	Sangat Tidak Setuju

Sloman, 8 Januari 2026

ELLEN