

**DEVELOPMENT AND EVALUATION OF A DIGITAL
DAKON GAME FOR ELEMENTARY
MATHEMATICS LEARNING
USING THE ADDIE MODEL**



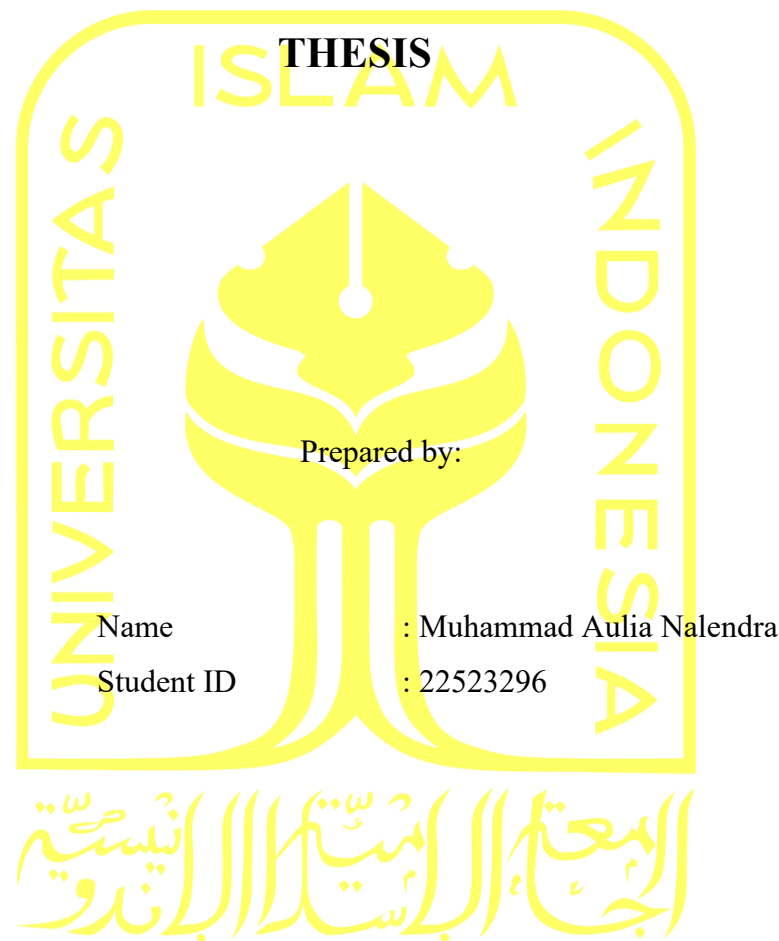
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**INFORMATICS STUDY PROGRAM – UNDERGRADUATE PROGRAM
FACULTY OF INDUSTRIAL TECHNOLOGY
UNIVERSITAS ISLAM INDONESIA
2026**

SUPERVISOR ENDORSEMENT PAGE

**DEVELOPMENT AND EVALUATION OF A DIGITAL
DAKON GAME FOR ELEMENTARY
MATHEMATICS LEARNING
USING THE ADDIE MODEL**



Yogyakarta, April 24th, 2026

Advisor,

(Chanifah Indah Ratnasari, S.Kom., M.Kom.)

EXAMINER ENDORSEMENT PAGE

**DEVELOPMENT AND EVALUATION OF A DIGITAL
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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 29th, 2026

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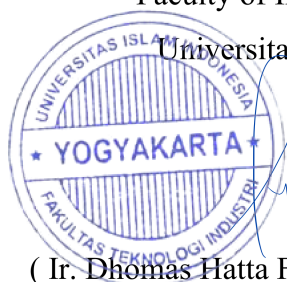
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DEVELOPMENT AND EVALUATION OF DIGITAL DAKON GAME FOR ELEMENTARY MATHEMATICS LEARNING USING THE ADDIE MODEL

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is proven that some parts of this work are not my own work, the final project submitted as my own work is ready to be withdrawn and ready to bear any risks and consequences.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 24th, 2026



Handwritten signature of Muhammad Aulia Nalendra.

(Muhammad Aulia Nalendra)

DEDICATION

This thesis is dedicated with deep gratitude and appreciation to those who have been part of my journey. First and foremost, I dedicate this work to my beloved parents, Dian Sriana and Heryanto Agus Wibowo, whose endless love, prayers, and unwavering support have been the foundation of my strength throughout this process. I also dedicate this work to my family, who have continuously supported and motivated me in completing my academic journey.

My sincere appreciation goes to my supervisor, Mrs. Chanifah Indah Ratnasari, S.Kom., M.Kom., for her guidance, patience, and valuable knowledge that have greatly contributed to my growth. I would also like to dedicate this work to the students and teachers of MI Fajar Shiddiq for their participation and support in this research.

To my partner, Abidila Zahra Harlian, thank you for your constant encouragement, understanding, and support during challenging times. I am also deeply grateful to my close friends, Muhammad Zidane Alfarizi, Dzahaban Zakiyan Murad, Abdullah Hisyam, Muhammad Rifqi, A'rafi Laksmara Dirgantara, Muhammad Fazli Ramadhani Sukma, Vladimirrorahman Salsabil Abdullah, and Khun Muhammad Dalle Jasmin, for their companionship, thoughtful discussions, and shared experiences that have helped me remain resilient throughout this journey. Lastly, I dedicate this work to myself as a reminder of perseverance, growth, and the commitment to never give up. May this work bring benefit and serve as a meaningful contribution to the advancement of knowledge and education.

MOTTO

Hard work is worthless for those that don't believe in themselves.

FOREWORD

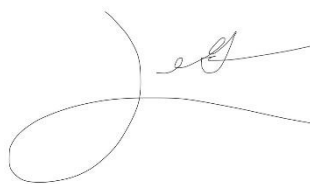
With the highest gratitude, I would like to express my sincere thanks to Allah Swt. for His blessings and mercy, which have enabled me to complete this final project entitled “Development and Evaluation of Digital Dakon Game for Elementary Mathematics Learning Using the ADDIE Model.” This final project is submitted as a requirement to obtain a bachelor’s degree in Informatics, Faculty of Industrial Technology, Universitas Islam Indonesia.

The completion of this final project would not have been possible without the support, guidance, and assistance from many parties. Therefore, I would like to express my deepest gratitude to:

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I realize that this final project is far from perfect. Therefore, I sincerely welcome any suggestions and constructive criticism for future improvement. Hopefully, this work can provide benefits and serve as a reference for future research.

Yogyakarta, April 22nd, 2026

A handwritten signature in black ink, featuring a large, stylized loop on the left and a series of smaller, connected strokes on the right.

(Muhammad Aulia Nalendra)

ABSTRACT

Mathematics learning in elementary school plays a fundamental role in developing students' logical thinking and numeracy skills. However, conventional learning methods that rely on repetitive exercises often reduce students' engagement and motivation. Digital game-based learning offers an alternative approach by integrating instructional content into interactive gameplay. In addition, the ethnomathematics perspective emphasizes the importance of connecting mathematical concepts with cultural contexts to enhance meaningful learning. One traditional Indonesian game that contains strong mathematical elements is Dakon, which involves counting, comparison, and distribution activities.

This study aims to develop and evaluate the functionality and user perception of a digital Dakon-based mathematics learning game for third-grade elementary school students using the ADDIE instructional design model, which consists of analysis, design, development, implementation, and evaluation stages. The game was developed as an Android-based application using the Unity game engine and integrates arithmetic questions directly into gameplay across three levels of difficulty. A rule-based artificial intelligence (AI) opponent was implemented to support interactive single-player gameplay.

System functionality was evaluated using black-box testing, while user evaluation was conducted through a questionnaire consisting of 13 items measured using a five-point Likert scale, covering aspects of usability, attractiveness, perceived learning support, and user acceptance. The evaluation involved 20 third-grade students from MI Fajar Siddiq Elementary School. The results of black-box testing indicated that all system features operated according to the expected behavior. The questionnaire-based evaluation results showed an overall mean score of 4.25 with a feasibility percentage of 85%, categorized as highly feasible. The reliability analysis produced a Cronbach's alpha value of 0.88, indicating strong internal consistency of the evaluation instrument.

The results indicate that the developed digital Dakon game is perceived as a feasible and engaging learning medium for third-grade elementary students. The integration of cultural context, structured instructional design, and gameplay mechanics shows potential to support students' motivation and learning experience. However, this study evaluates user perception and system functionality, and does not measure actual learning outcomes through experimental methods.

Keywords: digital game-based learning, Dakon, educational game, elementary mathematics, ADDIE, ethnomathematics.

GLOSSARY

ADDIE Model	An instructional design model consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation, used as the framework for developing the learning application in this study.
Analysis Stage	The initial phase in the ADDIE model where learning problems, student characteristics, and system requirements are identified.
Animation	Visual movement effects used to enhance user experience during gameplay.
AI	A system component that simulates an opponent player using predefined rules.
Cronbach's Alpha	A statistical measure used to evaluate the reliability and internal consistency of questionnaire items.
Dakon Game	A traditional Indonesian game involving the distribution of seeds across multiple holes, used as the core gameplay concept in this research.
Game-Based Learning	An instructional approach that integrates educational content into gameplay to enhance learning.
Hole (Pit)	A container in the Dakon board where seeds are placed and distributed.
Mean	The average value of collected data.
Seed	A game object distributed across holes in Dakon gameplay.
Unity Engine	A game development platform used to build the application.

TABLE OF CONTENTS

TITLE PAGE.....	i
SUPERVISOR ENDORSEMENT PAGE	ii
EXAMINER ENDORSEMENT PAGE.....	iii
AUTHENTICITY STATEMENT.....	iv
DEDICATION	v
MOTTO.....	vi
FOREWORD.....	vii
ABSTRACT	ix
GLOSSARY	x
TABLE OF CONTENTS	xi
LIST OF TABLES	xiv
LIST OF FIGURES	xv
CHAPTER I INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Scope of Work	2
1.4 Research Location and Subjects	3
1.5 Research Objectives.....	4
1.6 Research Benefits.....	4
1.6.1 Theoretical Benefits	4
1.6.2 Practical Benefits	5
1.7 Research Methodology	5
1.8 Thesis Organization	6
CHAPTER II LITERATURE REVIEW	7
2.1 Digital Game-Based Learning	7
2.2 Dakon as a Learning Medium.....	7
2.3 Game-Based Learning in Mathematics Education.....	9
2.4 Ethnomathematics in Learning Media	10
2.5 Integration of Ethnomathematics into Digital Games.....	11
2.6 Rule-Based Artificial Intelligence in Game Systems	12
2.7 Instructional Design Models	13
2.7.1 ADDIE Model.....	13

2.7.2	Agile Model	14
2.7.3	Game Development Life Cycle (GDLC)	14
2.7.4	Rapid Application Development (RAD).....	15
2.7.5	Comparative Analysis of Instructional Design Models	15
2.8	Evaluation Constructs in Educational Game Systems	15
2.9	Comparative Analysis of Previous Studies	17
CHAPTER III RESEARCH METHODOLOGY		22
3.1	Research Design.....	22
3.2	Research Location and Subjects	23
3.3	Research Procedure.....	24
3.3.1	Analysis Stage.....	25
3.3.2	Design Stage	26
3.3.3	Development Stage	28
3.3.4	Implementation Stage	29
3.3.5	Evaluation Stage	29
3.4	Ethical Considerations	32
CHAPTER IV RESULTS AND DISCUSSION		33
4.1	Analysis Stage.....	33
4.2	Design Stage	35
4.3	Development Stage	44
4.3.1	Main Menu Interface.....	45
4.3.2	Level Selection.....	47
4.3.3	Gameplay Interface	48
4.3.4	Level 1.....	55
4.3.5	Level 2.....	58
4.3.6	Level 3.....	60
4.4	Implementation	63
4.5	Evaluation	65
4.5.1	Functional Testing.....	65
4.5.2	User Evaluation.....	66
4.5.3	Reliability Analysis.....	69
4.5.4	Discussion	69
4.6	Limitations of the Study.....	71
CHAPTER V CONCLUSION AND SUGGESTIONS		73

5.1	Conclusion	73
5.2	Suggestions	74
REFERENCE		75
APPENDIX		80

LIST OF TABLES

Table 2.1 Topic-Based Analytical Framework of the Previous Studies	17
Table 2.2 Method-Based Analytical Framework of Previous Studies.....	19
Table 3.1 Interview Questions and Purposes	25
Table 3.2 Questionnaire Aspects and Item Distribution.....	31
Table 4.1 Analysis Findings and Design Implications	34
Table 4.2 Examples of Mathematical Questions	42
Table 4.3 AI Move Evaluation Rules	44
Table 4.4 User Questionnaire	64
Table 4.5 Black Box Testing	66
Table 4.6 Respondent Data	67
Table 4.7 Questionnaire Results	68
Table 4.8 Reliability Results.....	69

LIST OF FIGURES

Figure 3.1 Research Workflow Based on ADDIE Model	22
Figure 4.1 Gameplay Workflow	36
Figure 4.2 Starting Page Design	37
Figure 4.3 Main Menu Design	38
Figure 4.4 Level Selection Design.....	39
Figure 4.5 Gameplay Interface Design	39
Figure 4.6 Question Interface Design	40
Figure 4.7 Feedback Interface Design	40
Figure 4.8 Final Result Design	41
Figure 4.9 Unity Main Menu Screenshot.....	45
Figure 4.10 Scene Transition Script for Main Menu	46
Figure 4.11 Level Selection Interface	47
Figure 4.12 Level Selection Handling Using GlobalGameManager Script	48
Figure 4.13 Gameplay Board Interface.....	49
Figure 4.14 Question Popup	50
Figure 4.15 Correct Answer Feedback	50
Figure 4.16 Learning Trigger Based on Selected Level	51
Figure 4.17 Game Initialization Based on Selected Level.....	52
Figure 4.18 User Input Handling for Hole Selection.....	52
Figure 4.19 AI Move Selection Process	53
Figure 4.20 AI Move Evaluation Function	54
Figure 4.21 AI Move Execution with Delay.....	55
Figure 4.22 Level 1 Question Type – Addition	56
Figure 4.23 Level 1 Question Type – Subtraction.....	57
Figure 4.24 Level 1 Question Type – Comparison.....	57
Figure 4.25 Level 1 Question Type – Missing Number	58
Figure 4.26 Level 2 Question Type – Two Number Addition.....	59
Figure 4.27 Level 2 Question Type – Multi-Step Operation.....	59
Figure 4.28 Level 2 Question Type – Mixed Operation.....	60
Figure 4.29 Level 2 Question Type – Two Number Subtraction	60
Figure 4.30 Level 3 Question Types – Multiplication.....	61
Figure 4.31 Level 3 Question Type – Division.....	61

Figure 4.32 Level 3 Question Type – Mixed Operation	62
Figure 4.33 Level 3 Question Type – Missing Number	62
Figure 4.34 User Evaluation Results by Aspect	67

CHAPTER I

INTRODUCTION

1.1 Background

Mathematics learning in elementary school plays an important role in developing students' logical thinking, problem-solving skills, and numeracy competencies, which are fundamental for understanding more advanced mathematical concepts in later stages of education (Tambychik & Meerah, 2010). However, mathematics instruction is often dominated by procedural exercises and repetitive practice, which may improve computational skills but do not always promote meaningful understanding or active student engagement. Consequently, many students perceive mathematics as difficult, abstract, and less enjoyable, leading to lower motivation and participation in learning activities (Attard, 2012).

The rapid development of digital technology has opened new opportunities to create more interactive and engaging learning environments. One approach that has gained significant attention is Digital Game-Based Learning (DGBL), which integrates instructional content with game elements such as challenges, goals, feedback, and progression systems. Previous studies have shown that digital educational games can support student motivation, engagement, and learning experience when learning materials are meaningfully embedded within gameplay.

In addition to technological integration, contextual relevance is also an important factor in effective mathematics learning. The ethnomathematics perspective emphasizes that mathematical concepts are closely related to cultural practices and daily activities. By integrating local cultural elements into learning, abstract mathematical concepts can become more meaningful and easier to understand for students.

One example of a traditional Indonesian game that contains strong mathematical elements is *Dakon* (also known as *Congklak*). The gameplay involves counting, comparing, and distributing objects, which are closely related to basic arithmetic concepts. This makes *Dakon* a potential medium for integrating mathematics learning in a culturally relevant way. Recent studies have shown that digital game-based learning can increase student engagement and motivation in mathematics learning, while ethnomathematics-based approaches can help connect mathematical concepts with students' cultural experiences (Hui & Mahmud, 2023; Masruroh & Amir, 2024). However, most existing studies focus either on digital game-based learning or on ethnomathematics as separate approaches. Only a limited number of studies have

attempted to integrate both aspects into a structured digital learning system that combines educational gameplay with culturally relevant mathematical contexts.

Based on these conditions, there is a need to develop a learning medium that combines digital game-based learning, cultural context, and structured instructional design. This study does not only adapt *Dakon* into a digital format, but also integrates arithmetic questions directly into gameplay, applies the ADDIE model as a structured development framework, and evaluates the system in terms of functionality and user perception. Therefore, this study proposes the development of a digital Dakon-based mathematics learning game as an interactive learning medium. This study does not measure actual learning outcomes through experimental methods, but focuses on evaluating students' perceptions of the developed game.

1.2 Problem Statement

In this study, the research problems are formulated as follows:

1. How can a digital Dakon-based game be developed as a mathematics learning medium for elementary school students using a structured instructional design approach?
2. How can mathematical concepts be effectively integrated into gameplay mechanics to support meaningful learning?
3. How can cultural context (ethnomathematics) be incorporated into digital game-based learning to enhance students' understanding of mathematical concepts?
4. How feasible is the developed digital Dakon-based game in terms of usability, perceived learning support, and user acceptance among elementary school students?

1.3 Scope of Work

This study focuses on the development of a digital Dakon-based mathematics learning game for elementary school students using the ADDIE development model. The scope of work and limitations of this study are defined as follows:

1. This study involves the development of a digital mathematics learning game based on the traditional Dakon game using the ADDIE model, which includes analysis, design, development, implementation, and evaluation stages.
2. The system is developed using the Unity game engine with the C# programming language.
3. The application is designed for Android-based devices only.
4. The learning content is limited to basic arithmetic concepts suitable for elementary school students, including addition, subtraction, multiplication, and division.

5. The gameplay integrates mathematical questions into the Dakon game mechanics, where user responses influence the progression of the game.
6. The system includes a rule-based artificial intelligence opponent to support single-player mode.
7. The implementation stage involves testing the application with elementary school students to observe user interaction and usability.
8. The evaluation is conducted using a questionnaire-based approach focusing on usability, attractiveness, perceived learning support, and user acceptance.
9. The evaluation results are analyzed using descriptive statistics and reliability testing.
10. The cultural context applied in this study is limited to the traditional Dakon game as a form of ethnomathematics.
11. This study evaluates user perception and does not measure actual learning outcomes through experimental methods.

1.4 Research Location and Subjects

This study was conducted at MI Fajar Siddiq Elementary School located in Palembang, Indonesia. The selection of this location was based on its relevance to the research objectives, particularly in relation to elementary mathematics learning and the availability of students as target users of the developed educational game.

The subjects of this study consisted of twenty third-grade students enrolled at the school. These participants were selected because the developed digital Dakon game was specifically designed to support arithmetic learning at the elementary level, including basic operations such as addition, subtraction, multiplication, and division. Third-grade students were considered appropriate as they had already been introduced to these mathematical concepts in their curriculum.

The research was carried out over a period from July 2025 to January 2026. The analysis phase was conducted in July 2025, followed by the design phase from August to October 2025, and the development phase from October 2025 to January 2026. The implementation stage took place on January 28, 2026, during which the students interacted directly with the developed application in a classroom setting.

During the implementation, students used Android-based mobile devices to play the game under the supervision of the teacher and the researcher. The activity was conducted in a controlled classroom environment to ensure that students could follow the gameplay

instructions properly and provide reliable feedback during the evaluation stage. The classroom implementation environment is shown in Appendix A.

1.5 Research Objectives

Based on the problem statement described in the previous section, this study aims to develop and evaluate a culturally contextualized digital learning medium that integrates digital game-based learning, ethnomathematics, and structured instructional design in elementary mathematics education. The specific objectives of this research are as follows:

1. To design and develop a digital Dakon-based mathematics learning game using the ADDIE instructional design model, ensuring that the development process is carried out systematically through the stages of analysis, design, development, implementation, and evaluation.
2. To integrate arithmetic learning content into the gameplay mechanics of the Dakon game in a structured and meaningful manner, so that mathematical problem-solving activities become an integral part of the game and directly influence gameplay progression.
3. To implement cultural context through the adaptation of the traditional Dakon game into a digital format, in order to enhance the relevance and meaningfulness of mathematics learning for elementary school students.
4. To evaluate the feasibility of the developed application as a learning medium based on user perceptions, including aspects of usability, attractiveness, perceived learning support, and user acceptance.
5. To provide empirical evidence regarding students' perceptions of the potential of integrating digital game-based learning and ethnomathematics in elementary mathematics learning.

1.6 Research Benefits

This study is expected to provide several benefits, both theoretically and practically, in the field of educational technology and mathematics learning.

1.6.1 Theoretical Benefits

This study contributes to the development of knowledge in digital game-based learning and ethnomathematics, particularly in elementary mathematics education. It demonstrates how cultural context, instructional design, and interactive digital media can be integrated into a

cohesive learning system. In addition, this research provides a reference for future studies on the development of educational games using the ADDIE model.

1.6.2 Practical Benefits

Practically, this study provides benefits for several stakeholders. For students, the application serves as an interactive learning medium that supports understanding of basic arithmetic concepts. For teachers, it offers an alternative tool to complement conventional teaching methods. For developers and researchers, this study provides a structured approach to designing educational games by integrating instructional design, cultural context, and gameplay mechanics. Furthermore, the findings can serve as a reference for developing similar applications that enhance perceived learning support and user experience.

1.7 Research Methodology

This research uses the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model as the development methodology for designing and developing a digital Dakon-based educational game for elementary school mathematics learning. The ADDIE model is selected because it provides a systematic and structured approach, making it suitable for developing instructional media.

The stages of the research are described as follows:

1. Analysis

The analysis stage is the initial phase conducted to identify problems and user needs in mathematics learning for elementary school students. This stage involves literature study, observation, and analysis of user characteristics. The results of this stage are used to define learning objectives, determine the game concept, and identify system requirements.

2. Design

The design stage aims to develop the structure and concept of the game. This includes designing gameplay mechanics, user interface (UI/UX), storyboard, and user interaction flow. In addition, the integration between the traditional Dakon game and mathematical problem-solving activities is planned in this stage.

3. Development

The development stage involves implementing the design into a functional application using the Unity game engine. This stage includes asset creation, system coding, gameplay

implementation, question system integration, and overall system development to ensure the application runs properly.

4. Implementation

The implementation stage is conducted by applying the developed game in a real environment. The application is tested on target devices and used by users to evaluate its usability and functionality in actual learning conditions.

5. Evaluation

The evaluation stage is carried out to assess the quality and perceived learning support of the developed game. This stage includes both internal testing (alpha testing) and external testing (beta testing) involving users. The results are used to identify strengths and weaknesses and to support further improvements.

1.8 Thesis Organization

This thesis is organized into several chapters to provide a structured and systematic presentation of the research as follows:

1. Chapter I introduces the study, including the background, problem statement, research objectives, research benefits, scope and limitations, and thesis organization. This chapter provides an overview of the research context and the main issues addressed.
2. Chapter II presents the literature review, which discusses relevant studies and approaches related to digital game-based learning, ethnomathematics, educational game development, and the ADDIE model. This chapter focuses on analyzing previous solutions and justifying the selected approach used in this study.
3. Chapter III describes the research methodology, including the research approach and the system development process based on the ADDIE model (analysis, design, development, implementation, and evaluation). It also explains the data collection and evaluation methods used to assess the application.
4. Chapter IV presents the results and discussion, including the outcomes of each ADDIE phase, the developed game features, and the results of testing and user evaluation. The findings are discussed in relation to the research objectives.
5. Chapter V concludes the study by summarizing the main findings and providing recommendations for future research and further development of the educational game.

CHAPTER II

LITERATURE REVIEW

2.1 Digital Game-Based Learning

Digital game-based learning (DGBL) has emerged as an important approach in educational technology due to its ability to combine instructional content with interactive gameplay elements. In DGBL environments, learning activities are integrated into game mechanics such as goals, rules, challenges, feedback, and progression systems, allowing learners to actively engage with learning materials rather than passively receive information.

Previous studies have shown that digital educational games can support learning experiences, motivation, engagement, and satisfaction when instructional content is meaningfully embedded within gameplay mechanics (Nadeem et al., 2023; Sun et al., 2021; Yu et al., 2021). In addition, meta-analytic studies indicate that digital games can enhance academic achievement, including in mathematics and other STEM-related learning contexts (Barz et al., 2024; Gui et al., 2023; Hui & Mahmud, 2023). In primary mathematics education, DGBL has also been shown to support arithmetic fluency, conceptual understanding, and positive learning attitudes among elementary students (Dan et al., 2024; Kocabatmaz & Saraçoğlu, 2024).

However, the effectiveness of DGBL is not determined solely by the presence of game elements. Prior research emphasizes that learning experiences depend on how well instructional content is aligned with gameplay mechanics and learning objectives (All et al., 2021; Hussein et al., 2022; Ishak et al., 2021). Games that prioritize entertainment without strong pedagogical integration may fail to support meaningful understanding, while overly structured systems with limited interactivity may reduce learner engagement.

Therefore, DGBL should be viewed not only as a technological innovation but also as an instructional approach that requires careful design. Effective DGBL environments must balance engagement and pedagogy by ensuring that gameplay mechanics actively support learning processes. This highlights the importance of aligning instructional content, game design, and evaluation to achieve a meaningful learning experience.

2.2 Dakon as a Learning Medium

Dakon, also known as Congklak in several regions of Indonesia, is a traditional board game that has been widely played across generations. The game typically consists of a board

with multiple small pits and two larger storage pits, along with a number of seeds or shells. Players take turns distributing the seeds across the pits according to specific rules, with the objective of collecting as many seeds as possible in their main storage pit. As part of the mancala family of games, Dakon has been widely studied due to its structured gameplay and strategic characteristics, particularly in relation to counting and distribution processes (Donkers et al., 2003).

From a cultural perspective, Dakon represents an important element of Indonesia's traditional heritage. It is commonly played as a social activity that encourages interaction, turn-taking, and strategic thinking among players. As a form of traditional knowledge, Dakon reflects local cultural values and practices embedded in everyday life. This cultural relevance provides a strong foundation for integrating Dakon into educational contexts through the concept of ethnomathematics, which highlights the relationship between mathematical concepts and cultural practices (D'Ambrosio, 1985).

Beyond its cultural significance, Dakon also contains inherent mathematical affordances within its gameplay. The mechanics of the game require players to perform counting, sequential distribution, and basic arithmetic operations. Players must monitor the number of seeds, anticipate possible outcomes, and make decisions based on numerical reasoning. These processes support the development of fundamental arithmetic skills, such as addition, subtraction, and number sense. Furthermore, interactive gameplay has been shown to enhance mathematical understanding by engaging learners in active problem-solving processes (Ke, 2008).

From a pedagogical perspective, Dakon is particularly suitable for elementary school students, especially those who are learning basic arithmetic concepts. The game provides a concrete and interactive representation of abstract mathematical ideas, allowing students to learn through direct manipulation and experience. This aligns with constructivist learning principles, where students build understanding through active engagement rather than passive instruction. As a result, Dakon can support both conceptual understanding and learning motivation in mathematics education.

Building upon its cultural, mathematical, and pedagogical potential, Dakon can be effectively adapted into a digital learning environment. The transformation of Dakon into a digital educational game allows the integration of interactive features, feedback mechanisms, and structured difficulty levels. By embedding mathematical tasks directly into gameplay, the digital version can provide a more engaging and controlled learning experience. In addition,

digital game-based learning environments have been shown to enhance engagement and learning experiences when instructional content is meaningfully integrated into gameplay mechanics (Plass et al., 2015).

Therefore, beyond its role as a traditional cultural game, Dakon also demonstrates strong potential as a medium for supporting mathematical learning through interactive play. The inherent mathematical processes embedded in the gameplay indicate that traditional games can be aligned with structured learning approaches. This connection highlights the relevance of examining how game-based learning is applied more broadly in mathematics education.

2.3 Game-Based Learning in Mathematics Education

Mathematics learning in elementary education often presents challenges related to student engagement and conceptual understanding. Many students perceive mathematics as abstract and difficult, particularly when learning is dominated by repetitive exercises and procedural tasks. While such approaches may support memorization, they do not always promote meaningful understanding or problem-solving ability. As a result, students may struggle to apply mathematical concepts in different contexts, especially when higher-order thinking is required.

Game-based learning has been increasingly explored as an alternative approach to address these challenges. By integrating learning content into interactive environments, educational games can provide opportunities for active participation, immediate feedback, and continuous practice. Previous studies have shown that digital game-based learning can support arithmetic fluency, conceptual understanding, and positive attitudes toward mathematics among elementary students (Dan et al., 2024; Hui & Mahmud, 2023; Kocabatmaz & Saraçoğlu, 2024). In addition, game-based environments can enhance student motivation and persistence by presenting learning tasks in the form of achievable challenges and progressive levels.

However, not all game-based learning implementations in mathematics produce strong learning experience. Some studies indicate that while games can increase engagement, they do not always guarantee improvements in conceptual understanding if the learning content is not well integrated into the gameplay structure. In certain cases, students may focus more on completing game objectives rather than understanding the underlying mathematical concepts. This suggests that the effectiveness of game-based learning depends on how well instructional content is embedded within game mechanics and aligned with learning objectives (All et al., 2021; Hussein et al., 2022).

Therefore, in the context of mathematics education, game-based learning should not be designed solely for entertainment purposes but must also support structured learning processes. The integration of clear learning objectives, appropriate difficulty progression, and meaningful interaction is essential to ensure that students not only enjoy the learning experience but also develop a deeper understanding of mathematical concepts.

While game-based learning has been widely recognized for its ability to enhance engagement and understanding, most implementations focus primarily on gameplay mechanics and learning outcomes without considering cultural relevance. However, integrating cultural context into learning environments can further strengthen meaning and student connection to the material. This consideration leads to the concept of ethnomathematics, which connects mathematical ideas with cultural practices.

2.4 Ethnomathematics in Learning Media

The concept of ethnomathematics emphasizes that mathematical ideas are closely related to cultural practices, daily activities, and local ways of thinking. Rather than viewing mathematics as purely abstract and universal, ethnomathematics highlights how mathematical concepts are embedded in cultural contexts and can be understood through real-life experiences (Gerdes, 1996; D'Ambrosio, 2001). This perspective is particularly relevant in elementary education, where students tend to learn more effectively when new concepts are connected to familiar environments.

In recent years, ethnomathematics has been increasingly applied in the development of learning media to enhance student engagement and conceptual understanding. Studies have shown that integrating local cultural contexts into mathematics learning can improve students' interest, relevance, and comprehension of mathematical concepts (Suryawan et al., 2022; Putri et al., 2023; Rahmawati et al., 2021). By connecting mathematical problems with real-life cultural activities, students are able to construct knowledge more meaningfully rather than relying solely on memorization.

However, despite its potential, the implementation of ethnomathematics in learning media still faces several limitations. Many existing approaches utilize static formats such as textbooks, worksheets, or instructional modules, which limit student interaction and active participation. As a result, the learning process often remains passive, with students receiving information rather than engaging in problem-solving activities. In addition, even when digital

media are used, cultural elements are frequently presented only as contextual examples or visual representations, without being meaningfully integrated into the learning process.

These limitations indicate that ethnomathematics has not yet been fully utilized in interactive learning environments, particularly in terms of active engagement and meaningful interaction. To address this issue, cultural elements should not only serve as contextual backgrounds but also be embedded within interactive systems. Therefore, integrating ethnomathematics into digital educational games becomes an important direction to enhance both engagement and learning experience.

2.5 Integration of Ethnomathematics into Digital Games

Building upon the role of ethnomathematics in connecting cultural context and mathematical understanding, integrating these concepts into digital educational games becomes a relevant and necessary step in modern learning environments. By combining cultural context with interactive gameplay, digital educational games can provide meaningful learning experiences that connect abstract mathematical concepts with students' everyday experiences. In this context, traditional cultural activities function not only as thematic elements but also as integral components of gameplay that support the learning process.

Several studies have explored the use of ethnomathematics in digital or technology-supported learning media, showing that cultural integration can enhance student engagement and contextual understanding (D'Ambrosio, 1985; Harefa, 2024; Masruroh & Amir, 2024; Yandani & Agustika, 2022). However, most of these implementations are still limited in terms of interactivity and integration depth. Cultural elements are often presented as visual representations or contextual examples, rather than being embedded into gameplay mechanics that directly influence learning activities.

In digital game-based learning environments, the contribution of ethnomathematics depends on how deeply cultural elements are integrated into the core game system. When cultural aspects are used only as background themes, their impact on conceptual understanding tends to be limited. In contrast, embedding cultural practices within gameplay mechanics can create meaningful interactions that support active learning and problem-solving processes.

Despite this potential, the integration of ethnomathematics into digital games is still not widely implemented in a comprehensive manner. Many educational games emphasize gameplay and engagement while treating cultural elements as secondary components. Conversely, ethnomathematics-based learning media often lack interactive features and are not

developed as complete digital game systems with progressive levels and feedback mechanisms. This gap indicates that the integration of ethnomathematics, interactive gameplay, and structured instructional design has not been fully explored.

There remains a clear need for educational game designs that integrate cultural context directly into gameplay mechanics, allowing students to experience mathematical concepts through active participation. This approach is particularly relevant in the development of games based on traditional cultural activities such as Dakon, where gameplay naturally involves counting, distribution, and strategic thinking. By embedding mathematical tasks within culturally meaningful interactions, digital learning environments can support both engagement and conceptual understanding.

2.6 Rule-Based Artificial Intelligence in Game Systems

Artificial Intelligence (AI) in digital games refers to the ability of a system to simulate intelligent behavior in order to create interactive and responsive gameplay. In educational games, AI is commonly used to simulate opponents, maintain player engagement, and provide appropriate levels of challenge that match the player's ability (Yannakakis & Togelius, 2018).

One of the widely used approaches in game AI is rule-based artificial intelligence. This approach operates using a set of predefined rules or conditions that determine the system's behavior in specific situations. Instead of learning from data, the system follows logical instructions designed by the developer, allowing it to respond consistently to player actions. Due to its simplicity, predictability, and ease of implementation, rule-based AI is commonly applied in digital games (Yannakakis & Togelius, 2018).

In the context of board-based games such as Dakon, rule-based AI is particularly suitable because the gameplay is structured and governed by clear rules. The AI can evaluate possible moves based on predefined conditions, such as the number of seeds in each pit and the potential outcomes of each move. This enables the system to simulate a human-like opponent while maintaining consistent and understandable behavior.

A common implementation of rule-based AI in games involves the use of heuristic or greedy strategies, where the system selects actions that provide immediate benefits based on current conditions. Although this approach does not guarantee optimal long-term decisions, it is effective for maintaining gameplay flow and providing an appropriate level of challenge for players (Yannakakis & Togelius, 2018).

In addition to its technical advantages, the use of rule-based AI is particularly appropriate in educational game contexts. Since Dakon gameplay is highly structured, a predictable opponent behavior allows students to better understand the game mechanics and focus on the learning tasks embedded within the gameplay. An AI system that behaves consistently helps reduce cognitive load, enabling learners to concentrate on solving mathematical problems rather than adapting to unpredictable opponent behavior.

Furthermore, in educational settings, transparency and interpretability of the system are important considerations. Rule-based AI allows the decision-making process to be more easily understood and explained compared to more complex AI approaches. This makes it more suitable for learning environments, where the goal is not only to engage users but also to support meaningful and comprehensible interactions. Therefore, rule-based AI is selected in this study not only due to its simplicity and ease of implementation, but also because it aligns with the structured nature of Dakon gameplay and supports predictable, consistent, and pedagogically appropriate interactions within an educational game environment.

2.7 Instructional Design Models

Instructional design models play an important role in the development of educational games, as they provide a structured framework for organizing learning content, interaction, and evaluation. The selection of an appropriate development model is essential to ensure that the resulting system not only functions properly but also supports meaningful learning processes.

Several models have been widely used in the development of educational applications, including ADDIE, Agile, Game Development Life Cycle (GDLC), and Rapid Application Development (RAD). Each model offers different advantages and limitations in terms of flexibility, development speed, and alignment with instructional objectives. Therefore, this section discusses these models and compares their characteristics to determine the most suitable approach for developing a culturally contextualized digital mathematics game.

2.7.1 ADDIE Model

The ADDIE model (Analyze, Design, Develop, Implement, Evaluate) is a widely used instructional design framework in the development of educational media (Branch, 2009). This model provides a systematic approach that ensures learning objectives, content structure, and evaluation processes are well aligned.

The analysis stage focuses on identifying learner characteristics, learning needs, and contextual problems. The design stage involves planning instructional strategies, content organization, and interaction flow. The development stage translates the design into a functional product, while the implementation stage involves applying the product in a real learning environment. Finally, the evaluation stage is conducted to assess the perceived learning support of the learning process and to provide feedback for improvement (Branch, 2009).

The strength of the ADDIE model lies in its structured approach to integrating pedagogical aspects into product development. By emphasizing analysis and evaluation, ADDIE ensures that the developed system is not only functional but also effective in supporting learning experience. However, the model can be relatively time-consuming and less flexible compared to iterative development approaches (Branch, 2009).

2.7.2 Agile Model

Agile is an iterative development model that emphasizes flexibility, collaboration, and rapid adaptation to changes (Dingsøyr et al., 2012). In Agile development, the product is built incrementally through short development cycles known as sprints, allowing continuous improvement based on user feedback.

The Agile model emphasizes flexibility, iterative development, and continuous feedback, making it suitable for dynamic software environments. However, it places less emphasis on structured instructional design, which may limit its effectiveness in ensuring alignment between learning objectives and system development in educational applications.

However, Agile primarily focuses on technical development and flexibility, with less emphasis on structured instructional design. As a result, it may not fully support the systematic integration of learning objectives required in educational applications.

2.7.3 Game Development Life Cycle (GDLC)

The Game Development Life Cycle (GDLC) is specifically designed for game production, consisting of stages such as concept, design, development, testing, and release (Ramadan & Widayani, 2013). This model provides a clear structure for managing the technical and production aspects of game development.

Despite its strengths, GDLC mainly emphasizes production processes and does not explicitly address instructional design principles. Therefore, its application in educational game development may require additional frameworks to ensure alignment with learning objectives.

2.7.4 Rapid Application Development (RAD)

Rapid Application Development (RAD) focuses on fast prototyping and rapid system development through iterative cycles (Martin, 1991). This approach allows developers to produce functional systems in a relatively short time. However, the emphasis on speed often reduces the depth of analysis and instructional planning. In educational contexts, this limitation may affect the alignment between system design and learning objectives, making RAD less suitable for structured educational applications.

2.7.5 Comparative Analysis of Instructional Design Models

Based on the comparison of the models described above, each approach offers different strengths depending on the development context. Agile and RAD provide flexibility and rapid development, while GDLC supports structured game production processes. However, these models tend to focus more on technical or production aspects rather than instructional design.

In contrast, the ADDIE model provides a balanced framework that integrates analysis, design, development, and evaluation within a structured process (Branch, 2009). Its emphasis on instructional alignment and iterative refinement makes it particularly suitable for developing educational games that require integration between learning objectives, cultural context, and interactive gameplay.

Therefore, the ADDIE model is selected in this study as it supports the development of a digital Dakon-based mathematics learning game in a systematic, pedagogically grounded, and iterative manner. This model enables the integration of instructional design, cultural context, and interactive gameplay within a coherent framework, ensuring alignment between learning objectives and system development.

2.8 Evaluation Constructs in Educational Game Systems

The evaluation of educational games requires appropriate constructs to assess both the functional quality of the system and the user experience during interaction. In the context of digital game-based learning, evaluation is not limited to technical performance but also includes how users perceive usability, engagement, learning support, and overall acceptance of

the system. Therefore, this study adopts four main evaluation constructs, namely usability, attractiveness, perceived learning support, and user acceptance.

Usability refers to the extent to which a system can be used easily and effectively by users to achieve specific goals (Brooke, 1996). In educational games, usability is an important factor because it determines whether students can understand the game mechanics, navigate the interface, and interact with the system without confusion. A system with good usability enables learners to focus on learning tasks rather than struggling with interface complexity.

Attractiveness is related to the visual appeal and the overall user experience of the system. According to (Hassenzahl, 2004), attractiveness reflects users' emotional responses toward a product, including enjoyment, aesthetics, and engagement. In digital game-based learning environments, attractive design elements such as colors, animations, and visual feedback play an important role in maintaining user motivation and sustaining engagement throughout the learning process.

Perceived learning support refers to users' perceptions of how well a system facilitates their understanding of learning content. In this study, the focus is not on measuring actual learning outcomes, but rather on how students perceive the usefulness of the game in supporting their mathematical understanding. Previous research in digital game-based learning suggests that perceived learning support is an important indicator in early-stage evaluation, particularly when the system is assessed based on user experience rather than experimental learning outcomes (Plass et al., 2015).

User acceptance refers to the willingness of users to use and continue using a system, as well as their overall satisfaction with the experience. This construct is closely related to the Technology Acceptance Model (TAM), which emphasizes perceived usefulness and ease of use as key factors influencing user acceptance (Davis, 1989). In the context of educational games, user acceptance indicates whether the system is considered enjoyable, useful, and worth using as a learning medium.

These four constructs are used in this study to evaluate the developed digital Dakon-based mathematics game through a perception-based approach. By combining usability, attractiveness, perceived learning support, and user acceptance, the evaluation provides a comprehensive understanding of how the system performs as an interactive learning medium from the users' perspective.

2.9 Comparative Analysis of Previous Studies

Previous studies related to digital educational games, ethnomathematics, and mathematics learning were systematically reviewed to provide a comprehensive foundation for this research. The literature search was conducted using Google Scholar with keywords such as educational game, digital Dakon game, ethnomathematics, game-based learning, and mathematics learning game, focusing on publications from the last five years.

To provide a clearer overview, Table 2.1 presents a comparative analysis of previous studies based on key topics, including game-based learning, digital educational games, ethnomathematics, Dakon-based learning, and instructional design approaches.

Table 2.1 Topic-Based Analytical Framework of the Previous Studies

Source	GBL	Digital Educational Game	Ethnomathematics	Dakon Game	Instructional Design	Description
(Putra et al., 2025)	✓	✓			✓ (ADDIE)	Development of an educational game using the ADDIE model to improve student engagement and learning experience
(Eliyanti et al., 2024)	✓	✓			✓ (ADDIE)	Development of Android-based learning media using the ADDIE model
(Dahnial, 2024)	✓	✓			✓ (GDLC)	Development of a mathematics educational game focusing on gameplay and interaction
(Satriyo et al., 2025)		✓			✓ (Waterfall)	Development of an educational application using the Waterfall method
(Roostin, 2025)	✓	✓	✓	✓	✓ (R&D + ADDIE)	Development of a digital Dakon game (Smartda) to improve early childhood science literacy
(Sujaryanto, 2025)	✓		✓	✓		Implementation of Dakon as a

						mathematics learning medium in elementary school
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Based on Table 2.1, several analytical patterns can be identified across previous studies when examined from multiple perspectives. In terms of educational level, the majority of studies are conducted at the elementary school level, particularly in the development of digital educational games (Dahnial, 2024; Eliyanti et al., 2024; Putra et al., 2025). In contrast, studies that incorporate Dakon as a cultural learning medium, such as Roostin (2025) and Sujaryanto (2025), are more commonly associated with early childhood or lower-grade contexts, indicating a clear distinction where digital game-based learning is dominant in elementary education, while traditional cultural games are more prevalent in earlier learning stages.

From the perspective of system implementation, most studies adopt digital educational games (Dahnial, 2024; Eliyanti et al., 2024; Putra et al., 2025; Satriyo et al., 2025), highlighting the dominance of technology-based learning environments. These studies emphasize interactivity and engagement through technology as the main approach to support learning. However, the integration of ethnomathematics and Dakon within a digital game system is still very limited. Roostin (2025) represents one of the few studies that combine Dakon with digital implementation, while Sujaryanto (2025) utilizes Dakon in a non-digital format, indicating that the transformation of culturally grounded traditional games into fully integrated digital learning systems remains underexplored.

In terms of evaluation approaches, previous studies can be categorized into experimental or outcome-based evaluation and system-oriented or perception-related evaluation. Several studies, such as Putra et al. (2025) and Dahnial (2024), emphasize experimental evaluation through learning outcomes, including effectiveness testing and improvement in student performance. Meanwhile, studies such as Eliyanti et al. (2024) and Satriyo et al. (2025) focus more on system development and functionality, with limited emphasis on user perception. However, perception-based evaluation that explicitly measures usability, attractiveness, perceived learning support, and user acceptance as the primary evaluation framework has not been identified as the main focus in previous studies, indicating that user perception is generally treated as a secondary aspect rather than a central evaluation component.

Furthermore, various instructional design models such as ADDIE, GDLC, Waterfall, and R&D are employed in previous studies to guide the development process. These models

provide structured approaches for system design and implementation, particularly in organizing development stages and ensuring technical feasibility. However, their application is generally limited to supporting system development rather than integrating pedagogical design, cultural context, gameplay mechanics, and evaluation within a unified framework. This indicates that the role of instructional design models in previous studies has not been fully optimized to support a holistic educational game development approach.

Overall, the analysis shows that previous studies tend to address educational game development in a fragmented manner, focusing on individual aspects such as digital gameplay, instructional design, or cultural context. There is no study that simultaneously integrates digital game-based learning, Dakon as an ethnomathematical context, a structured ADDIE development model, and perception-based evaluation (including usability, attractiveness, perceived learning support, and user acceptance) as the primary assessment approach.

Therefore, this study positions itself as a more comprehensive and integrative approach by combining these elements into a single coherent educational game system. This distinction highlights the contribution of the present study, which addresses the identified gap by integrating pedagogical design, cultural context, and user-centered evaluation within one unified framework.

In addition to topic-based analysis, previous studies can also be examined from the perspective of development methods. Different development approaches influence how the system is designed, implemented, and evaluated. Therefore, Table 2.2 presents a comparative analysis based on the development methods used in previous studies.

Table 2.2 Method-Based Analytical Framework of Previous Studies

Method	Literature	Advantages	Limitations	Characteristics
ADDIE	(Eliyanti et al., 2024; Putra et al., 2025; Roostin, 2025)	Systematic and structured process; ensures alignment between learning objectives and system development; suitable for educational media	Requires more time; less flexible when changes occur	Consists of Analysis, Design, Development, Implementation, and Evaluation stages
GDLC	(Dahnial, 2024)	Focuses on gameplay and interactivity; suitable for game development	Lacks emphasis on pedagogical aspects and structured evaluation	Focuses on game development stages such as concept, design, development, and testing

Waterfall	(Satriyo et al., 2025)	Clear and structured development process; easy to manage	Not flexible to changes; difficult to revise during development	Linear process from requirement to maintenance
R&D	(Roostin, 2025)	Produces a product and validates it through experimental evaluation; strong evidence of effectiveness	Complex process; requires more time and resources	Combines product development with validation through experiments
Qualitative Approach	(Sujaryanto, 2025)	Provides in-depth understanding of user experience and learning process	Cannot measure effectiveness quantitatively; limited generalization	Based on observation, interviews, and descriptive analysis

Based on Table 2.2, it can be observed that different development methods offer distinct advantages depending on the focus of the system. Methods such as GDLC and Waterfall emphasize technical development and system structure, while R&D focuses on experimental validation, and qualitative approaches provide in-depth insights into user experience. However, these methods often lack a balanced integration between pedagogical design and system development.

In contrast, the ADDIE model provides a more comprehensive framework that integrates instructional design with system development. Its structured stages ensure that learning objectives, content design, implementation, and evaluation are systematically aligned. This makes ADDIE particularly suitable for educational game development, where both learning effectiveness and user experience must be considered.

In addition to the comparison of development methods, it is also important to consider how these methods relate to the type of evaluation used in previous studies. Methods such as R&D are commonly associated with experimental validation, focusing on measuring learning outcomes, while qualitative approaches emphasize user experience and descriptive analysis. In contrast, technical models such as GDLC and Waterfall often prioritize system development without explicitly integrating evaluation from a pedagogical perspective.

The ADDIE model offers a more balanced approach by incorporating evaluation as an integral part of the development process. Unlike models that focus solely on technical or experimental aspects, ADDIE enables the integration of instructional design, system development, and evaluation within a unified framework. This makes it particularly suitable for studies that aim to evaluate user perception as an initial validation of an educational system.

Furthermore, when viewed in relation to the findings in Table 2.1, it becomes evident that previous studies rarely combine structured development methods with culturally grounded learning content and perception-based evaluation. This highlights a methodological gap, where the alignment between instructional design, cultural context, and user-centered evaluation has not been fully achieved.

From this comparison, it becomes evident that no single approach in previous studies fully integrates interactive gameplay, cultural context, and structured instructional design within a unified system. Therefore, this study adopts the ADDIE model as the development framework to address this gap, while also incorporating ethnomathematics through the Dakon game and evaluating user perception as an initial validation of the system.

Based on the analysis of previous studies, a clear gap can be identified in the integration of several key aspects within educational game development. Existing studies rarely combine traditional games such as Dakon, ethnomathematics, interactive digital gameplay, structured instructional design using the ADDIE model, and perception-based evaluation within a single, unified system. Most prior research tends to focus on only one or two of these elements, resulting in partial and less comprehensive approaches.

Furthermore, previous studies generally emphasize either learning outcomes through experimental methods or user experience through qualitative analysis. The integration of systematic development processes with user perception-based evaluation remains limited, particularly in culturally grounded educational games that require both pedagogical alignment and engaging gameplay.

Therefore, this study is conducted to address the identified gap by developing a digital Dakon-based mathematics learning game that integrates cultural context through ethnomathematics and applies the ADDIE model as a structured instructional design framework. Unlike previous studies that primarily focus on experimental learning outcomes or qualitative user experience, this research emphasizes a perception-based evaluation approach, assessing usability, attractiveness, perceived learning support, and user acceptance as key indicators of system feasibility.

In addition, this study combines interactive gameplay, cultural relevance, and structured development within a single system, allowing mathematical learning activities to be embedded directly into gameplay mechanics. Through this integrated approach, the research contributes to the development of a more comprehensive and pedagogically grounded educational game framework, particularly for elementary mathematics learning.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research Design

This study adopts a Research and Development (R&D) approach to design and develop a digital Dakon-based mathematics learning game. The development process is conducted using the ADDIE instructional design model, which provides a systematic framework consisting of five stages: analysis, design, development, implementation, and evaluation.

The ADDIE model is selected because it ensures that instructional objectives, learning content, system design, and evaluation are aligned within a structured development process. This characteristic is particularly important in educational game development, where both pedagogical considerations and user experience must be integrated effectively. The overall research workflow based on ADDIE model applied in this study is illustrated in Figure 3.1.



Figure 3.1 Research Workflow Based on ADDIE Model

As shown in Figure 3.1, the development process begins with the analysis stage, which involves teacher consultation and identification of learning needs. The results of this stage are used to inform the design stage, where the game structure, user interface, and mathematical content are planned. The development stage then focuses on implementing the system using

the Unity game engine and integrating features such as gameplay mechanics and AI components.

Following development, the implementation stage involves testing the application in a classroom environment with students as users. Finally, the evaluation stage is conducted using questionnaires and statistical analysis, including Cronbach's alpha, to assess usability, attractiveness, perceived learning support, and user acceptance.

The workflow reflects a structured progression across the ADDIE stages, where the output of each stage becomes the input for the next stage. Although the ADDIE model conceptually allows iterative refinement, this study primarily follows a single development cycle. Feedback obtained during the evaluation stage is used as a reference for potential future improvements rather than being implemented through multiple redesign iterations within the scope of this research.

The use of the ADDIE model in this study provides a systematic and structured framework for integrating instructional design, cultural context, and interactive gameplay within a single educational system. This approach supports the alignment between learning design and user experience, making it suitable for the development of educational games based on user perception.

3.2 Research Location and Subjects

This study was conducted at MI Fajar Siddiq Elementary School located in Palembang, Indonesia. The selection of this location was based on its relevance to the research objectives, particularly in relation to elementary mathematics learning and the availability of students as target users of the developed educational game. In addition, the location was selected due to the researcher's accessibility to the school environment, which facilitated coordination with teachers and supported the implementation of the study in a controlled classroom setting.

The subjects of this study consisted of twenty third-grade students enrolled at the school. These participants were selected because the developed digital Dakon game was specifically designed to support arithmetic learning at the elementary level, including basic operations such as addition, subtraction, multiplication, and division. Third-grade students were considered appropriate as they had already been introduced to these mathematical concepts in their curriculum.

The selection of participants was carried out using a convenience sampling approach, where one third-grade class was chosen based on the recommendation of the mathematics

teacher and the willingness of the homeroom teacher to facilitate the research process. Therefore, not all third-grade classes in the school were included in this study. The selected class was considered suitable due to its accessibility and readiness to participate in the implementation and evaluation activities.

The research was carried out over a period from July 2025 to January 2026. The analysis phase was conducted in July 2025, followed by the design phase from August to October 2025, and the development phase from October 2025 to January 2026. The implementation stage took place on January 28, 2026, during which the students interacted directly with the developed application in a classroom setting.

During the implementation, students used Android-based mobile devices to play the game under the supervision of the teacher and the researcher. The activity was conducted in a controlled classroom environment to ensure that students could follow the gameplay instructions properly and provide reliable feedback during the evaluation stage.

3.3 Research Procedure

This study followed a systematic development procedure based on the ADDIE instructional design model, which consists of five stages: analysis, design, development, implementation, and evaluation. The model was selected because it provides a structured framework for integrating learning objectives, instructional content, and system development into a coherent process. This structured approach ensures that both pedagogical aspects and technical implementation are aligned throughout the development process.

Each stage in the ADDIE model plays a specific role in guiding the development of the digital Dakon-based mathematics game. The analysis stage focuses on identifying learning needs and contextual problems. The design stage translates these findings into a structured game concept and instructional plan. The development stage involves the implementation of the system using appropriate technologies. The implementation stage evaluates the system through real user interaction, while the evaluation stage assesses the perceived learning support and feasibility of the developed application.

These stages are interconnected, where the output of each stage becomes the input for the next stage. In particular, the results obtained from the analysis stage directly inform the design decisions, ensuring that the developed system aligns with students' learning needs and classroom conditions. This structured approach enables the integration of pedagogical considerations, cultural context, and interactive gameplay within a single educational system.

3.3.1 Analysis Stage

The analysis stage aimed to identify the learning needs, student characteristics, and contextual conditions relevant to the development of the digital Dakon-based mathematics game. This stage was conducted through a structured consultation with a third-grade mathematics teacher at MI Fajar Siddiq Elementary School. The documentation of this consultation activity is presented in Appendix B.

To systematically collect information during the analysis stage, a semi-structured interview was conducted with the third-grade mathematics teacher. The interview was designed to identify classroom learning conditions, students' characteristics, common learning difficulties, and mathematical topics suitable for integration into the game. The interview questions and their purposes are presented in Table 3.1.

Table 3.1 Interview Questions and Purposes

No	Interview Question	Purpose
1	How is mathematics usually taught in the classroom?	To understand current teaching practices and learning conditions.
2	What difficulties do students commonly experience when learning mathematics?	To identify learning challenges that should be addressed by the game.
3	How would you describe students' engagement and interest during mathematics lessons?	To understand students' motivation and participation levels.
4	Do students have varying mathematical skill levels in the classroom?	To identify differences in students' abilities and learning needs.
5	What mathematical topics have been taught and are appropriate for third-grade students?	To determine the learning content that should be included in the game.
6	What type of learning media do students respond to positively?	To identify suitable approaches for increasing engagement.
7	Are there any classroom constraints that should be considered during game development?	To ensure that the developed system is appropriate for the learning environment.

The consultation focused on several aspects, including classroom learning conditions, common difficulties experienced by students, and the suitability of mathematical topics for integration into the game. Based on the results of the consultation, it was found that mathematics learning in the classroom was predominantly conducted through worksheet-based activities. While these activities supported procedural practice, they tended to reduce students' attention and engagement over time. The teacher also reported that several students experienced difficulty maintaining concentration during repetitive exercises, which affected their overall learning performance. The teacher also explained that students demonstrated

varying levels of mathematical ability and interest. Some students were able to solve arithmetic problems independently, while others required additional guidance and practice. These differences highlighted the need for a learning medium capable of accommodating diverse learner characteristics while maintaining student engagement.

Furthermore, based on classroom observations and discussions with the mathematics teacher, it was identified that students possessed varying levels of mathematical ability and learning interest. Some students were able to solve arithmetic problems independently and demonstrated strong participation during classroom activities, while others required additional guidance and support when completing similar tasks. Differences in learning motivation and engagement were also observed among students. These variations reflect the actual classroom conditions and were considered during the game development process to ensure that the learning content could accommodate diverse learner characteristics.

In addition, the consultation identified specific mathematical topics that had already been introduced to the students and were appropriate for inclusion in the game. These topics included basic arithmetic operations such as addition, subtraction, comparison, multiplication, division, and missing-number problems. The selection of these topics was important to ensure that the game content aligned with the existing curriculum and students' prior knowledge.

The findings from the analysis stage were used as the foundation for the design stage. The identified student difficulties influenced the development of interactive gameplay mechanisms that promote active engagement, such as question-based progression and immediate feedback. Furthermore, the selection of mathematical topics informed the organization of content into progressive levels of difficulty. This ensures that the game not only provides an engaging experience but also supports structured learning development.

The analysis stage played a critical role in ensuring that the developed system addresses real classroom challenges and aligns with both pedagogical objectives and learner needs. These findings also served as the foundation for subsequent stages, particularly in guiding the design and development of the application.

3.3.2 Design Stage

The design stage focuses on translating the results of the analysis stage into a structured plan for system development. At this stage, several design outputs are produced to guide the implementation process and ensure that all components are clearly defined before development begins.

Several design tools were utilized during this stage to support the planning and visualization of the game. Figma was used to create storyboards, user interface (UI) mockups, screen layouts, and navigation flows. Through Figma, the researcher was able to visualize how users would interact with the system, from the main menu to gameplay and feedback screens, before implementation began. In addition, Procreate was used to design and illustrate several visual assets used in the game, including graphical elements, icons, and supporting visual components intended to enhance the attractiveness of the application for elementary school students.

The system design includes the gameplay flow, which defines how the traditional Dakon mechanics are integrated with mathematics questions, as well as the user interface structure, which is planned through layout arrangement and navigation flow suitable for elementary school students. A storyboard and interface flow were also developed to illustrate user interaction throughout the application, including menu navigation, gameplay processes, question presentation, and feedback mechanisms.

In addition, a question structure was designed based on different difficulty levels, where each level contains specific types of arithmetic problems aligned with students' learning progression. The design also includes the planning of a rule-based AI opponent, which determines game moves based on predefined Dakon rules, seed distribution conditions, and possible game outcomes. A rule-based approach was selected because it provides predictable gameplay behavior and is sufficient to support the educational objectives of the game without introducing unnecessary complexity.

The game content was organized into three progressive difficulty levels based on both classroom findings and educational game design principles. During the analysis stage, it was identified that students demonstrated varying levels of mathematical ability and learning readiness. Therefore, a progressive level structure was implemented to accommodate these differences and support gradual skill development. Level 1 focuses on fundamental arithmetic concepts such as addition, subtraction, comparison, and missing-number problems. Level 2 introduces multiplication, division, and more complex operations, while Level 3 presents arithmetic problems involving larger numbers and multi-step calculations.

Previous studies have suggested that educational games should provide challenges progressively to maintain learner engagement and support effective learning (Plass et al., 2015). Furthermore, scaffolding strategies in digital game-based learning can help reduce cognitive load and support learners in understanding increasingly complex concepts (Chang &

Yang, 2023; Faber et al., 2024). Therefore, three levels were considered sufficient to represent beginner, intermediate, and advanced stages while maintaining an appropriate balance between educational objectives, cognitive demands, and gameplay simplicity for third-grade elementary school students.

These design outputs serve as a blueprint for the development stage, ensuring that gameplay, learning components, and system behavior are clearly defined and aligned with the learning objectives. This structured design process helps reduce ambiguity during implementation and supports consistency across system components.

3.3.3 Development Stage

The development stage focuses on translating the design into a functional digital system. In this study, the application was developed using the Unity game engine with C# as the programming language, due to its capability in supporting interactive game development and compatibility with the Android platform.

At this stage, the system components designed in the previous phase were implemented into several main features, including gameplay mechanics, mathematical question integration, user interface, and AI opponent. The Dakon gameplay was implemented by simulating the traditional seed distribution mechanism, which serves as the core interaction within the game.

To support learning objectives, a mathematical question system was integrated into the gameplay flow. Each player interaction triggers arithmetic problems based on predefined difficulty levels, ensuring that learning activities are embedded within gameplay rather than presented as separate tasks. In addition, an AI-controlled opponent was developed using a rule-based approach to simulate player interaction. The AI determines moves based on predefined conditions to maintain game continuity and provide a consistent and predictable gameplay experience suitable for educational purposes.

The development process also involves integrating all system components into a unified application to ensure that gameplay mechanics, learning features, and user interaction function cohesively. Testing is conducted during development to identify and resolve technical issues, ensuring that the system operates as expected. The final output of this stage is a fully functional Android-based application that is ready to be used in the implementation stage. This ensures that the developed system can be directly applied and evaluated in a real classroom environment.

3.3.4 Implementation Stage

The implementation stage involved applying the developed digital Dakon-based mathematics game in a real classroom environment. This stage aimed to observe how students interacted with the system and to collect data for evaluating its usability and perceived learning support. The activity was conducted at an elementary school involving twenty third-grade students as participants. The session took place in a classroom under the supervision of the researcher to ensure that the activity ran effectively. This controlled environment helped ensure that all participants followed the procedure and that the collected data were reliable.

During the implementation, the application was used on three Android-based mobile devices prepared by the researcher. The students were divided into several groups consisting of four to five students per group, allowing them to take turns using the devices and ensuring that all participants could engage with the application. Before starting the gameplay session, the researcher provided a brief explanation of the game rules and instructions on how to use the application. This step was intended to ensure that students understood the gameplay mechanics and the learning process embedded within the system.

During the session, students interacted with the application in turns by playing the game, answering mathematical questions, and following the gameplay flow. The implementation session lasted for approximately 40 minutes, during which observations were conducted to monitor student engagement and interaction with the system. After completing the gameplay session, students were asked to fill out a questionnaire to evaluate their experience while using the application. The questionnaire consisted of 13 items covering usability, attractiveness, perceived learning support, and user acceptance, which were measured using a five-point Likert scale. The researcher guided the students during the questionnaire session to ensure that all questions were clearly understood. This session lasted for approximately 30 minutes, and the collected data were used as the basis for evaluation in the subsequent stage.

3.3.5 Evaluation Stage

The evaluation stage aims to assess the usability, perceived learning support, attractiveness, and user acceptance of the developed digital Dakon-based mathematics game. This stage was conducted after the implementation process through a questionnaire-based evaluation involving all participating students.

The evaluation instrument consisted of 13 items measured using a five-point Likert scale, ranging from strongly disagree to strongly agree (Joshi et al., 2015). The questionnaire items were grouped into four main aspects: usability, attractiveness, perceived learning support, and

user acceptance. These aspects were selected to capture students' perceptions of both the functional and experiential qualities of the application (Dan et al., 2024; Hui & Mahmud, 2023; Nadeem et al., 2023).

The questionnaire was developed by the researcher based on indicators derived from relevant theoretical frameworks, rather than being directly adapted from a single standardized instrument. The usability aspect includes indicators such as ease of use, clarity of instructions, and system navigation, which are commonly used to evaluate system usability (Brooke, 1996). The attractiveness aspect focuses on visual design, animation, and user enjoyment during gameplay, which influence user engagement in digital games (Hassenzahl, 2004). The perceived learning support aspect measures students' perceptions of how well the game supports their understanding of mathematical concepts (Plass et al., 2015). Meanwhile, the user acceptance aspect evaluates willingness to reuse the application and overall satisfaction, which are aligned with technology acceptance models (Davis, 1989).

To strengthen the evaluation process, the questionnaire dimensions were also reviewed against the MEEGA+KIDS framework, which is a validated model for evaluating educational games used by school-age learners (Gresse von Wangenheim et al., 2020). Although the study did not directly adopt the complete MEEGA+KIDS questionnaire, the evaluation aspects used in this research are conceptually aligned with several of its core dimensions. Specifically, usability corresponds to ease of use and interaction, attractiveness reflects player enjoyment and engagement, perceived learning support relates to perceived learning outcomes, and user acceptance reflects learners' overall experience and willingness to continue using similar educational games. This conceptual alignment provides additional support for interpreting the evaluation results using an established educational game evaluation framework designed for children and school-age students.

Before being used in the study, the instrument was reviewed by an elementary school teacher to ensure that the questionnaire items were appropriate, understandable, and suitable for third-grade students. The teacher acted as a content reviewer, evaluating the clarity of language, relevance of each item to the learning objectives, and suitability of the indicators for the students' level. Revisions were made based on the feedback provided to improve both clarity and content validity of the instrument.

Considering that the participants are third-grade elementary school students, the questionnaire was administered with guidance. Each question was read aloud and explained by the researcher to ensure that students understood the meaning of each item. In addition, simple

examples were provided to help students interpret the Likert scale correctly. The teacher and researcher were present during the process to assist students when necessary and to ensure that the responses reflected their actual perceptions.

The distribution of questionnaire items across each evaluation aspect is presented in Table 3.2. The complete questionnaire items used in this study are presented in Appendix R. The relationship between each evaluation aspect and its corresponding questionnaire items is defined explicitly to ensure clarity in measurement. The **usability aspect** consists of items 1 to 4, which evaluate ease of use, clarity of instructions, and gameplay understanding. For example, one of the items states that students find it easy to understand how to play the game. The **attractiveness aspect** includes items 5 to 7, which assess visual appeal, animation, and user enjoyment during gameplay. An example item in this aspect evaluates whether the game's visual design and animations make the learning experience more enjoyable.

The **perceived learning support aspect** is represented by items 8 to 10, which measure students' perceptions of how the game supports their understanding of mathematical concepts. For instance, one item asks whether the game helps students improve their arithmetic skills. Finally, the **user acceptance aspect** consists of items 11 to 13, which evaluate students' willingness to reuse the application and their overall satisfaction. An example item in this aspect assesses whether students are interested in using similar educational games in the future.

Table 3.2 Questionnaire Aspects and Item Distribution

Aspect	Number of Items	Description
Usability	4	Ease of use, interface clarity, and gameplay understanding
Attractiveness	3	Visual appeal, animation, and user enjoyment
Perceived Learning Support	3	Support for mathematics learning
User Acceptance	3	Willingness to reuse and overall acceptance
Total	13	-

To ensure the reliability of the instrument, Cronbach's alpha was used to measure the internal consistency of the questionnaire items (Cronbach, 1951). The collected data were analyzed using descriptive statistical methods and reliability analysis to obtain the mean scores and consistency of each aspect.

Overall, the evaluation stage provides a structured assessment of the developed system based on user perception. The results serve as an initial indication of the feasibility of the application as an interactive learning medium for elementary mathematics education.

3.4 Ethical Considerations

This study involved elementary school students as participants; therefore, ethical considerations were carefully addressed. Prior to the implementation, formal permission was obtained from the school, including approval from the headmaster, to conduct the research activities. The study was carried out under the supervision of the classroom teacher to ensure that the learning process remained appropriate, safe, and well-controlled.

Students participated voluntarily in the activity, and clear instructions were provided before the implementation. The data collected from the questionnaire were used solely for research purposes and were kept confidential to protect the participants' privacy. Where applicable, parental awareness and approval were ensured through coordination with the school. The study was designed to ensure that all activities were non-invasive, age-appropriate, and conducted in a manner that prioritizes the well-being of the students.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Analysis Stage

The analysis stage was conducted to identify learning conditions, student characteristics, and challenges in mathematics learning at the elementary school level. This stage aimed to ensure that the developed digital Dakon-based mathematics game aligns with students' needs and instructional objectives. The analysis was carried out through a consultation session with a third-grade mathematics teacher at MI Fajar Siddiq Elementary School, Palembang. During the consultation, information was collected regarding students' learning behavior, classroom challenges, mathematical skill levels, and mathematical topics suitable for integration into the game.

Based on the consultation results, it was found that students often experienced decreased attention and engagement during conventional mathematics learning activities, particularly those relying on repetitive worksheet-based exercises. The teacher also reported that students demonstrated varying levels of mathematical ability and learning readiness. While some students were able to solve arithmetic problems independently, others required additional guidance and practice. Furthermore, students were observed to respond more positively to visual and interactive learning activities compared to traditional instructional approaches.

The consultation also identified several mathematical topics that had already been introduced to students and were appropriate for integration into the game. These topics included addition, subtraction, number comparison, multiplication, division, and missing-number problems. The inclusion of these topics ensures alignment between the game content and the elementary mathematics curriculum.

The key findings obtained during the analysis stage and their implications for system design are summarized in Table 4.1.

Table 4.1 Analysis Findings and Design Implications

Analysis Findings	Evidence from Teacher Consultation	Design Implications
Low student engagement during conventional learning	Students tend to lose attention during repetitive worksheet-based activities.	Interactive gameplay mechanics were integrated into the game.
Difficulty maintaining concentration	Several students experience difficulty maintaining focus during learning activities.	Mathematical questions were embedded directly into gameplay to sustain attention.
Preference for visual and interactive media	Students respond positively to games and interactive learning activities.	Visual elements, animations, and feedback mechanisms were incorporated into the system.
Diverse mathematical abilities	Students demonstrate varying levels of mathematical skills and learning readiness.	Three progressive difficulty levels were designed to accommodate different ability levels.
Curriculum-aligned mathematical topics	Addition, subtraction, comparison, multiplication, division, and missing-number problems had already been taught in class.	These topics were incorporated into the game's question bank and distributed across different levels.
Need for engaging learning media	Interactive learning media are expected to improve motivation and participation.	A digital Dakon game with a space-themed visual design was developed.

Based on the findings presented in Table 4.1, several design decisions were formulated to address the identified classroom needs. The game was designed to combine traditional Dakon gameplay with mathematics learning activities in an interactive digital environment. A space-themed visual design was selected to increase students' interest while maintaining the cultural elements of the traditional Dakon game. In addition, mathematical questions were organized into progressive difficulty levels to support gradual learning progression according to students' abilities.

Overall, the analysis stage provided a clear foundation for the subsequent design and development stages. The findings ensured that the developed system was not only technically functional but also pedagogically relevant and aligned with the characteristics and learning needs of elementary school students.

4.2 Design Stage

The design stage was conducted to transform the findings obtained during the analysis stage into a structured plan for system development. This stage focused on defining the gameplay mechanics, user interface, learning content, artificial intelligence behavior, and reward system of the digital Dakon-based mathematics game. The purpose of this stage was to establish a clear blueprint that would guide the implementation process and ensure that all system components were aligned with the identified learning needs and instructional objectives.

Several design artifacts were produced during this stage, including gameplay flow diagrams, user interface mockups, mathematical question structures, and rule-based AI logic. Figma was used to design the user interface layouts and interaction flow, while Procreate was utilized to create and refine several visual assets used within the game. These design outputs served as references during the development stage and helped ensure consistency between educational objectives, gameplay mechanics, and visual presentation. The results of the design stage are presented in the following subsections.

4.2.1 Gameplay Design

The gameplay design defines how traditional Dakon mechanics are integrated with mathematics learning activities. The objective is to ensure that learning and gameplay occur simultaneously, allowing students to practice arithmetic skills while participating in an interactive game environment.

The gameplay begins when the player selects a difficulty level from the level selection screen. After entering the game, the player and the AI opponent take turns selecting pits and distributing seeds according to traditional Dakon rules. Before a selected move is executed, the player must answer a mathematical question presented by the system. A correct answer allows the move to proceed, whereas an incorrect answer causes the player's turn to end and be transferred to the AI opponent.

Several traditional Dakon rules were preserved in the digital version. These include seed distribution, additional turns when the final seed lands in the player's store, and seed capture when the final seed lands in an eligible empty pit. The game ends when all pits on one side of the board become empty. At the end of the game, the total number of collected seeds is calculated to determine the winner.

The integration of mathematical questions into gameplay serves as a learning checkpoint that encourages students to actively engage with arithmetic concepts throughout the game. By embedding learning activities directly into the game mechanics, students are required to continuously apply mathematical thinking as part of the gameplay process. The overall gameplay flow is illustrated in Figure 4.1.

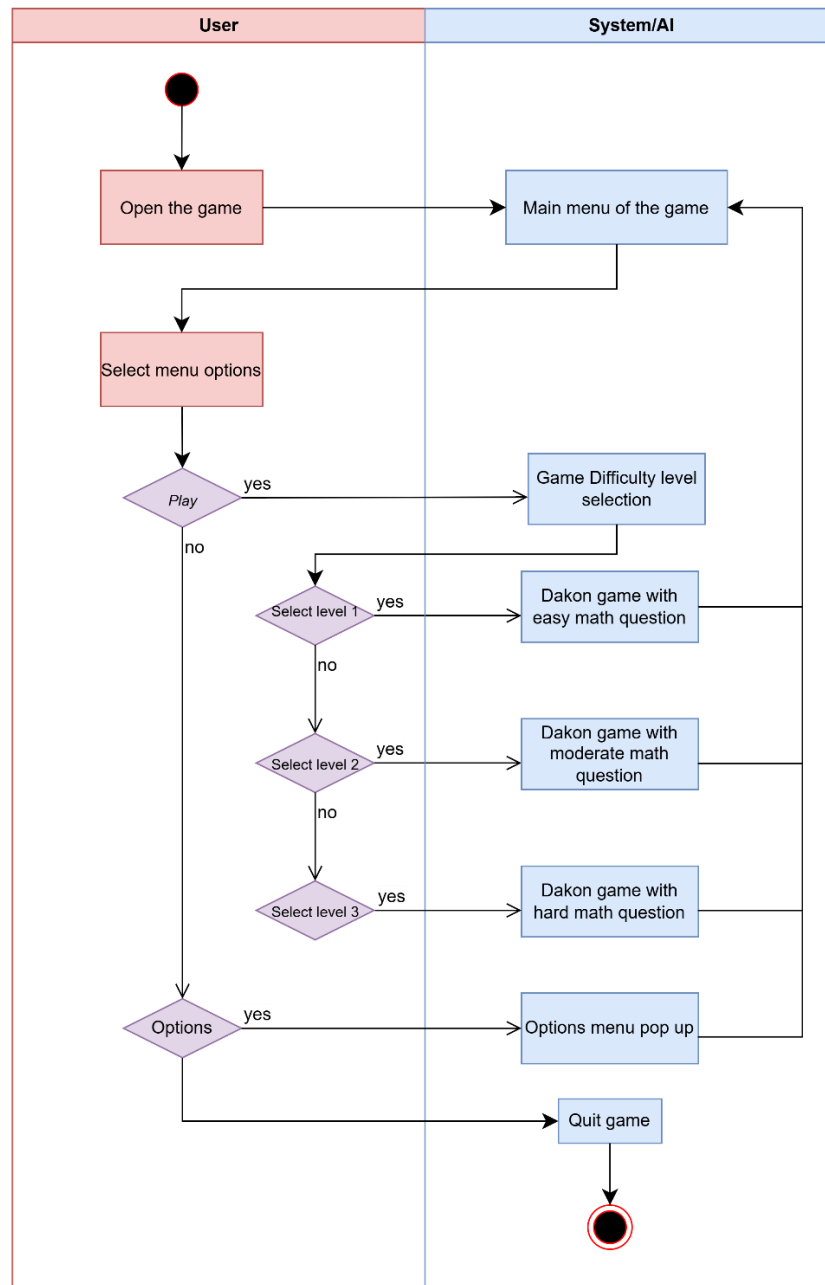


Figure 4.1 Gameplay Workflow

4.2.2 User Interface Design

The user interface design was developed to create an interactive and visually appealing learning environment suitable for elementary school students. The interface was designed using Figma to create screen layouts, navigation structures, and interaction flows before implementation. In addition, several visual assets, including icons, decorative elements, and game illustrations, were created and refined using Procreate. These tools enabled the researcher to visualize the application design and ensure consistency across all interface components before development.

A distinctive characteristic of the game is the adoption of a “Space Dakon” theme, which combines the traditional Dakon game with a modern visual appearance. The interface utilizes space-inspired elements such as stars, glowing effects, and futuristic colors to increase students’ engagement while maintaining the cultural identity of Dakon. This approach aims to present a familiar traditional game in a more attractive digital format for young learners.

The user interface design consists of several main screens that support the overall gameplay experience. These screens include the starting page, main menu, level selection screen, gameplay interface, question interface, feedback interface, and final result screen. The storyboard of the user interface was developed to illustrate the navigation flow between these components before implementation.

Starting Page Design

The starting page serves as the initial screen displayed when the application is launched. This screen introduces the visual identity of the game and provides the first interaction between the user and the system. The purpose of this page is to create an attractive first impression and prepare users before entering the main menu. The design of the starting page is presented in Figure 4.2.

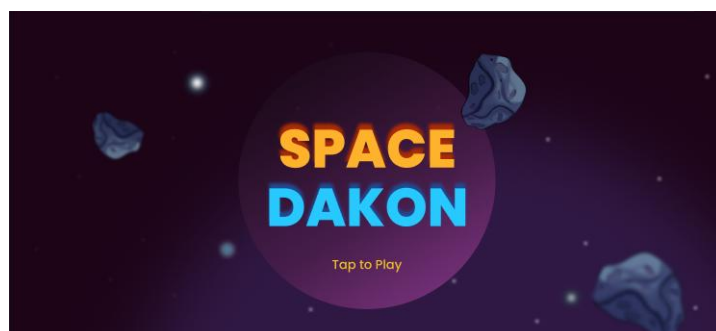


Figure 4.2 Starting Page Design

As shown in Figure 4.2, the starting page displays the game title and visual elements representing the Space Dakon theme. The interface was designed to be simple and visually appealing to capture students' attention when launching the application.

Main Menu Design

The main menu functions as the central navigation hub of the application. Through this screen, users can access the primary features of the game and begin the learning experience. The interface was designed with large buttons and a simple layout to ensure ease of use for elementary school students. The design of the main menu interface is presented in Figure 4.3.

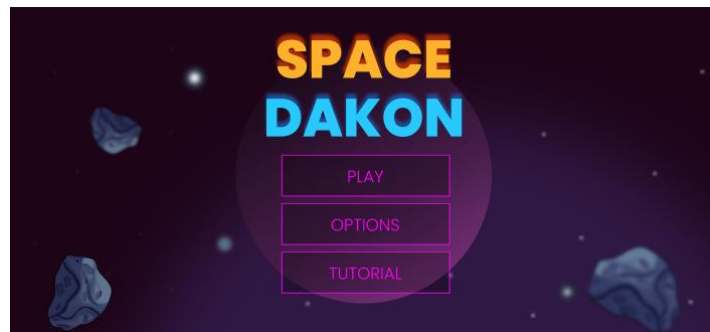


Figure 4.3 Main Menu Design

As illustrated in Figure 4.3, the main menu provides navigation options that allow users to start the game and access other available features. The layout emphasizes simplicity and accessibility to support young learners.

Level Selection Design

The level selection screen allows players to choose the desired difficulty level before entering gameplay. Three levels are provided to accommodate differences in students' mathematical abilities and learning progression. The level selection interface is presented in Figure 4.4.



Figure 4.4 Level Selection Design

As shown in Figure 4.4, players can select one of three available levels before starting the game. This design supports gradual progression and allows students to engage with mathematical content appropriate to their abilities.

Gameplay Interface Design

The gameplay interface represents the core interaction area of the application. This screen displays the Dakon board, seeds, player information, and gameplay status indicators. The gameplay interface design is presented in Figure 4.5.

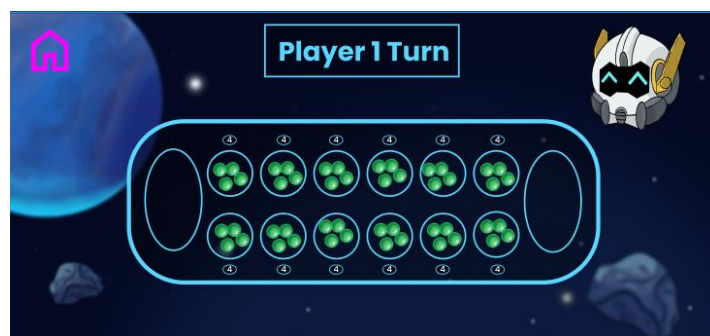


Figure 4.5 Gameplay Interface Design

As illustrated in Figure 4.5, the Dakon board is positioned at the center of the screen to become the primary focus of interaction. The space-themed visual style is implemented through glowing effects, color choices, and background elements inspired by outer space.

Question Interface Design

The question interface appears whenever a player selects a pit during gameplay. This interface integrates mathematical learning activities into the Dakon mechanics. The question interface design is presented in Figure 4.6.

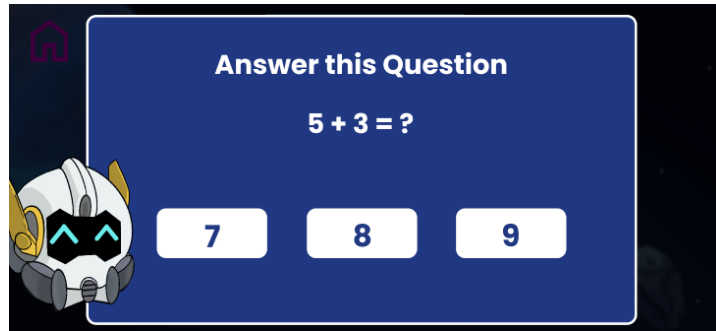


Figure 4.6 Question Interface Design

As shown in Figure 4.6, mathematical questions are displayed through a popup interface that temporarily pauses gameplay. Players are required to enter their answers manually before the selected move can proceed.

Feedback Interface Design

The feedback interface provides immediate responses after a player submits an answer. The feedback interface design is presented in Figure 4.7.

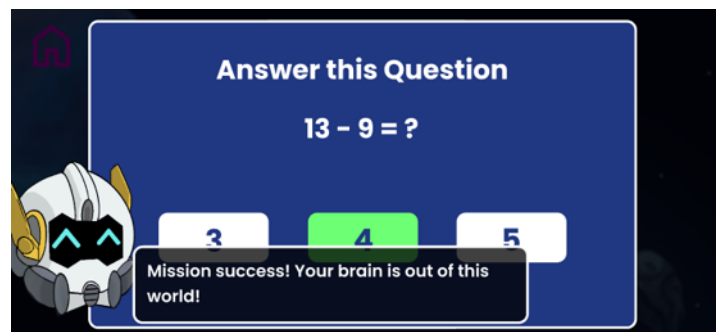


Figure 4.7 Feedback Interface Design

As illustrated in Figure 4.7, the system displays positive feedback for correct answers and corrective feedback for incorrect answers. This mechanism helps students understand the result of their actions and supports the learning process.

Final Result Design

The final result screen appears after the game ends and summarizes the player's performance. The final result and achievement interface is presented in Figure 4.8.

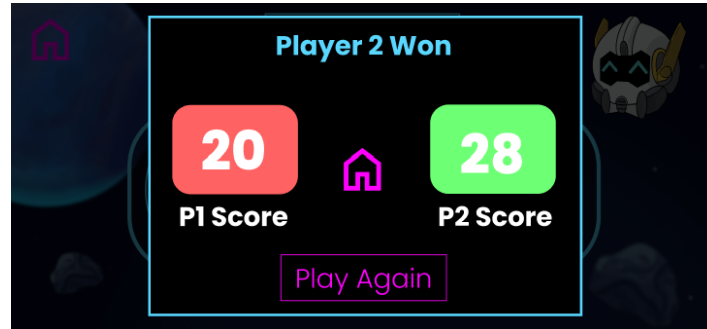


Figure 4.8 Final Result Design

As shown in Figure 4.8, the final result screen displays the winner of the match and provides an achievement reward in the form of the Juara Antariksa badge. This achievement serves as positive reinforcement and provides a clear objective for players to complete the game successfully.

4.2.3 Mathematics Content Design

The mathematics content design was developed to ensure that the educational objectives of the game are aligned with the mathematical competencies expected from third-grade elementary school students. Based on the findings from the analysis stage, students demonstrated varying levels of mathematical ability and learning readiness. Therefore, the mathematical content was structured into progressive levels of difficulty to accommodate these differences and support gradual learning progression.

The mathematical questions integrated into the game were selected based on topics that had already been introduced in the classroom curriculum. These topics include addition, subtraction, number comparison, multiplication, division, and missing-number problems. The integration of these topics ensures that students interact with mathematical concepts that are familiar while still being challenged through gameplay activities.

To support progressive learning, the game was designed with three difficulty levels representing beginner, intermediate, and advanced stages. This structure allows students to gradually build mathematical understanding without experiencing a sudden increase in complexity. Previous studies have suggested that educational games should provide

progressive challenges to maintain learner engagement and support effective learning processes (Plass et al., 2015). Furthermore, scaffolding strategies in digital game-based learning environments can help learners understand increasingly complex concepts while reducing excessive cognitive load (Chang & Yang, 2023; Faber et al., 2024).

The structure of the mathematical content, including the concepts, example problems, and learning objectives for each level, is presented in Table 4.2.

Table 4.2 Examples of Mathematical Questions

Level	Mathematical Concept	Example Problem Type	Learning Objective
Level 1	Basic addition and subtraction	$7 + 3 = ?$ $10 - 4 = ?$	To help students practice fundamental arithmetic operations and develop number sense
Level 1	Comparison	Which number is larger: 8 or 5?	To develop students' ability to compare numerical values
Level 1	Missing Number	$5 + \dots = 9$	To train students in recognizing simple number patterns
Level 2	Two-digit addition and Subtraction	$23 + 14 = ?$ $35 - 12 = ?$	To improve students' computational skills with larger numbers
Level 2	Mixed operations	$15 + 6 - 4 = ?$	To strengthen sequential arithmetic reasoning
Level 2	Missing number (two-digit)	$\dots + 18 = 25$	To enhance students' understanding of inverse operations
Level 3	Multiplication	$6 \times 4 = ?$	To introduce multiplication as repeated addition
Level 3	Division	$20 \div 4 = ?$	To develop students' understanding of equal grouping
Level 3	Advanced missing number	$3 \times \dots = 15$	To strengthen conceptual reasoning in multiplication relationships

As shown in Table 4.2, the mathematical content is organized progressively across the three levels. Level 1 emphasizes fundamental arithmetic concepts, including addition, subtraction, comparison, and missing-number problems. These question types are intended to strengthen students' basic numeracy skills and help them become familiar with the learning mechanics integrated into the game. Level 2 introduces larger numbers and mixed operations, requiring students to perform more complex calculations and develop sequential reasoning skills. Meanwhile, Level 3 focuses on multiplication, division, and advanced arithmetic reasoning tasks that require a higher level of conceptual understanding and problem-solving ability.

The design of mathematical questions is structured to align with both the gameplay context and students' learning needs. Each question type is intentionally linked to the Dakon gameplay, where numerical values such as the number of seeds are used as part of the problem context. This approach helps students connect abstract mathematical concepts with concrete in-game situations. In addition, the question format is designed to be simple and direct to ensure that it can be easily understood by elementary school students. The progression of question types across levels reflects an increase in cognitive demand, from basic recall and computation in Level 1 to more complex reasoning and problem-solving in Level 3.

The design decisions presented in this stage are closely aligned with the findings from the analysis stage. The use of interactive gameplay and visual elements reflects students' preference for engaging learning media, while the integration of mathematical questions within gameplay directly addresses the need to improve attention and participation. In addition, the structured level system is designed to accommodate variations in students' abilities and support gradual learning progression. Thus, the mathematics content design not only defines the educational component of the game but also translates identified learning needs into concrete learning activities embedded within the gameplay experience.

4.2.4 AI Opponent Design

The digital Dakon game incorporates a rule-based Artificial Intelligence (AI) opponent to provide a single-player learning experience. The AI was designed using a heuristic-based rule system rather than machine learning techniques because the primary objective of the game is to support mathematics learning while maintaining a manageable level of challenge for elementary school students. This approach offers predictable behavior, low computational complexity, and ease of implementation.

The AI evaluates all valid moves available on its side of the board and assigns a score to each possible move based on predefined decision rules. The move with the highest score is selected and executed. This strategy enables the AI to make simple strategic decisions while maintaining consistent gameplay behavior. The AI evaluation criteria are presented in Table 4.3.

Table 4.3 AI Move Evaluation Rules

Priority	Evaluation Rule	Score Contribution	Purpose
1	Move ends in the AI store and grants an extra turn	+200	Maximize opportunities for additional moves
2	Move has the potential to capture opponent seeds	+150	Increase the AI score through the capture mechanism
3	Move originates from a pit containing more seeds	+Number of Seeds	Improve seed distribution opportunities
4	Small random variation	+0 to +4	Reduce repetitive AI behavior

As shown in Table 4.3, the AI prioritizes moves that provide an additional turn because these moves offer the greatest strategic advantage. If multiple moves are available, the AI also considers opportunities to capture seeds from the opponent's side. In situations where neither condition is available, the AI prefers pits containing a larger number of seeds, as these moves generally create wider seed distribution across the board.

A small random factor is also incorporated into the evaluation process to avoid identical decision patterns in every game session. This variation helps create a more natural gameplay experience while preserving the overall decision priorities.

The use of a rule-based AI aligns with the educational objectives of the game. Rather than creating a highly competitive opponent, the AI is intended to maintain gameplay interaction and provide an appropriate level of challenge while allowing students to focus on solving mathematical problems integrated into the Dakon gameplay. Therefore, the selected AI design supports both learning activities and player engagement within the application.

4.3 Development Stage

The development stage involves implementing the system design into a functional application using the Unity game engine. This stage focuses on transforming the previously designed components into an interactive digital Dakon-based mathematics game.

The application was developed using Unity and programmed with the C# language. All visual assets, including the Dakon board, seeds, user interface elements, and background, were integrated into the Unity environment. The system was designed to ensure smooth interaction and responsive gameplay suitable for elementary school students.

4.3.1 Main Menu Interface

The main menu interface serves as the initial entry point of the application and provides users with access to the core functionality of the game. This interface is designed to be simple, intuitive, and easily understood by elementary school students. Figure 4.9 shows the implemented main menu interface in the application.

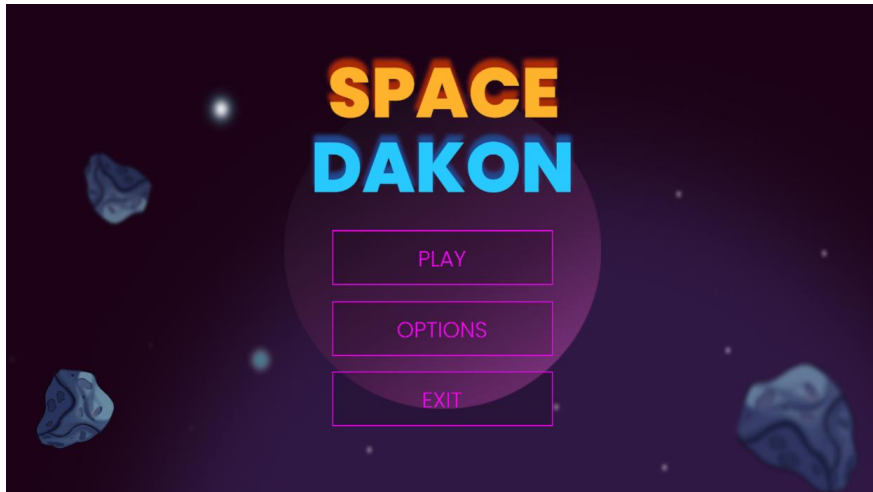


Figure 4.9 Unity Main Menu Screenshot

The main menu consists of several primary components, including the game title, background visual, and navigation buttons. The visual design adopts the “space Dakon” theme, featuring a dark outer space background combined with glowing elements that enhance visual appeal. The background of the main menu is designed to resemble outer space, incorporating star elements and gradient effects to create an immersive environment. The use of dark tones combined with bright neon accents helps to highlight the interactive elements on the screen.

The navigation buttons are positioned clearly in the center area of the interface and are designed with large sizes to ensure usability for young users. The primary button allows users to start the game, which directs them to the level selection interface. In addition, an exit button is provided to close the application. All user interface assets, including the background, buttons, and visual elements in the main menu, were designed independently by the researcher using Figma and Procreate. These tools were used to create custom visual components that match the space Dakon theme and ensure visual consistency across the application.

The layout of the main menu is structured to minimize cognitive load. The limited number of options helps users quickly understand the available actions without confusion. The use of contrasting colors between buttons and the background ensures that interactive elements

are easily recognizable. From an implementation perspective, the main menu interface was developed using Unity's UI system, utilizing components such as buttons, text elements, and background images. Event handling was implemented to ensure that each button responds correctly to user input.

One of the key mechanisms implemented in this interface is the transition from the main menu to the next scene using a fade-out effect. This transition improves user experience by avoiding abrupt changes between interfaces. Figure 4.10 shows a simplified implementation of the scene transition mechanism triggered by the "Play" button.

```
public void PlayGame()
{
    StartCoroutine(PlayWithFade());
}

IEnumerator PlayWithFade()
{
    yield return fade.FadeOut();
    SceneManager.LoadScene("Difficulty");
}
```

Figure 4.10 Scene Transition Script for Main Menu

The code in Figure 4.10 demonstrates how the system handles user interaction when the "Play" button is pressed. The `PlayGame()` function triggers a coroutine that executes a fade-out animation before loading the next scene. This ensures a smooth visual transition and enhances interface usability.

In addition to navigation, the main menu also provides an options feature that allows users to manage application settings such as background music. The system maintains synchronization between the interface and the current configuration to ensure consistent user feedback. Furthermore, an exit function is implemented to allow users to close the application directly from the main menu. This function is connected to the interface button using Unity's event system.

Overall, the main menu interface integrates navigation control, visual transitions, and basic system settings into a unified and user-friendly design. The complete implementation of the main menu scripts, including navigation control, fade transition, and options management, is provided in Appendix D, Appendix E, Appendix F, and Appendix G.

4.3.2 Level Selection

The level selection interface is implemented as a transition stage between the main menu and the gameplay. This interface allows users to choose the level of difficulty before entering the game, ensuring that the learning experience can be adjusted according to the user's ability. Figure 4.11 shows the implementation of the level selection interface in the Unity environment.



Figure 4.11 Level Selection Interface

The level selection interface consists of three main buttons, each representing a different level of difficulty: Level 1, Level 2, and Level 3. Each level corresponds to a different degree of mathematical complexity. Level 1 is designed for basic arithmetic operations such as addition, subtraction, and number comparison. Level 2 introduces more complex calculations, including two-digit operations and mixed arithmetic problems. Level 3 focuses on more advanced mathematical concepts such as multiplication, division, and higher-level problem-solving tasks.

The visual design of the interface follows the “space Dakon” theme, maintaining consistency with the main menu. The background uses a dark outer space appearance combined with glowing elements, while the level buttons are designed with clear labels and contrasting colors to ensure visibility and ease of interaction. From an implementation perspective, each level button is connected to the gameplay system through a centralized game management mechanism. When a user selects a level, the system stores the selected difficulty and then loads the gameplay scene. Figure 4.12 shows a simplified implementation of the level selection mechanism using a centralized game manager.

```
public void SelectLevel(GameLevel level)
{
    currentLevel = level;
    SceneManager.LoadScene("Game");
}
```

Figure 4.12 Level Selection Handling Using GlobalGameManager Script

The code in Figure 4.12 illustrates how the system processes user input when a level is selected. The selected difficulty level is stored in a global variable, which is then used to configure the gameplay. After storing the selected level, the system loads the main game scene. This approach allows the application to use a single gameplay scene while dynamically adjusting the difficulty based on user selection. To ensure consistency across scenes, the system utilizes a centralized game manager that persists throughout the application lifecycle. This enables the selected level to be retained and accessed during gameplay.

The layout of the level selection interface is designed to be simple and intuitive, ensuring that elementary school students can easily select their desired level without confusion. The use of large buttons and minimal text helps reduce cognitive load and supports usability. Overall, the level selection interface provides a clear and structured mechanism for selecting learning difficulty. The integration of a centralized management system improves scalability and maintainability, while ensuring consistent interaction and system behavior across different levels. The complete implementation of the level selection scripts, including the global game manager and button handling logic, is provided in Appendix H.

4.3.3 Gameplay Interface

The gameplay implementation is the core part of the system where the designed mechanics and learning features are realized into a functional application. This stage focuses on how the Dakon game mechanics are executed and how the learning component is integrated within the gameplay process. Figure 4.13 shows the implementation of the gameplay interface in the Unity environment.



Figure 4.13 Gameplay Board Interface

The gameplay is based on the traditional Dakon rules, where each player distributes seeds from one pit to the next pits in a sequential manner. At the beginning of the game, each pit contains four seeds. The player selects a pit to initiate the move, and the system processes the distribution of seeds accordingly.

From an implementation perspective, the gameplay is controlled by a system that manages the interaction between the player and the game board. When a player selects a pit, the system first validates the action and determines whether the move can be executed. Unlike the traditional Dakon game, this application integrates a learning mechanism into the gameplay. Before the seed distribution process is executed, the system displays a mathematical question to the player. Figure 4.14 shows the question popup that appears during gameplay.

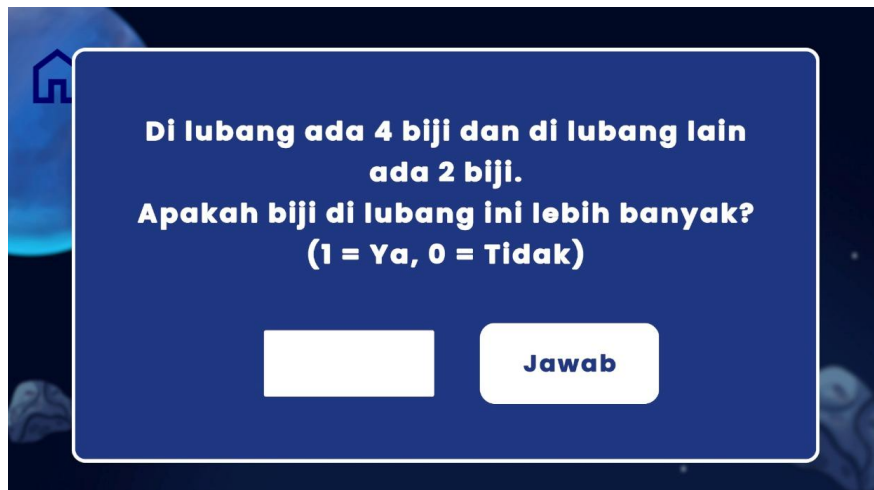


Figure 4.14 Question Popup

The question is presented in a simple format to ensure that it can be easily understood by elementary school students. The player is required to input an answer and submit it before continuing the game. After the answer is submitted, the system evaluates the result. If the answer is correct, the system provides feedback in the form of a confirmation message, as shown in Figure 4.15.

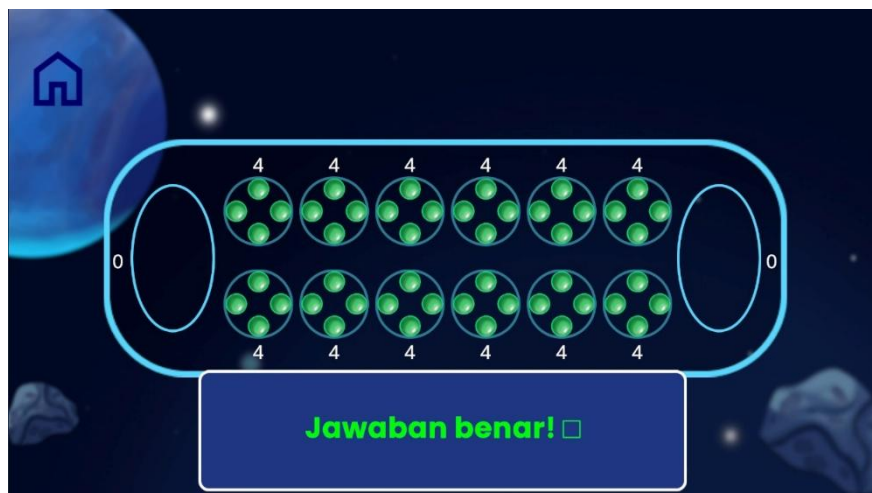


Figure 4.15 Correct Answer Feedback

After the correct answer is confirmed, the system proceeds to execute the seed distribution process based on the selected pit. The seeds are distributed sequentially across the board following the Dakon gameplay rules. However, if the answer is incorrect, the system does not execute the move and may transfer the turn to the opponent. This mechanism ensures that the learning component directly influences the gameplay outcome.

In addition, the gameplay implements a turn-based mechanism, where the system alternates between the player and the opponent. The system continuously updates the state of the game, including the number of seeds in each pit and the current turn. Overall, the gameplay implementation demonstrates how traditional game mechanics can be combined with an educational approach. The integration of mathematical questions within the gameplay ensures that users are not only engaged in playing but also actively involved in the learning process.

A. Learning Integration Mechanism

The learning system is responsible for presenting questions and validating user responses during gameplay. The system dynamically generates questions based on the selected difficulty level to ensure that the learning experience is appropriate for the user's ability. Figure 4.16 shows a simplified implementation of the learning trigger mechanism.

```
public void ShowMathQuestionFromHole(int seedCount)
{
    if (BoardManager.Instance.IsAITurn()) return;

    switch (GlobalGameManager.Instance.currentLevel)
    {
        case GameLevel.Level1:
            GenerateQuestionLevel1(seedCount);
            break;
        case GameLevel.Level2:
            GenerateQuestionLevel2(seedCount);
            break;
        case GameLevel.Level3:
            GenerateQuestionLevel3(seedCount);
            break;
    }

    questionPanel.SetActive(true);
    Time.timeScale = 0f;
}
```

Figure 4.16 Learning Trigger Based on Selected Level

The code in Figure 4.16 demonstrates how mathematical questions are integrated into gameplay. When a player selects a pit, the system determines the difficulty level and generates a corresponding question. The gameplay is temporarily paused until the player submits an answer, ensuring that the learning process becomes a mandatory step before continuing the game. The complete implementation of the learning system is provided in Appendix I (LearningManager Script).

B. Game Flow Management

The gameplay flow is controlled through a centralized management system that coordinates interactions between different components, including the board system and the user interface. This system ensures that the selected level is correctly applied and that gameplay transitions occur smoothly. Figure 4.17 shows a simplified implementation of the game initialization process.

```
void Start()
{
    board = FindFirstObjectByType<BoardManager>();

    if (GlobalGameManager.Instance != null)
    {
        currentLevel = GlobalGameManager.Instance.currentLevel;
    }
}
```

Figure 4.17 Game Initialization Based on Selected Level

This mechanism ensures that the gameplay adapts dynamically according to the selected difficulty level. By retrieving the selected level from a global manager, the system maintains consistency across different scenes. The full implementation of the game flow controller is available in Appendix J (GameManager Script).

C. Board Interaction System

The board interaction system manages user input and ensures that player actions follow the Dakon game rules. This system acts as a bridge between user interaction and gameplay logic. Figure 4.18 shows the interaction mechanism between user input and the board system.

```
public void OnPressed()
{
    if (BoardManager.Instance != null)
    {
        BoardManager.Instance.OnHoleSelected(boardIndex);
    }
}
```

Figure 4.18 User Input Handling for Hole Selection

The code demonstrates how user input is captured and forwarded to the main gameplay controller. This ensures that each interaction is validated and processed according to the game rules. The complete implementation of board interaction scripts is provided in Appendix K

(Hole Script), Appendix L (StoreHole Script), Appendix M (HoleButtonHandler Script), and Appendix N (HoleTapHandler Script).

D. AI System

The AI system is implemented to enable single-player gameplay, allowing users to compete against the computer. The AI operates using a rule-based decision-making approach, where each possible move is evaluated based on predefined criteria. This approach is selected due to its simplicity, efficiency, and suitability for elementary-level gameplay.

Unlike complex AI methods such as machine learning or search-based algorithms, the rule-based approach ensures predictable and interpretable behavior. This is important in an educational game context, where the gameplay should remain understandable and not overly difficult for students.

The AI system is integrated with the game flow through the BoardManager. When the game turns change, the system checks whether the current turn belongs to the AI. If it is the AI's turn, the system initiates a delayed action using a coroutine to simulate thinking time and create a more natural interaction experience. Figure 4.19 shows how the AI determines the best move by evaluating all possible actions.

```
int GetBestMoveIndex()
{
    int bestMove = -1;
    int bestScore = int.MinValue;

    for (int i = 6; i <= 11; i++)
    {
        if (!board.IsMoveValid(i, false)) continue;

        int seeds = board.holes[i].seedCount;
        int score = EvaluateMove(i, seeds);

        if (score > bestScore)
        {
            bestScore = score;
            bestMove = i;
        }
    }

    return bestMove;
}
```

Figure 4.19 AI Move Selection Process

The code in Figure 4.19 demonstrates how the AI evaluates all available moves and selects the one with the highest score. Each possible move is assessed using a scoring function, which determines the strategic value of the move. Other than that, the evaluation process is one of the core components of the AI system. Each move is assigned a score based on several factors that reflect the game strategy. Figure 4.20 shows a simplified implementation of the evaluation function.

```
int EvaluateMove(int holeIndex, int seeds)
{
    int score = 0;

    // Prefer moves with more seeds
    score += seeds;

    // Simulate landing position
    int landing = SimulateLanding(holeIndex, seeds);

    // Bonus for extra turn
    if (landing == 13)
        score += 200;

    // Bonus for capture opportunity
    if (IsCaptureOpportunity(landing))
        score += 150;

    return score;
}
```

Figure 4.20 AI Move Evaluation Function

The scoring system considers multiple strategic factors:

1. Seed Count: Moves with more seeds are slightly preferred, as they provide more distribution opportunities.
2. Extra Turn: Moves that result in an additional turn are highly prioritized, as they allow the AI to play consecutively.
3. Capture Opportunity: Moves that enable capturing opponent seeds are also prioritized, as they provide a strategic advantage.

This combination of factors allows the AI to simulate basic strategic reasoning without requiring complex computation. Once the best move is determined, the AI executes the move automatically through the game system. Figure 4.21 shows how the AI performs the selected action.

```
IEnumerator ThinkAndMove()
{
    yield return new WaitForSeconds(delayBeforeMove);

    int best = GetBestMoveIndex();

    if (best >= 0)
    {
        board.OnPitClickedAI(best);
    }
}
```

Figure 4.21 AI Move Execution with Delay

The use of a delay mechanism ensures that the AI does not act instantly, which improves realism and makes the interaction feel more natural for players. On the other hand, the AI system is intentionally designed to balance challenge and accessibility. Since the target users are elementary school students, the AI should not be overly difficult or unpredictable. The rule-based approach ensures that:

1. The AI behavior is consistent and understandable
2. The gameplay remains fair and engaging
3. The system performance remains efficient.

In addition, the integration of AI with the learning system ensures that gameplay remains interactive and educational, as players must still answer mathematical questions before executing moves. The complete implementation of the AI system is provided in Appendix O (AIPlayer Script).

E. Seed Management System

The seed management system handles the creation, movement, and reuse of seed objects during gameplay. This system utilizes an object pooling technique to improve performance by minimizing the overhead of object creation and destruction.

In addition, seed movement is visualized using animation based on interpolation between positions. This approach enhances user understanding of the gameplay process and provides a smoother visual experience. The complete implementation of the seed management system is provided in Appendix P (SeedPool Script) and Appendix Q (SeedMover Script).

4.3.4 Level 1

Level 1 represents the introductory stage of the game, where basic mathematical concepts are introduced to the player. This level is designed to be simple and easy to understand, making

it suitable for elementary school students. In this level, the learning system focuses on basic arithmetic operations such as addition and subtraction. The questions are generated using the `GenerateQuestionLevel1()` function in the `LearningManager` script.

The questions are designed using simple language and are presented in a contextual format based on the Dakon gameplay. For example, the number of seeds in a hole is used as the main variable in the question. This approach helps students relate the mathematical problem to the game situation. Level 1 consists of several types of questions, including addition, subtraction, comparison, and missing number problems. These variations are used to introduce different basic mathematical concepts while maintaining a low level of difficulty. Figure 4.22, Figure 4.23, Figure 4.24, and Figure 4.25 shows examples of question types in Level 1.

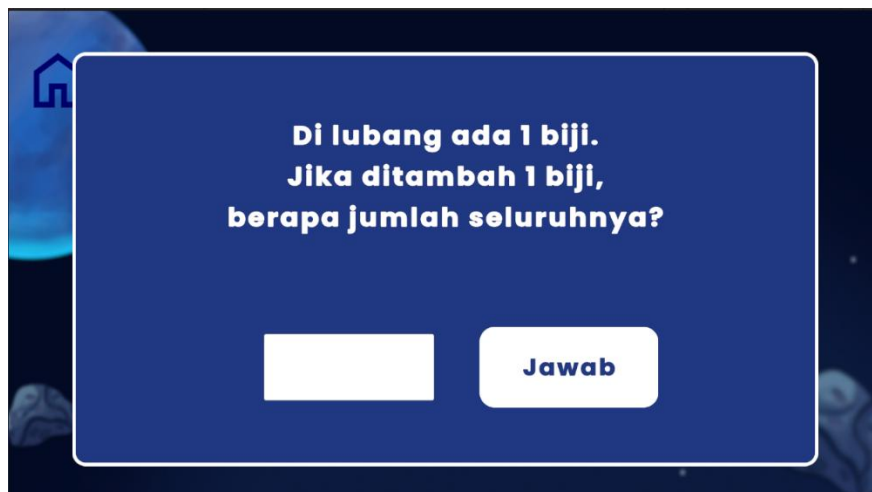


Figure 4.22 Level 1 Question Type – Addition

The addition question asks the player to calculate the total number of seeds after adding a certain number.

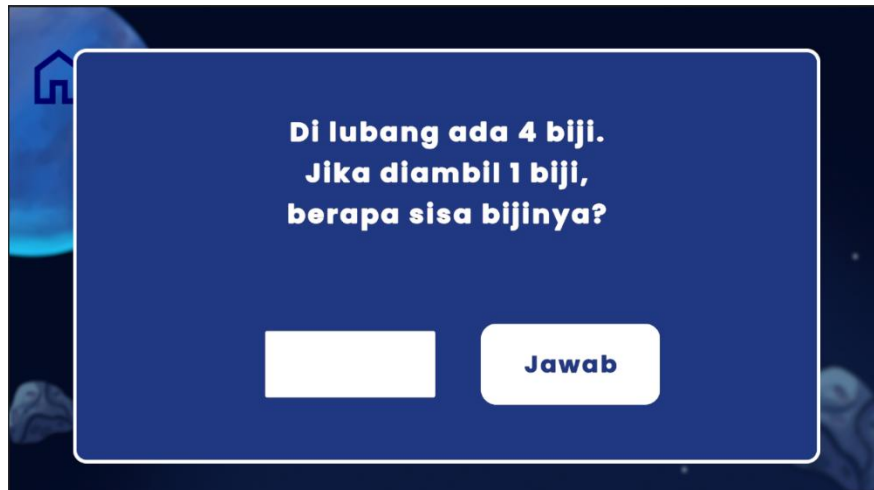


Figure 4.23 Level 1 Question Type – Subtraction

The subtraction question requires the player to determine the remaining number of seeds after some are taken away.

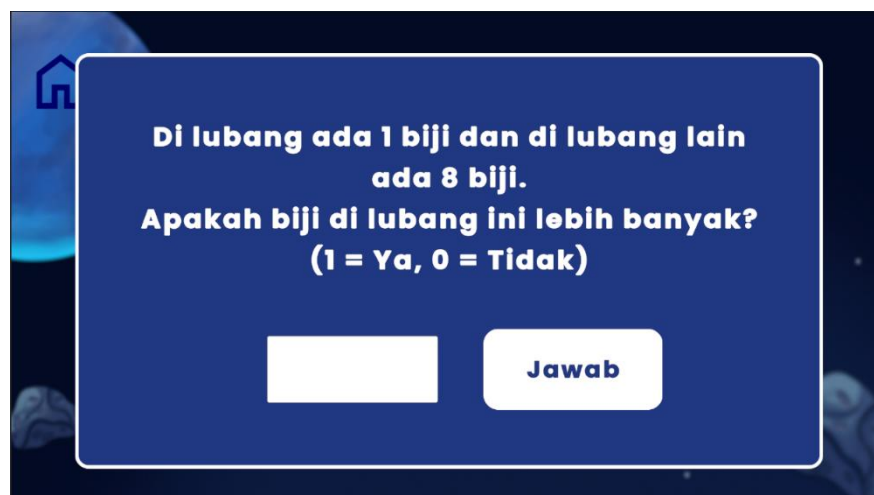


Figure 4.24 Level 1 Question Type – Comparison

The comparison question asks the player to compare two quantities and determine which one is greater.



Figure 4.25 Level 1 Question Type – Missing Number

The missing number question requires the player to find an unknown value in a simple equation. The questions in this level are designed to reinforce fundamental arithmetic skills while keeping the interaction engaging. By integrating the questions into the gameplay, students are encouraged to think and solve problems as part of the game process. Overall, Level 1 serves as the foundation for the learning system, preparing players for more complex problems in higher levels.

4.3.5 Level 2

Level 2 represents the intermediate stage of the game, where the difficulty of the mathematical problems is increased compared to Level 1. In this level, the learning system introduces more complex arithmetic operations, including two-digit addition, multi-step calculations, and combined operations. The questions are generated based on the second level configuration implemented in the system.

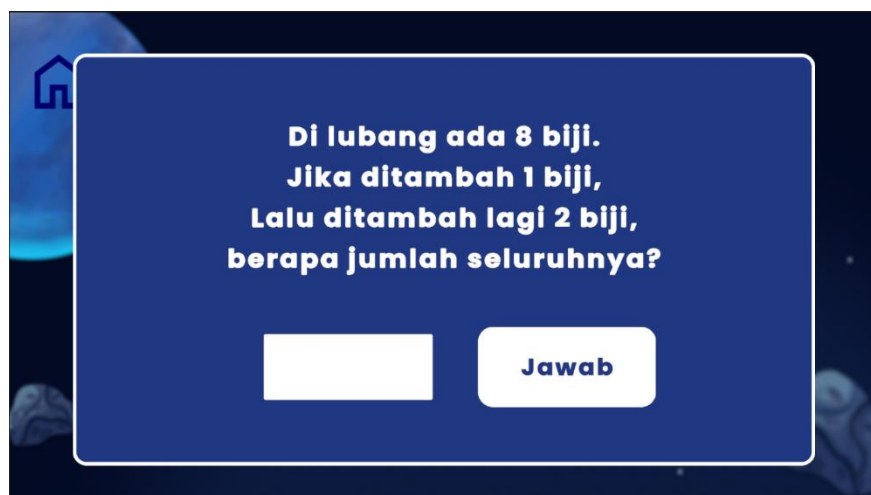
The problems in Level 2 require students to perform calculations involving larger numbers and multiple steps. This encourages students to develop better accuracy and problem-solving skills. Figure 4.26, Figure 4.27, Figure 4.28, and Figure 4.29 shows examples of question types in Level 2.



The screenshot shows a dark blue rectangular box with a white border. Inside the box, the text is in white and reads: "Di lubang ada 88 biji. Jika ditambah 41 biji, berapa jumlah seluruhnya?". Below the text, there is a white rectangular input field and a white button with the word "Jawab" in blue text. The background of the entire screen is dark blue with a faint, stylized illustration of a cave entrance and some rocks.

Figure 4.26 Level 2 Question Type – Two Number Addition

The two-number addition question involves adding larger numbers, typically two-digit values.



The screenshot shows a dark blue rectangular box with a white border. Inside the box, the text is in white and reads: "Di lubang ada 8 biji. Jika ditambah 1 biji, Lalu ditambah lagi 2 biji, berapa jumlah seluruhnya?". Below the text, there is a white rectangular input field and a white button with the word "Jawab" in blue text. The background of the entire screen is dark blue with a faint, stylized illustration of a cave entrance and some rocks.

Figure 4.27 Level 2 Question Type – Multi-Step Operation

The multi-step operation question requires the player to perform calculations involving more than two numbers.



Figure 4.28 Level 2 Question Type – Mixed Operation

The mixed operation question combines addition and subtraction in a single expression.



Figure 4.29 Level 2 Question Type – Two Number Subtraction

The subtraction question involves larger numbers and requires careful calculation. Compared to Level 1, the questions in this level are more challenging due to the increased number size and multi-step operations. However, the questions are still presented in a clear format to ensure that students can understand them. Overall, Level 2 serves as a transition from basic to more advanced mathematical problems.

4.3.6 Level 3

Level 3 represents the advanced stage of the game, where the mathematical problems are designed to be more complex and require higher-level thinking. In this level, the learning

system introduces multiplication, division, and mixed arithmetic operations. The questions are generated based on the highest level configuration in the system. The problems in Level 3 require students to perform more advanced calculations, including multiplication and division, which involve a deeper understanding of mathematical concepts. Figure 4.30, Figure 4.31, Figure 4.32, and Figure 4.33 shows examples of question types in Level 3.



Figure 4.30 Level 3 Question Types – Multiplication

The multiplication question requires the player to calculate the total number of objects based on grouped values.

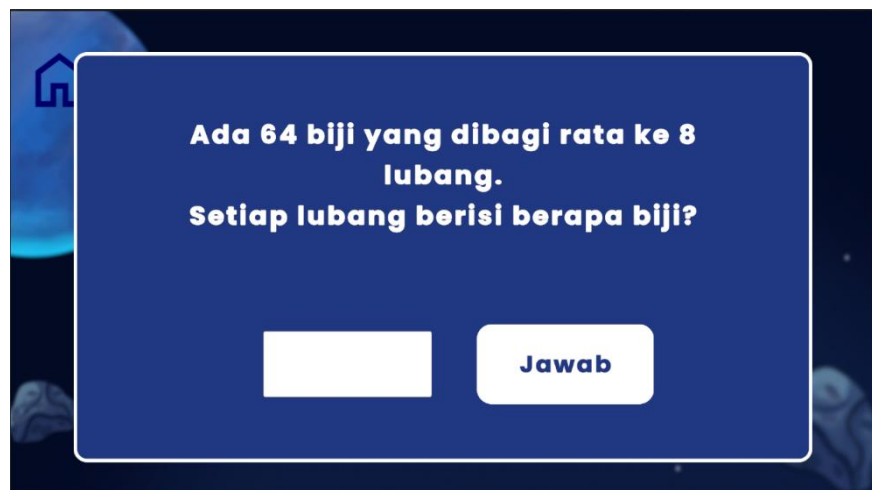


Figure 4.31 Level 3 Question Type – Division

The division question asks the player to distribute values evenly into groups.



Figure 4.32 Level 3 Question Type – Mixed Operation

The mixed operation question combines multiplication and addition in a single expression.



Figure 4.33 Level 3 Question Type – Missing Number

The missing number question requires the player to determine an unknown value in a mathematical equation. Compared to Level 2, the questions in this level are more complex because they introduce new operations such as multiplication and division. This increases the level of difficulty and requires higher cognitive processing. Overall, Level 3 serves as the highest level in the game, providing advanced mathematical challenges for the players.

The implementation of system components in this stage reflects the design decisions derived from the analysis results. The integration of gameplay mechanics with mathematical problem-solving ensures that learning is embedded within user interaction, addressing the issue

of low engagement identified earlier. In addition, the use of a rule-based AI supports predictable and manageable gameplay, which is suitable for elementary school students.

Therefore, the development stage not only focuses on technical realization but also ensures that the system remains aligned with pedagogical objectives and user needs. This alignment demonstrates that the developed application is not merely a functional game system, but also a structured learning medium designed based on identified instructional requirements.

4.4 Implementation

This stage involved applying the developed digital Dakon-based mathematics game in a real classroom environment as a trial implementation phase. The purpose of this stage was to observe how students interacted with the system and to collect data that would later be used for evaluation, rather than to directly assess learning outcomes. The activity was conducted at an elementary school involving twenty students as participants. The session took place in a classroom under the supervision of the researcher to ensure that the activity ran effectively. This controlled environment helped ensure that all participants followed the procedure and that the collected data were reliable.

During the implementation, the application was used on three Android-based mobile devices prepared by the researcher. The students were divided into several groups consisting of four to five students per group, allowing them to take turns using the devices. Each student was given the opportunity to directly interact with the application, while other group members observed the gameplay process. This turn-taking mechanism ensured that all participants experienced the system, although the duration of interaction for each student may vary slightly depending on group dynamics. Before starting the gameplay, the researcher provided a brief explanation of the game rules and instructions on how to use the application. This step ensured that students understood the gameplay mechanics and the learning process embedded within the system.

During the session, students interacted with the application in turns by playing the game, answering mathematical questions, and following the gameplay flow. The session lasted for approximately 40 minutes. During this process, the researcher conducted observations to monitor student engagement, interaction patterns, and any difficulties encountered. In general, students showed active participation and interest in the game, although several challenges were identified during the implementation process.

One notable issue occurred when students entered answers using letters instead of numerical values. In such cases, the system displayed an “invalid input” message, but the question was not re-displayed after the error occurred. As a result, students were unable to view the previous question, which caused confusion and temporarily disrupted the gameplay flow. This indicates that the input validation and feedback mechanism in the system was not yet fully optimized for the target users.

After the implementation stage was completed, this issue was addressed by improving the input handling mechanism to ensure that questions remain accessible after an invalid input occurs. This improvement was made to enhance system usability and ensure smoother gameplay in subsequent use.

After completing the gameplay session, students were asked to fill out a questionnaire to capture their perceptions of the application. The questionnaire consisted of 13 statements divided into four aspects, namely usability, attractiveness, perceived learning support, and user acceptance, which were measured using a five-point Likert scale. The detailed questionnaire items are presented in Table 4.4.

Table 4.4 User Questionnaire

No	Question	Score (1 – 5)
1	Saya mudah memahami cara bermain game ini	
2	Tombol dan menu pada game mudah digunakan	
3	Aturan permainan tidak membuat saya bingung	
4	Saya dapat menyelesaikan permainan dengan baik	
5	Tampilan warna dan gambar game ini menarik	
6	Animasi dalam game membuat saya senang bermain	
7	Game ini membuat saya tidak cepat bosan	
8	Game ini membantu saya belajar berhitung	
9	Setelah bermain game, saya lebih paham berhitung	
10	Belajar matematika dengan game ini lebih menyenangkan	
11	Saya senang bermain game dakon digital ini	
12	Saya ingin bermain game ini lagi	
13	Saya ingin belajar matematika menggunakan game seperti ini	

Considering that the participants were third-grade elementary school students, the questionnaire was administered with guidance. Each item was read aloud and explained by the researcher to ensure that students understood the meaning of each statement. Students filled out the questionnaire individually, while the researcher provided assistance when needed. Simple explanations and examples were also given to help students understand the Likert scale from 1 to 5, ensuring that their responses accurately reflected their perceptions.

Overall, the implementation process ran smoothly, and all participants were able to interact with the application within the available time. The data collected during this stage serve as the basis for further analysis, including functional testing, user evaluation, and reliability analysis, which are presented in the following section.

4.5 Evaluation

The evaluation stage aims to assess the functionality, usability, and perceived learning support of the developed digital Dakon-based mathematics game. This evaluation was conducted through functional testing and user evaluation using a questionnaire.

4.5.1 Functional Testing

Functional testing was conducted using the black-box testing method to evaluate whether each system function operates according to the expected output based on user input. The testing was primarily performed by the researcher during the development stage and prior to classroom implementation to ensure that all system features functioned correctly.

The testing covered several main features of the application, including main menu navigation, level selection, gameplay mechanics, question system, answer validation, and game completion. In particular, the gameplay mechanics were tested to ensure that the Dakon rules were implemented correctly, including seed distribution (capture rule), additional turns when seeds end in the player's store, and the condition where the game ends when one side of the board is empty.

In addition, the level selection feature was tested to verify that each button correctly loads the corresponding difficulty level and applies the appropriate question configuration. Interface-related features such as the main menu display and exit button functionality were also tested to ensure proper system navigation. The question system and answer validation were tested to confirm that correct answers allow gameplay to proceed, while incorrect or invalid inputs trigger appropriate system responses. The detailed results of the functional testing are presented in Table 4.5.

Table 4.5 Black Box Testing

Tested Feature	Input Scenario	Expected Output	Results
Main menu navigation	Select Play	Navigate to level selection	Valid
Level selection	Select level 1	Load the gameplay board	Valid
Question trigger	Click pit	Display math question	Valid
Correct answer	Input the correct answer	Continue seed distribution	Valid
Incorrect answer	Input the wrong answer	Turn transferred to the opponent	Valid
Invalid input	Input a non-numeric value	Warning message displayed	Valid
Game end	All pits empty	Display the final results screen	Valid

Based on the testing results, all tested features functioned according to the expected outcomes. The system successfully handled valid input, incorrect answers, and invalid input such as non-numeric responses. This indicates that the core functionality of the system is stable and ready for use in the implementation stage.

Although no critical errors were found during functional testing, minor usability issues were later identified during the implementation stage, particularly related to input handling and user feedback. These findings suggest that while the system is functionally reliable, further refinement is still necessary to improve user experience. Therefore, the functional testing confirms that the system meets the basic operational requirements while also providing a basis for iterative improvement.

4.5.2 User Evaluation

User evaluation was conducted using a questionnaire distributed to 20 elementary school students after they used the application. The questionnaire consisted of 13 statements measured using a five-point Likert scale. The detailed responses from each participant are presented in Table 4.6.

Table 4.6 Respondent Data

No	Gender	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1	Male	3	5	5	5	5	3	5	5	4	5	5	5	5
2	Male	3	5	5	5	5	5	5	5	3	4	4	5	5
3	Female	5	3	4	4	4	5	5	5	5	5	5	4	4
4	Female	4	4	4	3	3	4	4	4	4	4	5	3	5
5	Male	4	2	3	3	3	3	3	3	3	4	4	3	4
6	Female	5	5	4	3	4	3	4	4	4	4	4	4	4
7	Male	5	5	5	5	5	3	3	5	5	5	5	4	4
8	Male	5	5	5	5	5	5	3	3	3	3	4	3	3
9	Male	5	5	5	5	5	5	5	5	5	5	5	5	5
10	Male	4	3	3	3	5	4	4	4	5	3	3	3	3
11	Male	4	5	3	4	3	4	5	5	5	5	5	5	5
12	Female	4	5	5	3	4	3	3	3	2	5	5	4	5
13	Female	2	5	5	5	5	5	2	5	5	5	5	2	5
14	Male	5	5	5	5	5	5	1	5	5	5	5	5	5
15	Female	5	5	2	5	3	5	5	5	3	5	4	5	5
16	Female	3	5	5	4	5	5	5	5	5	5	4	5	5
17	Male	3	5	5	3	5	3	5	5	4	5	5	5	5
18	Male	3	5	5	5	5	5	5	5	5	5	4	5	4
19	Female	5	4	4	5	5	5	3	5	4	5	3	3	4
20	Female	2	3	2	2	5	3	3	4	4	3	4	2	5

Table 4.6 presents the questionnaire responses of each participant along with demographic information such as gender. This data provides an overview of how each respondent evaluated the application. To facilitate the interpretation of the questionnaire results, the percentage scores for each evaluation aspect are also presented graphically in Figure 4.34.

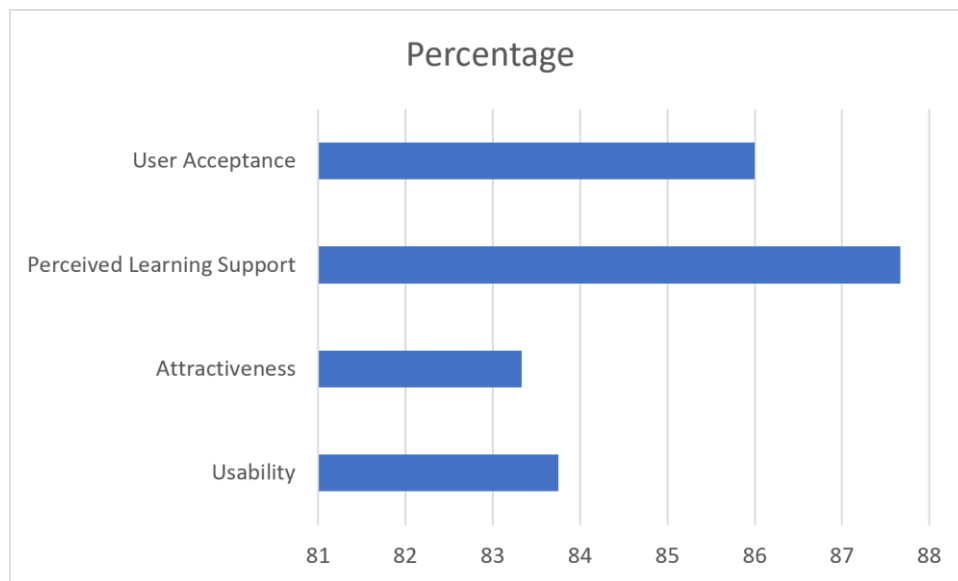


Figure 4.34 User Evaluation Results by Aspect

As shown in Figure 4.34, all evaluation aspects obtained percentage scores above 80%, indicating highly positive user perceptions of the developed application. Perceived learning support achieved the highest score (87.67%), suggesting that students considered the game effective in supporting mathematics learning. User acceptance obtained a score of 86.00%, indicating a strong willingness among students to continue using similar educational games. Meanwhile, usability (83.75%) and attractiveness (83.33%) also received positive evaluations, demonstrating that the application was easy to use and visually engaging for elementary school students. To simplify the interpretation, the questionnaire data were further analyzed using descriptive statistics. The results of the analysis are presented in Table 4.7.

Table 4.7 Questionnaire Results

Aspect	Mean	Standard Deviation	Percentage	Category
Usability	4.19	0.68	83.75%	Highly Feasible
Attractiveness	4.17	0.59	83.33%	Highly Feasible
Perceived learning support	4.38	0.67	87.67%	Highly Feasible
User Acceptance	4.30	0.63	86.00%	Highly Feasible
Overall	4.25	-	85%	Highly Feasible

Table 4.7 shows the mean and standard deviation values for each evaluation aspect. The usability aspect obtained a mean score of 4.19, attractiveness 4.17, perceived learning support 4.38, and user acceptance 4.30. The overall mean score obtained was 4.25 with a feasibility percentage of 85%, which indicates that the application is categorized as highly feasible. The standard deviation values indicate that the responses among participants were relatively consistent.

The overall feasibility score of 85% indicates that the developed game was positively perceived by the participants across all evaluation aspects. From the perspective of educational game evaluation, this result suggests that the application successfully met key dimensions commonly used to assess educational games, including usability, engagement, perceived learning support, and user acceptance. These dimensions are consistent with the MEEGA+KIDS framework proposed by Gresse von Wangenheim et al. (2020), which emphasizes both player experience and perceived learning outcomes as important indicators of educational game quality. Therefore, the obtained score provides empirical support that the developed game achieved a high level of acceptance among the participating students.

4.5.3 Reliability Analysis

Reliability testing was conducted using Cronbach's Alpha to measure the internal consistency of the questionnaire. Cronbach's Alpha is widely used to evaluate the reliability of an instrument, where a value greater than 0.7 indicates acceptable reliability (Cronbach, 1951). The results of the reliability analysis are presented in Table 4.8.

Table 4.8 Reliability Results

Aspect	Cronbach Alpha
Usability	0.81
Attractiveness	0.77
Perceived Learning Support	0.84
User Acceptance	0.80
Overall	0.88

The overall Cronbach's Alpha value obtained was 0.88, indicating strong reliability. The values for each aspect were 0.81 (usability), 0.77 (attractiveness), 0.84 (perceived learning support), and 0.80 (user acceptance). These results indicate that the questionnaire instrument used in this study is reliable and consistent for measuring user perceptions of the developed system. The high reliability values suggest that the responses provided by the participants are internally consistent across all questionnaire items. This means that each item within the same aspect measures a similar underlying construct, allowing the data to be interpreted with a higher level of confidence.

Therefore, the results obtained from the user evaluation, including usability, attractiveness, perceived learning support, and user acceptance, can be considered dependable and representative of students' perceptions. This strengthens the validity of the findings presented in the previous section and supports the conclusion that the developed system meets the expected evaluation criteria.

4.5.4 Discussion

The results of this study indicate that integrating arithmetic tasks into Dakon gameplay has the potential to create an interactive learning environment for elementary mathematics education. The developed system combines gameplay interaction with arithmetic problem-solving activities, allowing mathematical accuracy to directly influence gameplay progression.

One important design decision in this study is the use of a rule-based AI opponent rather than a complex artificial intelligence model. For elementary educational games, the main objective is not to simulate highly competitive gameplay but to maintain consistent interaction

flow while keeping the focus on learning activities. A rule-based AI provides predictable responses, faster computation, and stable gameplay behavior, making it suitable for young learners interacting with educational game systems.

The progressive level structure also contributes to the perceived educational value of the game. The three levels were designed to support the gradual development of arithmetic skills, beginning with basic operations and progressing toward more complex mathematical concepts. This staged progression is expected to help learners adapt to increasing cognitive demands without creating an abrupt difficulty gap. Such a structure is consistent with prior studies indicating that progressive challenge in game-based learning environments can enhance engagement and cognitive development (Alotaibi, 2024; Hussein et al., 2022).

The user evaluation results indicate positive perceptions across all measured aspects, confirming that the system supports usability and engagement in mathematics learning contexts (Dan et al., 2024; Hui & Mahmud, 2023; Nadeem et al., 2023). Among the evaluated aspects, perceived learning support obtained the highest mean score, indicating that students perceived the game as helpful in supporting mathematics learning. In contrast, attractiveness obtained the lowest mean score, although it still remained within the highly feasible category. This suggests that while the system is perceived as helpful for learning, further improvements may enhance visual engagement. The high reliability value (Cronbach's $\alpha = 0.88$) further supports the consistency of the evaluation instrument, indicating that the questionnaire items reliably measure user perceptions.

The evaluation results can also be interpreted through the perspective of the MEEGA+KIDS framework (Gresse von Wangenheim et al., 2020), which was specifically developed for evaluating educational games used by school-age learners. Although the complete MEEGA+KIDS instrument was not directly adopted in this study, the evaluation dimensions used are conceptually aligned with several of its core constructs. The usability aspect corresponds to ease of interaction and understanding of the game, attractiveness reflects enjoyment and engagement, perceived learning support relates to the educational benefits perceived by students, and user acceptance indicates learners' willingness to continue using similar educational games. Based on this perspective, the overall feasibility score of 85% indicates positive outcomes across these dimensions. These findings suggest that the developed digital Dakon game provides a satisfactory balance between usability, engagement, and perceived learning support, which are important indicators of quality in educational game evaluation for elementary school students.

Another important contribution of this study lies in the integration of cultural context within the digital learning environment. Dakon, as a traditional Indonesian game, naturally involves counting, distribution, and strategic thinking. Embedding arithmetic tasks within Dakon gameplay allows students to interact with mathematical concepts through a culturally familiar activity. Ethnomathematics research suggests that connecting mathematics learning with cultural practices can enhance conceptual understanding and student engagement (D'Ambrosio, 1985; Masruroh & Amir, 2024).

From a pedagogical perspective, the developed digital Dakon game can serve as a supplementary learning tool for elementary school teachers. Teachers may use the game during mathematics lessons to provide interactive practice activities, where students solve arithmetic problems while engaging in gameplay-based interaction.

Despite these promising findings, several limitations should be acknowledged. The study involved a relatively small sample and a short implementation period, and it focused primarily on user perception rather than direct measurement of learning outcomes. In addition, students' prior familiarity with digital games may have influenced their responses.

These limitations suggest that further research is needed. Future studies may involve larger and more diverse participant groups, incorporate experimental comparisons with traditional learning methods, and extend the duration of implementation to better evaluate long-term learning outcomes.

From a practical perspective, scalability should also be considered. Variations in device availability, technical infrastructure, and teacher readiness may affect implementation in broader educational contexts. These challenges may be addressed through optimization for lower-specification devices, improvement of user interface clarity, and clearer guidance for teachers in integrating the application into classroom activities.

Overall, the findings indicate that the developed system is perceived positively by users and shows strong potential as a feasible digital learning medium that integrates cultural context, interactive gameplay, and arithmetic learning in elementary mathematics education. These results highlight that the system is not only functionally reliable but also capable of providing an engaging and meaningful learning experience from the perspective of its users.

4.6 Limitations of the Study

The limitations of this study should be acknowledged to provide a balanced interpretation of the findings. First, the evaluation was based on students' perceptions using a questionnaire,

without employing an experimental design such as a pre-test and post-test. Therefore, the study does not measure actual learning outcomes, and the findings are limited to perceived learning support rather than objective improvement in students' mathematical performance.

Second, the number of participants was limited to twenty third-grade students from a single elementary school. This relatively small and homogeneous sample may affect the generalizability of the results, as the findings may not fully represent students with different backgrounds, learning environments, or levels of familiarity with digital games.

Third, the artificial intelligence implemented in the game uses a rule-based approach, which may limit the adaptability and complexity of the system compared to more advanced AI methods. In the context of educational gameplay, this means that the level of challenge provided by the system is not dynamically adjusted to individual student abilities, resulting in a relatively uniform gameplay experience for all users.

In addition, the use of a questionnaire-based evaluation with third-grade students introduces potential limitations related to their ability to fully understand the questionnaire items and the Likert scale. Although guidance was provided during the data collection process, students' responses may still be influenced by their level of comprehension and interpretation.

These limitations indicate that further research is needed to strengthen the findings and improve the system. Future studies may employ experimental designs to measure actual learning outcomes, involve larger and more diverse participant groups from different schools, and explore the use of more adaptive AI approaches to provide personalized gameplay experiences.

CHAPTER V

CONCLUSION AND SUGGESTIONS

5.1 Conclusion

Based on the results of this study, the conclusions are presented as follows:

1. The development of a digital Dakon-based mathematics learning game using the ADDIE model was successfully carried out through the stages of analysis, design, development, implementation, and evaluation. The resulting application integrates arithmetic questions directly into gameplay mechanics, allowing students' responses to influence game progression.
2. Mathematical concepts were successfully integrated into the gameplay in a structured manner. The use of question-based interactions and progressive difficulty levels enables students to engage with arithmetic problems as part of the game process, supporting meaningful and interactive learning experiences.
3. The integration of cultural context through the adaptation of the traditional Dakon game demonstrates that ethnomathematics can be incorporated into digital game-based learning. This approach provides a culturally relevant learning environment that is familiar and engaging for elementary school students.
4. The developed application is considered feasible as a learning medium based on user perception evaluation. The results showed positive responses across usability, attractiveness, perceived learning support, and user acceptance, with an overall mean score of 4.25 and a feasibility percentage of 85%.
5. The system functionality was validated through black-box testing, which indicated that all features operated according to the expected behavior without critical errors. In addition, the reliability analysis produced a Cronbach's Alpha value of 0.88, indicating strong internal consistency of the questionnaire instrument.
6. Overall, the developed game is perceived as engaging and well-received by students, and it shows potential as an interactive mathematics learning medium. However, this study focuses on user perception and does not measure actual learning outcomes through experimental methods.

5.2 Suggestions

A. Suggestions for Future Research

Future studies should involve a larger and more diverse group of participants to improve the generalizability of the findings. Expanding the evaluation to multiple schools or different regions would provide more comprehensive insights into user perceptions and the feasibility of the system as a learning medium.

Considering that the current study is limited to perception-based evaluation, further research is recommended to examine the impact of the application on students' actual learning outcomes. Experimental approaches, such as pre-test and post-test designs, may be applied to evaluate potential improvements in students' mathematical understanding.

In addition, future studies may explore longer implementation periods to observe sustained user interaction and to better understand how the system supports learning over time. This would provide deeper insights into both engagement and potential long-term learning benefits.

B. Suggestions for Product Development

The game can be further enhanced by improving the artificial intelligence system. While the current rule-based AI provides consistent and predictable gameplay, future development may explore more adaptive approaches that can adjust the level of challenge based on individual student performance, thereby creating a more personalized learning experience.

In addition, technical improvements can be carried out to optimize the application for lower-specification devices and to refine user interaction mechanisms, particularly in handling input and feedback to ensure smoother gameplay. These improvements are important to enhance usability and reduce potential confusion during gameplay.

Further feature development may also be considered, such as adding multiplayer interaction or additional game variations to increase user engagement. Moreover, providing clearer guidance for teachers and aligning the application with formal curriculum standards may support its integration into classroom teaching practices and improve its usability as a learning medium.

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APPENDIX

Appendix A. Classroom Implementation Environment



Appendix B. Discussion with the Teacher Prior to Implementation



Appendix C. Students Interacting with the Application



Appendix D. Main Menu Controller Script

```
using UnityEngine;
using UnityEngine.SceneManagement;
using System.Collections;

public class MainMenuController : MonoBehaviour
{
    public FadeController fade;
    public void PlayGame()
    {
        StartCoroutine(PlayWithFade());
    }

    IEnumerator PlayWithFade()
    {
        yield return fade.FadeOut();
        SceneManager.LoadScene("Difficulty");
    }

    public void QuitGame()
    {
        Application.Quit();
    }

    public void Options()
    {
    }
}
```

Appendix E. Fadeout function Script

```
public IEnumerator FadeOut()
{
    float t = 0f;
    while (t < fadeDuration)
    {
        t += Time.deltaTime;
        float a = Mathf.Clamp01(t / fadeDuration);
        fadeImage.color = new Color(0, 0, 0, a);
        yield return null;
    }
}
```

Appendix F. OptionsUI Script

```
using UnityEngine;

public class OptionsUI : MonoBehaviour
{
    public GameObject optionsPanel;

    public void OpenOptions()
    {
        optionsPanel.SetActive(true);
    }

    public void CloseOptions()
    {
        optionsPanel.SetActive(false);
    }
}
```

Appendix G. OptionsPanel Script

```
using UnityEngine;
using UnityEngine.UI;

public class OptionsPanel : MonoBehaviour
{
    public Toggle musicToggle;

    void OnEnable()
    {
        if (MusicManager.Instance != null)
        {
            musicToggle.isOn = MusicManager.Instance.IsMusicEnabled();
        }
    }
}
```

Appendix H. GlobalGameManager Script

```
using UnityEngine;
using UnityEngine.SceneManagement;

public class GlobalGameManager : MonoBehaviour
{
    public void SetLevel(GameLevel level)
    {
        currentLevel = level;
    }

    public static GlobalGameManager Instance;

    public GameLevel currentLevel = GameLevel.Level1;

    void Awake()
    {
        if (Instance == null)
        {
            Instance = this;
            DontDestroyOnLoad(gameObject);
        }
        else
        {
            Destroy(gameObject);
        }
    }

    // =====
    // LEVEL SELECTION
    // =====
    public void SelectLevel1()
    {
        currentLevel = GameLevel.Level1;
        Debug.Log("[GlobalGameManager] Level 1 selected");
        SceneManager.LoadScene("Game");
    }

    public void SelectLevel2()
    {
        currentLevel = GameLevel.Level2;
        Debug.Log("[GlobalGameManager] Level 2 selected");
        SceneManager.LoadScene("Game");
    }

    public void SelectLevel3()
    {
        currentLevel = GameLevel.Level3;
        Debug.Log("[GlobalGameManager] Level 3 selected");
        SceneManager.LoadScene("Game");
    }

    // =====
    // NAVIGATION
    // =====
    public void GoToMainMenu()
    {
        Debug.Log("[GlobalGameManager] Back to MainMenu");
        SceneManager.LoadScene("MainMenu");
    }
}
```

```

    }

    public void GoToDifficulty()
    {
        Debug.Log("[GlobalGameManager] Back to Difficulty");
        SceneManager.LoadScene("Difficulty");
    }
}

```

Appendix I. LearningManager Script

```

using UnityEngine;
using TMPro;
using System.Collections;

public enum MathQuestionType
{
    Addition,
    Subtraction,
    Comparison,
    MissingNumber
}

public enum MathQuestionTypeLevel2
{
    Multiplication,
    Division,
    MixedOperation,
    MissingNumberHard
}

public enum MathQuestionTypeLevel3
{
    TwoNumberAddition,
    MoreOperation,
    MixedOperationEasy,
    TwoNumberSubtraction
}

public class LearningManager : MonoBehaviour
{
    public TMP_Text errorText;
    [Header("Feedback UI")]
    public GameObject feedbackPanel;
    public TextMeshProUGUI feedbackText;

    public static LearningManager Instance;

    [Header("UI")]
    public GameObject questionPanel;
    public TextMeshProUGUI questionText;
    public TMP_InputField answerInput;

    private int correctAnswer;

    void Awake()
    {
        if (Instance == null)
            Instance = this;
    }
}

```

```

        else
            Destroy(gameObject);
    }

    // =====
    // DIPANGGIL OLEH BoardManager
    // =====
    public void ShowMathQuestionFromHole(int seedCount)
    {
        // ⚡ Jangan muncul saat AI
        if (BoardManager.Instance.IsAITurn())
        {
            Debug.Log("[Learning] Skip question (AI turn)");
            return;
        }

        // 🔑 PILIH SOAL BERDASARKAN LEVEL
        if (GlobalGameManager.Instance != null)
        {
            switch (GlobalGameManager.Instance.currentLevel)
            {
                case GameLevel.Level1:
                    GenerateQuestionLevel1(seedCount);
                    break;

                case GameLevel.Level2:
                    GenerateQuestionLevel2(seedCount);
                    break;

                case GameLevel.Level3:
                    GenerateQuestionLevel3(seedCount);
                    break;

                default:
                    GenerateQuestionLevel1(seedCount);
                    break;
            }
        }
        else
        {
            // fallback kalau GameManager null
            GenerateQuestionLevel1(seedCount);
        }

        answerInput.text = "";
        questionPanel.SetActive(true);

        Time.timeScale = 0f;
        Debug.Log("[Learning] Question shown");
    }

    // =====
    // LEVEL 1 - SOAL LAMA (TIDAK DIUBAH)
    // =====
    void GenerateQuestionLevel1(int seedCount)
    {
        MathQuestionType type =
            (MathQuestionType)Random.Range(
                0,
                System.Enum.GetValues(typeof(MathQuestionType)).Length
            );
    }

```

```

        );

int a = seedCount;
int b = Random.Range(1, 5);

switch (type)
{
    case MathQuestionType.Addition:
        correctAnswer = a + b;
        questionText.text =
            $"Di lubang ada {a} biji.\n" +
            $"Jika ditambah {b} biji,\n" +
            $"berapa jumlah seluruhnya?";
        break;

    case MathQuestionType.Subtraction:
        b = Random.Range(1, a + 1);
        correctAnswer = a - b;
        questionText.text =
            $"Di lubang ada {a} biji.\n" +
            $"Jika diambil {b} biji,\n" +
            $"berapa sisa bijinya?";
        break;

    case MathQuestionType.Comparison:
        int other = Random.Range(0, 10);
        correctAnswer = a > other ? 1 : 0;
        questionText.text =
            $"Di lubang ada {a} biji dan di lubang lain ada
{other} biji.\n" +
            $"Apakah biji di lubang ini lebih banyak?\n" +
            $"(1 = Ya, 0 = Tidak)";
        break;

    case MathQuestionType.MissingNumber:
        correctAnswer = a;
        questionText.text =
            $"Jika ada .... biji dan ditambah {b} biji menjadi
{a + b},\n" +
            $"berapa jumlah biji awalnya?";
        break;
    }
}

// =====
// LEVEL 2 - SOAL LEBIH SULIT
// =====
void GenerateQuestionLevel2(int seedCount)
{
    MathQuestionTypeLevel2 type =
        (MathQuestionTypeLevel2)Random.Range(
            0,
            System.Enum.GetValues(typeof(MathQuestionTypeLevel2)).
Length
        );

    int a, b;

    switch (type)
    {

```

+

```
case MathQuestionTypeLevel2.Multiplication:
    a = Random.Range(1, 10);
    b = Random.Range(1, 10);
    correctAnswer = a * b;
    questionText.text =
        $"Ada {a} kelompok, tiap kelompok berisi {b} biji.\n"

        $"Berapa jumlah seluruh biji?";
    break;

case MathQuestionTypeLevel2.Division:
    b = Random.Range(1, 10);
    correctAnswer = Random.Range(1, 10);
    a = correctAnswer * b;
    questionText.text =
        $"Ada {a} biji yang dibagi rata ke {b} lubang.\n" +
        $"Setiap lubang berisi berapa biji?";
    break;

case MathQuestionTypeLevel2.MixedOperation:
    a = Random.Range(1, 10);
    b = Random.Range(1, 10);
    int c = Random.Range(1, 10);
    correctAnswer = a * b + c;
    questionText.text =
        $"Hitung hasil dari:\n" +
        $"{a} × {b} + {c} = ?";
    break;

case MathQuestionTypeLevel2.MissingNumberHard:
    b = Random.Range(1, 10);
    correctAnswer = Random.Range(1, 10);
    a = correctAnswer * b;
    questionText.text =
        $"Jika ? × {b} = {a},\n" +
        $"berapa nilai ?";
    break;
}
}

void GenerateQuestionLevel3(int seedCount)
{
    MathQuestionTypeLevel3 type =
        (MathQuestionTypeLevel3)Random.Range(
            0,
            System.Enum.GetValues(typeof(MathQuestionTypeLevel2)).
                Length
            );

    int a, b, c;

    switch (type)
    {
        case MathQuestionTypeLevel3.TwoNumberAddition:
            a = Random.Range(10, 99);
            b = Random.Range(10, 99);
            correctAnswer = a + b;
            questionText.text =
                $"Di lubang ada {a} biji.\n" +
                $"Jika ditambah {b} biji,\n" +
```

```

        $"berapa jumlah seluruhnya?";
        break;

    case MathQuestionTypeLevel3.MoreOperation:
        a = Random.Range(1, 10);
        b = Random.Range(1, 10);
        c = Random.Range(1, 10);
        correctAnswer = a + b + c;
        questionText.text =
            $"Di lubang ada {a} biji.\n" +
            $"Jika ditambah {b} biji,\n" +
            $"Lalu ditambah lagi {c} biji,\n" +
            $"berapa jumlah seluruhnya?";
        break;

    case MathQuestionTypeLevel3.MixedOperationEasy:
        a = Random.Range(1, 10);
        b = Random.Range(1, 10);
        c = Random.Range(1, 10);
        correctAnswer = a + b - c;
        questionText.text =
            $"Hitung hasil dari:\n" +
            $"{a} + {b} - {c} = ?";
        break;

    case MathQuestionTypeLevel3.TwoNumberSubtraction:
        a = Random.Range(10, 99);
        b = Random.Range(10, 99);
        correctAnswer = a - b;
        questionText.text =
            $"Di lubang ada {a} biji.\n" +
            $"Jika diambil {b} biji,\n" +
            $"berapa sisa bijinya?";
        break;
    }
}

// =====
// BUTTON JAWAB
// =====
public void SubmitAnswer()
{
    // Reset error text
    errorText.text = "";

    if (!int.TryParse(answerInput.text, out int playerAnswer))
    {
        errorText.text = "Masukkan angka yang benar!";
        return; // STOP di sini, soal tetap tampil
    }

    bool correct = playerAnswer == correctAnswer;

    // Baru tutup panel kalau format sudah benar
    questionPanel.SetActive(false);

    ShowFeedback(correct);
}

void ShowFeedback(bool correct)

```

```

{
    if (feedbackPanel == null || feedbackText == null)
    {
        Debug.LogError("[Learning] Feedback UI not assigned!");
        return;
    }

    feedbackPanel.SetActive(true);

    if (correct)
    {
        feedbackText.text = "Jawaban benar! 🎉";
        feedbackText.color = Color.green;
    }
    else
    {
        feedbackText.text = "Jawaban salah 🤔\nGiliran di-skip";
        feedbackText.color = Color.red;
    }

    StartCoroutine(FeedbackDelay(correct));
}
IEnumerator FeedbackDelay(bool correct)
{
    yield return new WaitForSecondsRealtime(2f);

    feedbackPanel.SetActive(false);
    Time.timeScale = 1f;

    if (BoardManager.Instance != null)
    {
        BoardManager.Instance.ResumeAfterQuestion(correct);
    }
}

```

Appendix J. GameManager Script

```

using UnityEngine;
using UnityEngine.SceneManagement;

// =====
// GAME MANAGER (GAME SCENE ONLY)
// - Tidak DontDestroyOnLoad
// - Ambil level dari GlobalGameManager
// - Hubungkan BoardManager
// =====
public class GameManager : MonoBehaviour
{
    public static GameManager Instance;

    [Header("Runtime References")]
    public BoardManager board;

    [Header("Current Level (Read Only)")]
    public GameLevel currentLevel;

    // =====
    // LIFECYCLE
    // =====

```

```

void Awake()
{
    if (Instance == null)
        Instance = this;
    else
        Destroy(gameObject);
}

void Start()
{
    // ambil BoardManager
    board = FindFirstObjectByType<BoardManager>();
    if (board == null)
    {
        Debug.LogError("[GameManager] BoardManager NOT FOUND!");
    }

    // ambil level dari GlobalGameManager
    if (GlobalGameManager.Instance != null)
    {
        currentLevel = GlobalGameManager.Instance.currentLevel;
        Debug.Log("[GameManager] Current Level = " + currentLevel);
    }
    else
    {
        Debug.LogWarning("[GameManager] GlobalGameManager not found,
default Level1");
        currentLevel = GameLevel.Level1;
    }
}

// =====
// HOME BUTTON
// =====
public void GoHome()
{
    Debug.Log("[GameManager] Go Home");
    SceneManager.LoadScene("MainMenu");
}

// =====
// HELPER
// =====
public bool IsLevel1() => currentLevel == GameLevel.Level1;
public bool IsLevel2() => currentLevel == GameLevel.Level2;
}

```

Appendix K. Hole Script

```

using System.Collections.Generic;
using UnityEngine;
using TMPro;

public class Hole : MonoBehaviour
{
    [Header("Fixed Seed Size (DO NOT SCALE)")]
    public Vector2 fixedSeedSize = new Vector2(18f, 18f);

    public void ResetHole()

```

```

{
    seedCount = 0;
    ClearAndReturnVisualsToPool();
}

public void UpdateDisplay()
{
    if (seedText != null)
        seedText.text = seedCount.ToString();
}

[Header("Game data")]
public int seedCount = 7;          // jumlah biji logis

[Header("UI")]
public TextMeshProUGUI seedText;  // text menampilkan jumlah biji

[Header("Meta")]
public int boardIndex = -1;       // index hole pada board (0..11)
public bool isStore = false;      // flag jika ini store (lambung)

[Header("Transform Reference")]
public RectTransform rectTransform; // rect transform lubang (untuk
layout visual)

    // visual seeds yang "persist" di lubang ini (GameObject dari
SeedPool)
private List<GameObject> visualSeeds = new List<GameObject>();

    // settings layout (bisa disesuaikan di Inspector apabila ingin
expose)
[Header("Visual Layout Settings")]
[Tooltip("Base proportional size relative to hole diameter")]
[Range(0.1f, 0.6f)]
public float baseSizeRatio = 0.28f;
public float minSeedSize = 8f;
public float maxSeedSize = 40f;

void Awake()
{
    if (rectTransform == null)
        rectTransform = GetComponent<RectTransform>();
}

void Start()
{
    RefreshUI();
}

#region -- Data / UI --
public void RefreshUI()
{
    if (seedText != null)
        seedText.text = seedCount.ToString();

    UpdateVisualLayout();
}

public void AddSeeds(int amount = 1)
{

```

```

        seedCount += amount;
        RefreshUI();
    }

    public int TakeAllSeeds()
    {
        int t = seedCount;
        seedCount = 0;
        RefreshUI();
        return t;
    }
    #endregion

    #region -- Visual seed management --
    /// <summary>
    /// Menambahkan satu visual seed ke lubang (seedGO diasumsikan sudah
berada pada posisi yang tepat).
    /// Fungsi akan mem-parent seed ke rectTransform lubang dan merapikan
pos/scale.
    /// </summary>
    public void AddVisualSeed(GameObject seedGO)
    {
        if (seedGO == null) return;

        // parent ke lubang sehingga pos relatif ke lubang
        seedGO.transform.SetParent(rectTransform, false);

        // disable raycast pada image agar tidak mengganggu input tombol
        var img = seedGO.GetComponent<UnityEngine.UI.Image>();
        if (img != null) img.raycastTarget = false;

        // pastikan RectTransform ada
        var rt = seedGO.GetComponent<RectTransform>();
        if (rt != null)
        {
            rt.localScale = Vector3.one;
        }

        visualSeeds.Add(seedGO);
        UpdateVisualLayout();
    }

    /// <summary>
    /// Mengambil semua visual seed dari lubang (mengosongkan
visualSeeds)
    /// Digunakan ketika pemain memilih lubang – visual akan dianimasikan
keluar.
    /// </summary>
    public List<GameObject> TakeAllVisualSeeds()
    {
        var list = new List<GameObject>(visualSeeds);
        visualSeeds.Clear();
        UpdateVisualLayout();
        return list;
    }

    /// <summary>
    /// Mengembalikan (return) semua visual seed ke pool, dan kosongkan
list.
    /// Dipanggil saat endgame atau reset.

```

```

    /// </summary>
    public void ClearAndReturnVisualsToPool()
    {
        for (int i = visualSeeds.Count - 1; i >= 0; i--)
        {
            var go = visualSeeds[i];
            if (go == null) continue;
            if (SeedPool.Instance != null)
                SeedPool.Instance.Return(go);
            else
                Destroy(go);
        }
        visualSeeds.Clear();
        UpdateVisualLayout();
    }
    #endregion

    #region -- Layout algorithm --
    /// <summary>
    /// Mengatur penempatan dan ukuran visual seeds berdasarkan
    jumlahnya.
    /// Circle layout untuk n <= 6; grid layout untuk jumlah lebih
    banyak.
    /// </summary>
    void UpdateVisualLayout()
    {
        int n = visualSeeds.Count;
        if (rectTransform == null || n == 0) return;

        float holeMin = Mathf.Min(
            rectTransform.rect.width,
            rectTransform.rect.height
        );

        // radius saja yang menyesuaikan
        float radius = holeMin * 0.32f;

        if (n <= 6)
        {
            // === CIRCLE LAYOUT ===
            for (int i = 0; i < n; i++)
            {
                var go = visualSeeds[i];
                if (go == null) continue;

                var rt = go.GetComponent<RectTransform>();
                if (rt == null) continue;

                // 🔒 FIX SIZE (INI KUNCI)
                rt.sizeDelta = fixedSeedSize;
                rt.localScale = Vector3.one;

                float ang = (360f / n) * i * Mathf.Deg2Rad;
                Vector2 pos = new Vector2(Mathf.Cos(ang), Mathf.Sin(ang))
* radius;

                rt.anchoredPosition = pos;
            }
        }
        else
        {

```

```

        // === GRID LAYOUT ===
        int cols = 4;
        int rows = Mathf.CeilToInt((float)n / cols);
        float spacing = 6f;

        float startX = -((cols - 1) * spacing) / 2f;
        float startY = ((rows - 1) * spacing) / 2f;

        for (int i = 0; i < n; i++)
        {
            int r = i / cols;
            int c = i % cols;

            var go = visualSeeds[i];
            if (go == null) continue;

            var rt = go.GetComponent<RectTransform>();
            if (rt == null) continue;

            // 🔒 FIX SIZE
            rt.sizeDelta = fixedSeedSize;
            rt.localScale = Vector3.one;

            float x = startX + c * spacing;
            float y = startY - r * spacing;
            rt.anchoredPosition = new Vector2(x, y);
        }
    }

#endregion

#region -- Helpers --
/// <summary>
/// Untuk animasi: kembalikan posisi world/screen dari
RectTransform.
/// Biasanya dipakai oleh SeedMover (mengharapkan screen pos).
/// </summary>
public Vector3 GetWorldPosition()
{
    if (rectTransform != null) return rectTransform.position;
    return transform.position;
}
#endregion
// in Hole.cs (inside class Hole)

// Initialize visuals at game start: create 'count' visual seeds
and parent ke lubang
public void InitializeVisuals(int count)
{
    // bersihkan dulu bila ada
    ClearAndReturnVisualsToPool();

    if (SeedPool.Instance == null) return;

    for (int i = 0; i < count; i++)
    {
        GameObject go = SeedPool.Instance.Get();
        // posisi & parent di-handle oleh AddVisualSeed
        AddVisualSeed(go);
    }
}

```

```

    }

    // refresh text & layout
    RefreshUI();
}

// debug helper: mengembalikan jumlah visual seeds saat runtime
public int DebugVisualCount()
{
    // visualSeeds adalah private list di Hole.cs; jika kamu
    menggunakan versi Hole.cs saya sebelumnya,
    // fungsi ini bisa langsung mengaksesnya. Jika visualSeeds
    berbeda nama, sesuaikan.
    // Pastikan visualSeeds field ada (List<GameObject>
    visualSeeds).
    return visualSeeds != null ? visualSeeds.Count : 0;
}
}

```

Appendix L. StoreHole Script

```

using System.Collections.Generic;
using UnityEngine;
using TMPPro;

/// <summary>
/// StoreHole: menampilkan stones sebagai angka dan (opsional) visual
representative seeds.
/// - showRepresentativeVisuals: jika true, tampilkan sampai maxVisual
biji.
/// - jika stones > maxVisual: tampilkan maxVisual biji + angka total.
/// - jika ingin menampilkan visual semua biji, set maxVisual tinggi
(ingat performa).
/// </summary>
public class StoreHole : MonoBehaviour
{
    [Header("Store Data")]
    public int stones = 0;

    [Header("UI")]
    public TextMeshProUGUI stoneText;
    public RectTransform rectTransform;

    [Header("Visual options")]
    [Tooltip("Tampilkan visual biji representatif di store (jika false
-> hanya angka)")]
    public bool showRepresentativeVisuals = true;
    [Tooltip("Maks visual seeds yang ditampilkan di store (untuk
performa)")]
    public int maxVisual = 12;
    [Tooltip("Ukuran dasar tiap seed di store (px)")]
    public float representativeSeedSize = 20f;

    // internal list of visual GameObjects currently shown in store
    private List<GameObject> visualSeeds = new List<GameObject>();

    void Awake()
    {

```

```

        if (rectTransform == null) rectTransform =
GetComponent<RectTransform>();
    }

    void Start()
    {
        UpdateDisplay();
    }

    #region Data ops
    // Add logical stones (dipanggil BoardManager.PlaceSeedToLogical)
    public void AddSeeds(int amount)
    {
        stones += amount;
        UpdateDisplay();
    }

    public int GetStoneCount() => stones;

    public void UpdateDisplay()
    {
        if (stoneText != null)
            stoneText.text = stones.ToString();

        // Ensure visuals reflect stone count (but limited by maxVisual)
        if (showRepresentativeVisuals)
            SyncVisualsToCount();
    }

    // Reset store state (dipanggil oleh BoardManager saat reset/new
game)
    public void ResetStore()
    {
        stones = 0;
        ClearVisualsToPool();
        UpdateDisplay();
    }
    #endregion

    #region Visual management
    // Add an existing seed gameobject as representative visual
    public void AddVisualSeed(GameObject seedGO)
    {
        if (seedGO == null) return;

        if (!showRepresentativeVisuals)
        {
            // if not showing visuals, just return seed to pool
            if (SeedPool.Instance != null)
SeedPool.Instance.Return(seedGO);
            else Destroy(seedGO);
            return;
        }

        // if we've reached max visuals, return to pool
        if (visualSeeds.Count >= maxVisual)
        {
            if (SeedPool.Instance != null)
SeedPool.Instance.Return(seedGO);
            else Destroy(seedGO);

```

```

        return;
    }

    // parent to store rect and layout
    seedGO.transform.SetParent(rectTransform, false);

    // disable raycast so it won't block clicks
    var img = seedGO.GetComponent<UnityEngine.UI.Image>();
    if (img != null) img.raycastTarget = false;

    // set size & random-ish position
    var rt = seedGO.GetComponent<RectTransform>();
    if (rt != null)
    {
        rt.sizeDelta = new Vector2(representativeSeedSize,
representativeSeedSize);
        rt.localScale = Vector3.one;
        float areaW = Mathf.Max(10f, rectTransform.rect.width *
0.6f);
        float areaH = Mathf.Max(10f, rectTransform.rect.height *
0.6f);
        rt.anchoredPosition = new Vector2(Random.Range(-areaW / 2f,
areaW / 2f), Random.Range(-areaH / 2f, areaH / 2f));
    }

    visualSeeds.Add(seedGO);
}

// Ensure visuals reflect current stones (up to maxVisual)
// If we have fewer visuals than needed, create from pool (if
available).
// If we have more visuals than maxVisual, return extras to pool.
void SyncVisualsToCount()
{
    int desired = Mathf.Min(maxVisual, stones);

    // remove extras
    while (visualSeeds.Count > desired)
    {
        var go = visualSeeds[visualSeeds.Count - 1];
        visualSeeds.RemoveAt(visualSeeds.Count - 1);
        if (go != null)
        {
            if (SeedPool.Instance != null)
SeedPool.Instance.Return(go);
            else Destroy(go);
        }
    }

    // add missing visuals
    while (visualSeeds.Count < desired)
    {
        if (SeedPool.Instance != null)
        {
            var go = SeedPool.Instance.Get();
            // configure and parent
            go.transform.SetParent(rectTransform, false);
            var rt = go.GetComponent<RectTransform>();

```

```

        if (rt != null) { rt.sizeDelta = new
Vector2(representativeSeedSize, representativeSeedSize); rt.localScale =
Vector3.one; }

        var img = go.GetComponent<UnityEngine.UI.Image>();
        if (img != null) img.raycastTarget = false;

        // position in store area
        float areaW = Mathf.Max(10f, rectTransform.rect.width *
0.6f);
        float areaH = Mathf.Max(10f, rectTransform.rect.height
* 0.6f);

        if (rt != null) rt.anchoredPosition = new
Vector2(Random.Range(-areaW / 2f, areaW / 2f), Random.Range(-areaH / 2f,
areaH / 2f));

        visualSeeds.Add(go);
    }
    else
    {
        // no pool: break to avoid infinite loop
        break;
    }
}

// Initialize visuals at start
public void InitializeVisuals(int count)
{
    ClearVisualsToPool();
    stones = count;
    UpdateDisplay();
}

// Clear visuals and return to pool
public void ClearVisualsToPool()
{
    for (int i = visualSeeds.Count - 1; i >= 0; i--)
    {
        var go = visualSeeds[i];
        if (go != null)
        {
            if (SeedPool.Instance != null)
SeedPool.Instance.Return(go);
            else Destroy(go);
        }
    }
    visualSeeds.Clear();
}
#endregion
}

```

Appendix M. HoleButtonHandle Script

```

using UnityEngine;

public class HoleButtonHandler : MonoBehaviour
{
    [Tooltip("Index lubang sesuai mapping di BoardManager (0..11)")]
    public int boardIndex = -1;
}

```

```

// Hubungkan method ini ke Button.OnClick() di Inspector
public void OnPressed()
{
    if (BoardManager.Instance != null)
    {
        BoardManager.Instance.OnHoleSelected(boardIndex);
    }
    else
    {
        Debug.LogWarning("[HoleButtonHandler] BoardManager.Instance
is null. Pastikan BoardManager ada di scene.", this);
    }
}
}

```

Appendix N. HoleTapHandler Script

```

using UnityEngine;
using UnityEngine.EventSystems;

/// <summary>
/// Handler tap pada lubang, mobile-friendly.
/// Hanya memicu efek (vibrate/highlight/select) jika
BoardManager.CanSelectHole(holeIndex) == true
/// dan BoardManager.isBusy == false.
/// </summary>
[RequireComponent(typeof(Collider2D))] // atau Collider untuk 3D
public class HoleTapHandler : MonoBehaviour, IPointerClickHandler
{
    [Tooltip("Index hole (0..11) - set di inspector atau di-initialize
otomatis oleh BoardManager")]
    public int holeIndex = -1;

    [Tooltip("Durasi vibrasi (ms) saat tap valid")]
    public int vibMs = 20;

    // optional visual feedback script (scale bounce)
    public TapHighlight tapHighlight;

    BoardManager board;

    void Awake()
    {
        // safer lookup (non-deprecated)
        board = Object.FindFirstObjectByType<BoardManager>();
        // try to auto-fill holeIndex if not set and this object is a
child of a Hole
        if (holeIndex < 0 && board != null)
        {
            int idx = board.GetHoleIndexFromObject(gameObject);
            if (idx >= 0) holeIndex = idx;
        }
    }

    public void OnPointerClick(PointerEventData eventData)
    {

```

```

        Debug.Log($"[HoleTapHandler] OnPointerClick called on
'{gameObject.name}' (holeIndex={holeIndex}) eventData={ (eventData==null?
"NULL": eventData.pointerId.ToString())}");

        // if BoardManager unavailable, ignore (but log so we know)
        if (board == null)
        {
            Debug.LogWarning("[HoleTapHandler] BoardManager instance
not found - ignoring click.");
            if (tapHighlight != null) tapHighlight.Play(); // optional
visual for feedback
            return;
        }

        // jika game singleplayer dan sekarang giliran AI, jangan izinkan
pemain menekan lubang Player2
        if (board.singlePlayer && board.IsAITurn())
        {
            // optional: beri feedback audio / visual

            // if (debugLogs) Debug.Log("[HoleTapHandler] Input ignored
- it's AI's turn in singlePlayer mode.");
        }

        // if board busy, ignore input (avoid vibrating) and log reason
        if (board.isBusy)
        {
            Debug.Log("[HoleTapHandler] Board is busy - input ignored.");
            return;
        }

        // ensure holeIndex resolved
        if (holeIndex < 0) holeIndex =
board.GetHoleIndexFromObject(gameObject);
        if (holeIndex < 0)
        {
            Debug.LogWarning("[HoleTapHandler] Unable to resolve
holeIndex from object - ignoring.");
            return;
        }

        Debug.Log($"[HoleTapHandler] Resolved holeIndex={holeIndex}.
Now checking CanSelectHole...");

        // check if selectable (turn + non-empty)
        bool canSelect = board.CanSelectHole(holeIndex);
        if (!canSelect)
        {
            Debug.Log("[HoleTapHandler] Hole not selectable right now
(either not your turn or empty).");
            // optional: play "invalid tap" feedback (sound) here instead
of vibrate
            return;
        }

        Debug.Log("[HoleTapHandler] Valid tap detected - invoking
vibration & highlight.");

        // valid tap: vibrate and play highlight, then select hole
        try

```

```

        {
            DeviceVibration.Vibrate(vibMs);
            Debug.Log($"[HoleTapHandler] Requested vibrate {vibMs}ms
for hole {holeIndex}");
        }
        catch (System.Exception ex)
        {
            // swallow errors but log to help debugging on device logs
            Debug.LogWarning("[HoleTapHandler] Vibrate call failed: " +
ex.Message);
        }

        if (tapHighlight != null) tapHighlight.Play();

        // finally call board to handle selection
        board.SelectHole(holeIndex);
    }

    // Editor test fallback
    void OnMouseDown()
    {
        // simulate pointer click in editor
        OnPointerClick(null);
    }
}

```

Appendix O. AIPlayer Script

```

using System.Collections;
using UnityEngine;

/// <summary>
/// AI sederhana (greedy) yang kompatibel dengan BoardManager versi yang
diberikan.
/// - Subscribe ke BoardManager.OnTurnChangedEvent
/// - Saat giliran AI (Player2 & singlePlayer == true) AI akan menunggu
delayBeforeMove lalu memilih langkah
/// - Heuristik: extra-turn > capture potential > jumlah biji
/// </summary>
public class AIPlayer : MonoBehaviour
{
    public BoardManager board;
    [Tooltip("Delay (detik) sebelum AI melakukan langkah agar terlihat
natural")]
    public float delayBeforeMove = 0.6f;

    Coroutine thinkRoutine;

    void Start()
    {
        if (board == null) board = BoardManager.Instance;
        if (board != null)
        {
            board.OnTurnChangedEvent += OnTurnChanged;
            Debug.Log("[AIPlayer] Subscribed to OnTurnChangedEvent");
        }
        else
        {
            Debug.LogWarning("[AIPlayer] BoardManager not found.");
        }
    }
}

```

```

    }
}

void OnDestroy()
{
    if (board != null) board.OnTurnChangedEvent -= OnTurnChanged;
}

void OnTurnChanged(PlayerTurn newTurn)
{
    Debug.Log($"[AIPlayer] Turn changed to {newTurn},
singlePlayer={board.singlePlayer}");

    if (thinkRoutine != null)
    {
        StopCoroutine(thinkRoutine);
        thinkRoutine = null;
    }

    if (board == null) return;

    // 🗑️ PASTIKAN BENAR-BENAR GILIRAN AI
    if (!board.singlePlayer) return;
    if (newTurn != PlayerTurn.Player2) return;

    thinkRoutine = StartCoroutine(ThinkAndMove());
}

IEnumerator ThinkAndMove()
{
    // Tunggu sebentar supaya natural
    yield return new WaitForSeconds(delayBeforeMove);

    // 🕒 WAJIB: tunggu sampai board bebas
    yield return new WaitUntil(() => board != null && !board.isBusy);

    int best = GetBestMoveIndex();

    if (best < 0)
    {
        Debug.Log("[AIPlayer] No valid move found.");
        thinkRoutine = null;
        yield break;
    }

    Debug.Log("[AIPlayer] Chosen hole: " + best);
    board.OnPitClickedAI(best);

    thinkRoutine = null;
}

int GetBestMoveIndex()
{
    if (board == null || board.holes == null) return -1;

    int bestMove = -1;
    int bestScore = int.MinValue;

    // AI side in your setup is hole indices 6..11
    for (int i = 6; i <= 11; i++)

```

```

    {
        // ensure move is valid for AI
        if (!board.IsMoveValid(i, false)) continue;

        int seeds = board.holes[i].seedCount;
        if (seeds <= 0) continue;

        int score = EvaluateMove(i, seeds);

        if (score > bestScore)
        {
            bestScore = score;
            bestMove = i;
        }
    }

    return bestMove;
}

int EvaluateMove(int holeIndex, int seeds)
{
    int score = 0;

    // baseline: prefer more seeds (small weight)
    score += seeds;

    // simulate landing logical index
    int logical = board.HoleIndexToLogicalPublic(holeIndex);
    int landing = logical;
    int remaining = seeds;

    while (remaining > 0)
    {
        landing = (landing + 1) % 14;

        // skip opponent store if configured
        if (board.skipOpponentStore)
        {
            if (board.currentTurn == PlayerTurn.Player1 && landing
== 13) { continue; }
            if (board.currentTurn == PlayerTurn.Player2 && landing
== 6) { continue; }
        }

        remaining--;
    }

    // 1) extra turn (landing in AI store logical 13)
    if (landing == 13) score += 200;

    // 2) capture potential:
    // capture occurs if landing is on AI side (logical 7..12), and
the opposite hole has seeds
    if (!board.IsLogicalStorePublic(landing))
    {
        // landing on AI side logical 7..12 (player1 side is 0..5,
store6)
        if (landing >= 7 && landing <= 12)
        {
            int oppositeLogical = 12 - landing;

```

```

board.GetHoleByLogicalPublic(oppositeLogical);
// capture also requires that the landing hole would be
empty before placing (i.e., we are placing 1 there)
// but exact sim of hole emptiness is complex; approximate
by checking opposite has seeds
    if (opposite != null && opposite.seedCount > 0)
    {
        score += 150;
    }
}

// small randomness/variance to avoid deterministic ties (not
necessary but helpful)
score += Random.Range(0, 5);

return score;
}
}

```

Appendix P. SeedPool Script

```

using System.Collections.Generic;
using UnityEngine;

public class SeedPool : MonoBehaviour
{
    public static SeedPool Instance;

    public GameObject seedPrefab;
    public int initialSize = 40;

    public Transform uiParent;

    private Queue<GameObject> pool = new Queue<GameObject>();

    void Awake()
    {
        if (Instance == null) Instance = this;
        else Destroy(gameObject);

        if (seedPrefab == null)
            Debug.LogWarning("[SeedPool] Seed Prefab not assigned!");

        // AUTO FIND CANVAS (Unity 6 safe)
        if (uiParent == null)
        {
            // cari object bernama GameCanvas di scene
            GameObject g = GameObject.Find("GameCanvas");
            if (g != null)
            {
                uiParent = g.transform;
            }
            else
            {
                // fallback: cari canvas pertama dengan API Unity 6
                var canvas = FindFirstObjectByType<Canvas>();
                if (canvas != null)

```

```

        uiParent = canvas.transform;
    }
}

// buat isi pool
for (int i = 0; i < initialSize; i++)
    pool.Enqueue(CreateNew());
}

GameObject CreateNew()
{
    Transform parent = uiParent != null ? uiParent : transform;
    GameObject go = Instantiate(seedPrefab, parent);
    go.SetActive(false);
    return go;
}

public GameObject Get()
{
    GameObject go;
    if (pool.Count == 0)
        go = CreateNew();
    else
        go = pool.Dequeue();

    if (uiParent != null)
        go.transform.SetParent(uiParent, false);
    else
        go.transform.SetParent(transform, false);

    go.SetActive(true);
    return go;
}

public void Return(GameObject go)
{
    go.SetActive(false);
    go.transform.SetParent(transform, false);
    pool.Enqueue(go);
}
}

```

Appendix Q. SeedMover Script

```

using System;
using System.Collections;
using UnityEngine;

[RequireComponent(typeof(RectTransform))]
public class SeedMover : MonoBehaviour
{
    // RectTransform dari visual seed (UI)
    public RectTransform rect;

    [Header("Motion")]
    public AnimationCurve ease = AnimationCurve.EaseInOut(0, 0, 1, 1);
    public float arcHeight = 8f; // efek lengkung (pixel)
    public float minDuration = 0.06f; // durasi minimal
}

```

```

// internal
Vector2 startAnch;
Vector2 targetAnch;
float duration;
Action onArrive;

void Awake()
{
    if (rect == null) rect = GetComponent<RectTransform>();
}

// NEW API: terima RectTransform sumber & tujuan -> ini lebih aman
untuk UI
// owner: objek yang memulai coroutine (contoh: BoardManager)
public void StartMoveFromToRects(MonoBehaviour owner, RectTransform
fromRect, RectTransform toRect, float time, Action callback)
{
    if (rect == null) rect = GetComponent<RectTransform>();

    // cari canvas
    Canvas canvas = rect.GetComponentInParent<Canvas>();
    if (canvas == null)
    {
        Debug.LogWarning("[SeedMover] Canvas parent not found. Using
world positions fallback.");
        // fallback: gunakan world pos
        startAnch = rect.anchoredPosition;
        targetAnch = rect.anchoredPosition;
    }
    else
    {
        RectTransform canvasRect =
canvas.GetComponent<RectTransform>();
        Camera cam = (canvas.renderMode ==
RenderMode.ScreenSpaceOverlay) ? null : canvas.worldCamera;

        Vector2 fromLocal, toLocal;
        RectTransformUtility.ScreenPointToLocalPointInRectangle(ca
nvasRect, GetRectWorldPosition(fromRect), cam, out fromLocal);
        RectTransformUtility.ScreenPointToLocalPointInRectangle(ca
nvasRect, GetRectWorldPosition(toRect), cam, out toLocal);

        startAnch = fromLocal;
        targetAnch = toLocal;

        // set immediate so seed appears pada posisi start
        rect.anchoredPosition = startAnch;
        rect.localScale = Vector3.one;
    }

    duration = Mathf.Max(minDuration, time);
    onArrive = callback;

    // start coroutine on owner (BoardManager) -> safer for lifetime
    owner.StartCoroutine(MoveRoutine());
}

// helper: world position of a RectTransform (use .position)
Vector3 GetRectWorldPosition(RectTransform r)
{

```

```

        if (r == null) return Vector3.zero;
        return r.position;
    }

    IEnumerator MoveRoutine()
    {
        float t = 0f;
        while (t < duration)
        {
            t += Time.deltaTime;
            float n = Mathf.Clamp01(t / duration);
            float e = ease.Evaluate(n);

            Vector2 mid = Vector2.LerpUnclamped(startAnch, targetAnch,
e);

            float arc = Mathf.Sin(n * Mathf.PI) * arcHeight;
            rect.anchoredPosition = mid + Vector2.up * arc;

            yield return null;
        }

        rect.anchoredPosition = targetAnch;
        onArrive?.Invoke();
    }
}

```

Appendix R. Full Questionnaire Instrument

KUESIONER PENGUJIAN KE USER

Game Dakon Digital sebagai Media Pembelajaran Matematika

Petunjuk:

Beri tanda (✓) pada jawaban yang paling sesuai.

1 = Sangat Tidak Setuju | 2 = Tidak Setuju | 3 = Biasa Saja | 4 = Setuju | 5 = Sangat Setuju

Identitas Responden

Kelas : III

Jenis Kelamin : L / P

Nama :

Uji Usability (Kemudahan Penggunaan)

1. Saya mudah memahami cara bermain game ini. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
2. Tombol dan menu pada game mudah digunakan. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
3. Aturan permainan tidak membuat saya bingung. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
4. Saya dapat menyelesaikan permainan dengan baik. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Uji Kemenarikan

5. Tampilan warna dan gambar game ini menarik. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
6. Animasi dalam game membuat saya senang bermain. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
7. Game ini membuat saya tidak cepat bosan. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Uji dukungan pembelajaran yang dirasakan

8. Game ini membantu saya belajar berhitung. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
9. Setelah bermain game, saya lebih paham berhitung. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
10. Belajar matematika dengan game ini lebih menyenangkan. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Uji Penerimaan Pengguna

11. Saya senang bermain game dakon digital ini. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
12. Saya ingin bermain game ini lagi. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
13. Saya ingin belajar matematika menggunakan game seperti ini. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Pertanyaan Terbuka

Bagian game yang paling saya sukai:

Bagian game yang sulit atau membingungkan:

Appendix S. Permission Letter from University



FAKULTAS
TEKNOLOGI INDUSTRI

Gedung KH. Mas Mansur
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext. 4100, 4101
F. (0274) 895007
E. fti@uii.ac.id
W. fti.uii.ac.id

Nomor : 6/Kaprodi.IF.S1/20/IF/I/2026
Lamp : -
Hal : Permohonan Penelitian Tugas Akhir

Kepada Yth.
Kepala Sekolah
MI Fajar Siddiq
di Jl. Syakyakirti, Karang Anyar, Kec. Gandus, Kota Palembang, Sumatera Selatan 30148

Assalamu'alaikum Warahmatullahi Wabarokatuh

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 Aulia Nalendra
No. Mhs : 22523296

Kami berharap mahasiswa kami dapat melaksanakan penelitian di institusi Bapak/Ibu antara bulan Januari 2026 sampai dengan Februari 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'alaykum Warahmatullahi Wabarokatuh

Yogyakarta, 27 Januari 2026

Ketua Program Studi Informatika - Program
Sarjana, Fakultas Teknologi Industri



Ir. Thomas Hatta Fudholi, S.T., M.Eng., Ph.D.