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Gamification Modeling in Learning Logic Gate Concepts with User Acceptance Testing

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ABSTRACT

Logic gates are a fundamental concept in digital electronic systems, yet they are often difficult for students to understand theoretically. To address this, we developed a learning media study in the form of the educational game "Zero One", which aims to enhance conceptual understanding by using binary inputs as keys and logic gates as locks. This research included a needs analysis, system design, and prototype development. Descriptive statistical analysis indicated that most players successfully completed level 15, with level 2 being the easiest and level 5 the most challenging. The results suggest that "Zero One" has the potential to effectively support learning in digital logic gates. Future research will aim to adjust the difficulty levels and introduce a multiplayer mode to further enhance understanding of logic gates.

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1. INTRODUCTION

Logic gates are a key element in the development of modern digital systems. Their function is crucial in binary decision-making processes and forms the basis for constructing logic circuits to support the functions of computers, electronic devices, and programming. Without a solid understanding of this concept, students will struggle to keep up with future developments in information technology and electronics.

However, in higher education learning models, the concept of logic gates is often understood in a limited and theoretical manner. Many students lack a grasp of the concept and struggle to implement abstract concepts without practical support. Consequently, this understanding of the material becomes less applicable.

Logic gates are typically taught in several courses on computer architecture, digital systems, and information systems. Although this material spans various disciplines, the teaching approach tends to be conventional (Susilowati & Wicaksono, 2021). The presentation of the material still focuses on theoretical aspects such as truth tables and logical equations, which are insufficient to develop a strong conceptual understanding.

The abstract model of logic gates is a major problem in the learning process. Students not only struggle to understand the definitions of logic gates such as AND, OR, and NOT, but also struggle to see how these gates are interconnected and function in complex circuits (Yunita & Harahap, 2020). When material is presented through text and logical symbols, student motivation to learn is low.

One drawback in learning logic gates is the lack of interactive and contextual learning media. The material is not linked to real-life visual implementations that would enable students to visualize how the concepts are developed.

To address this challenge, innovation in learning methods is needed that goes beyond passively delivering material and actively engages students in problem-solving. The gamification model is one potential approach to addressing this problem, as it can create a fun and meaningful learning environment (Prensky, 2007; Squire, 2011).

To response this issue, the educational game Zero One was developed. This game was developed to help students understand the concept of logic gates through simulations based on logical challenges. With an approach that combines educational and entertainment elements, it is hoped that it can increase student engagement and understanding of the material (Arifianto & Rachmadyanti, 2023).

The Zero One game uses a lock and key mechanism, where logical input combinations act as "keys" and logic gates serve as "locks." Students are encouraged to try different input combinations to unlock the "logic locks" within the simulation. This approach allows students to actively understand logic gates engagingly (Nugroho et al., 2022). Zero One helps students learn about logic gates like AND, OR, and NOT. Input and output visuals are shown live, enabling students to see logic changes as they happen. This offers a more effective learning experience compared to just studying theory (Wulandari & Hidayati, 2021). With this method, Zero One functions not only as entertainment but also as a valuable learning tool. It can be integrated into digital learning systems for students. The goal is that active exploration and playful experiences will deepen understanding of logic gates and boost learning motivation (Sutrisno et al., 2023).

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2. METHODS

In this research, a needs analysis was conducted to identify problems and user needs related to learning digital logic gates. This stage involved reviewing the literature to gain a theoretical understanding of basic logic concepts, effective learning strategies, and irrelevant learning materials.

Based on the results of the needs analysis, the next step was designing the game application system. This system design employed the Key and Lock Mechanism approach, where the combination of logical inputs functions as the "key" and the logic gate as the "lock." This mechanism was selected because it visually and interactively demonstrates how basic logic gates such as AND, OR, and NOT operate. At this stage, the game flow, user interface, game level system, and game challenges were developed into game mechanics.

In addition to the gameplay concept, another design stage focused on defining the flow of player interaction with the system. Each level was created to teach one or more logic gate concepts, starting from the introductory level and progressing to complex combinations of logic gates. Flowcharts and storyboards were developed to illustrate the development process. Gamification principles, such as point accumulation, life system modelling, and immediate feedback, were incorporated to boost learning motivation.

The prototype was developed using a platformer-based game development tool. This game type was chosen for its ease of integration with familiar game mechanics that many players already understand. The prototype included features like interactive logic gates and visual effects to clarify the results of each player's input.

During prototype development, digital logic gate concepts were integrated directly into gameplay. For example, for an AND gate, players must activate two switches simultaneously to open a door. For an OR gate, only one switch needs to be activated. This hands-on approach aims to provide a more effective learning experience than purely theoretical methods.

Once the prototype was ready, a trial was conducted with students from the Multimedia Engineering Technology (TRM) program who had prior basic logic knowledge. The purpose was to assess user acceptance of the game from educational and entertainment perspectives. During the trial, students played several levels and provided feedback on gameplay ease, clarity of material, and their enjoyment.

Evaluation data were gathered through a questionnaire designed to measure participants' achievement levels. The perceived difficulty was also assessed through constructive criticism and suggestions for improvement. A Likert scale provided quantitative data, while open-ended questions collected detailed qualitative insights.

The collected data was analyzed to identify the game's strengths and weaknesses. This included evaluating players' success in completing levels, their understanding of logical concepts, and the technical aspects such as controls, visual design, and system stability. Based on this analysis, game elements were refined to enhance the effectiveness of the learning model and usability for future implementations.

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Figure 1. Game Development Process

Zero One is an educational puzzle-platformer designed to provide an interactive experience for understanding and applying fundamental concepts of digital logic. The material covers the binary representation of 0 and 1 and introduces basic logic gates like AND, OR, and NOT through a series of puzzle-based challenges. The name "Zero One" represents the binary number system, which is the foundation of computing, as well as the two characters players can interchange to activate mechanisms and solve challenges. Beyond entertainment, Zero One aims to strengthen logical thinking, problem-solving skills, and computational literacy

3. RESULTS AND DISCUSSION

In the game, players navigate through levels step by step while managing logic values with converters, switches, and buttons that assign characters to either 0 or 1. These values are fed into a series of gates to open doors, deactivate lasers, activate devices, and solve rule-based puzzles. Each level introduces increasingly complex mechanics, such as double conditions in AND, alternative paths in OR, and conditional reversals in NOT. Clear goal design, rapid visual feedback, and time- and efficiency-based assessments encourage players to plan, test hypotheses, and develop optimal solution strategies.

Figure 2. Zero One Game Visualization

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The game consists of 19 levels, divided into 15 single-player levels and 4 multiplayer levels. The difficulty curve is designed to be gradual. Each group of levels follows a pattern of concept introduction, guided practice, and then integration of the concepts in more complex situations. Completion time, number of attempts, and puzzle execution efficiency are assessed.

Table 1. The Mechanical Elements of Zero One

No	Mechanical Elements	Description
1	Converters	A device that assigns a logical value to a character as it passes through, such as marking it with a 0 or 1. This device is available in single-player mode.
2	Logic Gates	Logic circuits such as AND, OR, and NOT produce an active output only if the input values match specific rules.
3	Button 0/1	A button activates only when pressed on a character with a specific value (either 0 or 1).
4	Laser and Trap	Dangerous obstacle. It can be disabled by providing the appropriate logic signal through a button or gate.
5	Firewall	A path supervisor that verifies binary values. It only allows characters with the correct values; incorrect values can trigger an alarm, reset, or a penalty.
6	Enemy: Sentry	Enemies patrol a specific field of view and can be temporarily disabled by a signal or rerouted by a logic trigger.
7	Timer and Score	The completion time for each level is recorded and affects the final rating, represented in stars.
8	Win Condition	Victory occurs when the level prerequisites are met.

The game features two gameplay modes: single-player and multiplayer. The initial stages are designed to introduce the concept of binary values simply. Players learn how the logic of 0 and 1 translates through buttons or converters. At this level, the mechanisms are basic, such as opening a door with a single command. Players primarily focus on mastering character movement controls, switching between Zero and One characters, and using input buttons to access the target exit. Obstacles are minimal to encourage a focus on understanding the basic concepts of digital logic.

Levels 1-3 aim to provide mastery of the control mechanism and include an interactive tutorial that illustrates the relationship between binary values and game outputs. For example, pressing the 0 button keeps the gate closed, while pressing the 1 button opens the path. This approach allows players to learn through direct visuals while engaging in gameplay. This foundational concept prepares players for understanding the more complex logic gate puzzles in later levels.

After understanding the basic functions of binary values, players are introduced to combinations of two logic gates, such as AND, NOT, or OR, and AND. At this stage, puzzles begin to develop a strategic pattern as players determine the correct sequence of moves to

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match the gate outputs. Challenges increase with the introduction of lasers, traps, and moving timers, requiring players to combine their understanding of logic with efficient character control.

Figure 3. Level 4-8 Visualization

Levels 4 through 8 explain the synchronization of actions. Players do not randomly select and press buttons; instead, they must plan logical moves throughout the game. For instance, activating a button emits a specific signal that can be combined with signals from other buttons before the laser reactivates. This stage trains logic-based problem-solving skills and tests players' reflexes.

The next stage, levels 9-15, introduces a more complex puzzle mode featuring logic gates that span over three nodes. Players encounter challenges that require careful planning, synchronized actions, and effective time management. Several mechanisms, such as the active alternative path mode and the use of sequential buttons, are integrated.

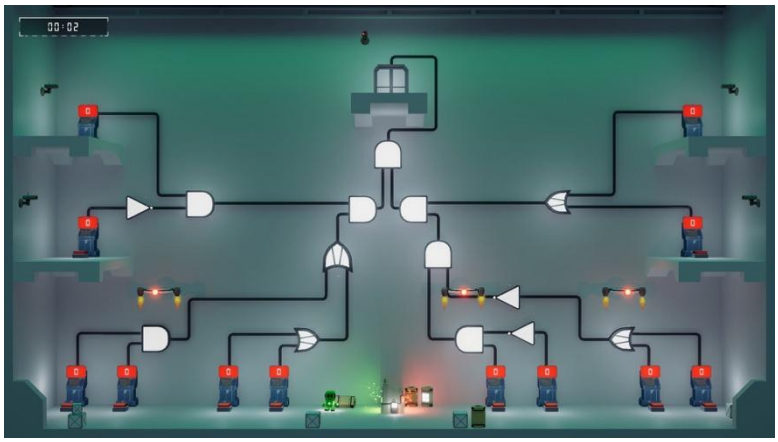

Figure 4. Level 9-15 Visualization

The primary objective of this mode is to consistently solve a series of logic gates to unlock doors at each level, guiding the character to the exit. As players progress, analytical thinking and the ability to anticipate the consequences of each action become increasingly important. This enables the game to be implemented in complex digital logic modes.

The game's multiplayer mode has been expanded, introducing a new dynamic: Zero and One each have distinct roles. Player, one controls Zero, while player two controls One. This

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mode emphasizes coordination and communication between players, with challenges that include activating buttons, defeating enemies, and maintaining a sequence of actions as the path remains open.

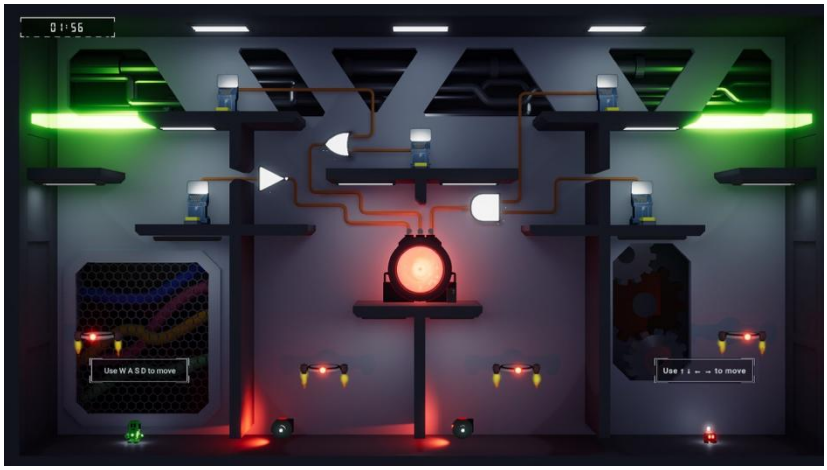

Figure 5. Multiplayer Mode Visualization

The main objective in multiplayer mode isn't just to open gates; it's to close portals that disrupt the game. This puzzle game is designed for effective collaboration between two players, and it is considered complete when all commands have been executed. Consequently, multiplayer participants not only practice digital logic but also develop collaborative and communication strategies to tackle challenges.

The use of descriptive statistical methods is important in research because it facilitates the processing of collected data. Descriptive statistics include measures like the mean, median, and data distribution metrics, such as standard deviation. This approach helps in understanding respondents' tendencies when answering various questions.

$$x = \frac{\sum_{i=1}^{n} xi}{n}$$

Score equation of each concept:

X : Shows the average of a data set
I : Starting from the first data
n : up to the nth data

User Acceptance Testing was conducted using a questionnaire. The questionnaire was developed to assess respondents' performance during gameplay, particularly in terms of usability, learning support, difficulty level, and user engagement. The questionnaire items are shown in Table 2.

Table 2. User Acceptance Testing Questionnaire Items

No	Assessment Aspects	Questionnaire Items
1	Clarity of Instructions	The instructions are easy to understand.

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2	Ease of use	The character controls and game mechanics are easy to use.
3	Visual clarity	The visual representation of binary values and logic gates is clearly displayed.
4	Learning support	Games helped me understand the concept of AND, OR, and NOT gates.
5	Difficulty level	The difficulty level is appropriate and increases gradually.
6	Game feedback	The game provides clear feedback when the player provides correct or incorrect input.
7	User Engagement	Games make learning logic gates more engaging.
8	Overall Acceptance	This game is acceptable as an interactive learning tool for logic gates.

The User Acceptance Testing results provided insights into gameplay completion, level difficulty, and user perceptions of gameplay. The evaluation was conducted with 30 respondents who tried the game and provided feedback on their gameplay experience. Based on the UAT results, 27 of the 30 respondents reported a positive response to the game, while 3 respondents reported a mixed response. As shown in Figure 6, the number of respondents with a positive response significantly outnumbered those with a mixed response. These results indicate that the majority of respondents positively accepted Zero One as an interactive learning tool for the concept of logic gates. The positive user response rate reached 90%; thus, the game can be considered to have a good level of user acceptance.

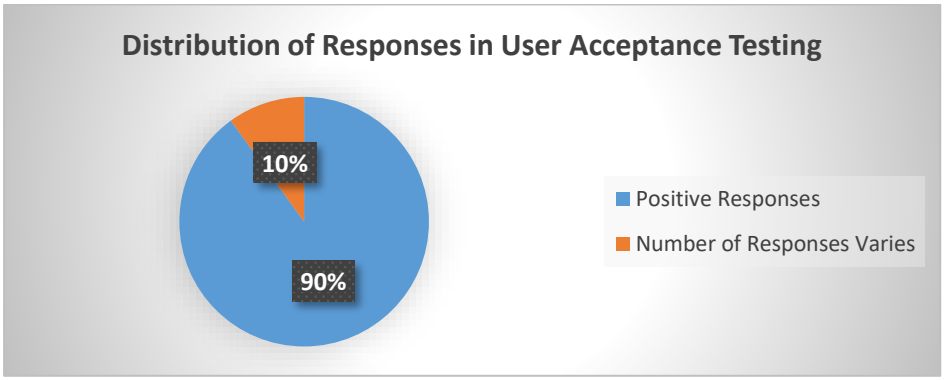

Figure 6. Distribution of Responses in User Acceptance Testing

In addition to the average level achievement, the UAT results also showed that 22 out of 30 respondents completed all 15 single player levels. As shown in Figure 8, the majority of respondents were able to complete the entire single-player mode, while 8 respondents had not completed all levels. These results reinforce the indication that Zero One has a good level of usability and playability. The majority of respondents were not only able to understand the basic game mechanics but were also able to apply the concept of logic gates in the game's challenges until the final stage.

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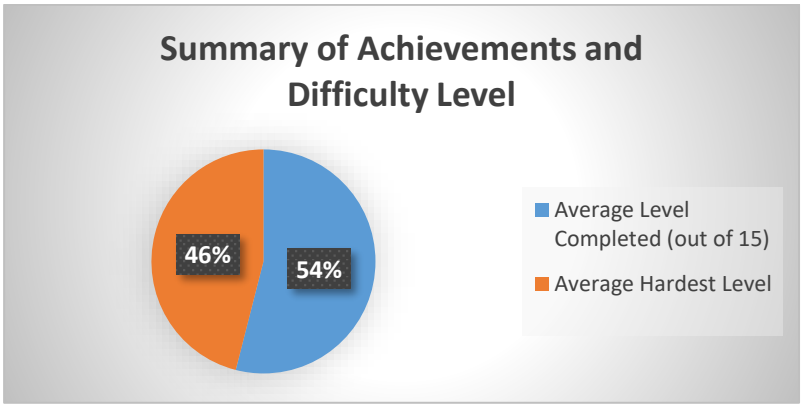

Figure 7. Summary of Achievements and Difficulty Level

Test results showed an average achievement score of 12.1 at the most difficult level. The main challenge analysis was observed among respondents at the advanced level. From a game design perspective, this pattern can be considered quite good, as the difficulty level increases as players progress through the basic and intermediate stages.

Overall, the UAT results indicated that Zero One received a positive response from users. These results also suggest that the game can support the learning process by allowing direct interaction to introduce the concept of digital logic gates. The presentation score for positive user responses averaged 14.2 out of 15.

4. CONCLUSION

Some respondents played the game up to intermediate and advanced levels. Among these levels, the percentage of completed levels reached 9.86%. This shows that the game has a strong ability to keep players engaged over long periods. These challenging sections can motivate players to keep playing. From a player's perspective, level 2 is the easiest, while level 5 is considered difficult. This imbalance provides useful information for developers to reassess the difficulty at level 5 to prevent frustration during gameplay. Overall, the results of the User Acceptance Test indicate that the game is well-received as an interactive learning tool for introducing digital logic gates. Future updates will include a multiplayer mode to enhance the collaborative experience.

However, this research still has several limitations. The UAT method used in this study focused on gameplay and user experience. Therefore, future research could develop a more comprehensive learning evaluation to determine whether Zero One can improve conceptual understanding of logic gates. Further testing could use a more diverse sample of respondents to yield more robust results.

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