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Gamified English Vocabulary Puzzle Game with FSM-Based Emotional Feedback and Fisher–Yates Shuffle

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ABSTRACT

English vocabulary learning among elementary school students often faces challenges related to low engagement, repetitive practice activities, and limited interactive feedback in conventional learning media. Educational games with gamification elements can provide a more engaging learning environment, while rule-based character feedback and randomized puzzle arrangements may improve gameplay variation and user interaction. Objective: This study aimed to develop an Android-based English vocabulary puzzle game that integrates gamification elements, an FSM-based emotional feedback mechanism, and the Fisher–Yates Shuffle algorithm for sixth-grade elementary school students. Methods: The game was developed using the Game Development Life Cycle (GDLC) method through initiation, pre-production, production, testing, beta, and release stages. The application was implemented using Unity and C#, with Firebase Realtime Database used for data management. System evaluation was conducted through Black Box Testing, White Box Testing, and User Acceptance Testing involving 35 sixth-grade students of SD Negeri 2 Cikeusal. Results: The developed game successfully implemented gamification elements, including scores, levels, time limits, life indicators, and visual character feedback. The FSM-based mechanism generated predefined emotional responses through thirteen states and seventeen events, while the Fisher–Yates Shuffle algorithm produced varied puzzle arrangements. Black Box Testing confirmed that all main features functioned as expected, and White Box Testing verified the control flow of the FSM and Fisher–Yates Shuffle implementations. User Acceptance Testing produced an overall acceptance score of 94.3%, indicating that the game was well accepted by users. Conclusion: The integration of gamification, FSM-based emotional feedback, and Fisher–Yates Shuffle indicates its potential to provide an engaging and interactive medium for English vocabulary practice. However, this study evaluated user acceptance and system functionality, not direct vocabulary learning improvement.

1. Introduction

English is one of the most widely used international languages and plays an important role in communication, education, and access to information. In English language learning, vocabulary is a fundamental component because it supports the development of listening, speaking, reading, and writing skills [1],[2]. For elementary school students, vocabulary acquisition needs to be introduced through learning activities that are simple, contextual, and engaging so that students can recognize word meanings and associate them with visual representations more easily.

Despite its importance, vocabulary learning among elementary school students still faces several challenges. Conventional instructional approaches that mainly rely on memorization, textbooks, and written exercises often reduce student engagement and participation during learning activities [3]. As a result, students may experience difficulties in understanding, retaining, and applying newly learned vocabulary. Based on observations conducted at SD Negeri 2 Cikeusal, Kuningan Regency, Indonesia, similar conditions were identified among sixth-grade students. Several students showed difficulties in mastering English vocabulary and demonstrated limited participation during classroom activities. These conditions indicate the need for interactive learning media that can support vocabulary practice while providing more engaging feedback and learning experiences.

Educational games have been widely used as interactive learning media because they can provide enjoyable activities and encourage learner participation during the learning process [4], [5]. For elementary school students, interface simplicity and visual interaction are important considerations in designing vocabulary learning games. Previous research on AR-based English vocabulary learning showed that interactive visual media, audio support, and gamified elements were positively received by young learners [6]. In addition, gamification has become a relevant strategy in educational technology because it incorporates game elements, such as scores, levels, challenges, time limits, and feedback, into learning environments to improve user engagement [7]. Previous studies have also reported that gamification can positively influence student motivation and learning engagement in various educational contexts [8]. Therefore, integrating gamification into a vocabulary learning game can provide students with a more interactive and enjoyable medium for practicing English vocabulary.

In addition to gamification elements, feedback mechanisms are important for maintaining interaction between students and the game system. One method commonly used to regulate character behavior in digital games is the Finite State Machine (FSM). FSM enables a character to move from one state to another based on predefined events and conditions [9], [10]. In this study, FSM is not used to recognize or infer the actual emotional state of the player. Instead, it is implemented as a rule-based emotional feedback mechanism that generates predefined character responses according to gameplay events, such as correct answers, incorrect answers, inactivity, winning conditions, and losing conditions. Through this mechanism, the character can provide contextual visual feedback that supports player interaction during vocabulary practice [11].

Gameplay variation is also an important factor in preventing repetitive and predictable learning activities. In puzzle-based educational games, fixed question sequences or answer positions may encourage students to memorize patterns rather than focus on understanding the relationship between vocabulary and visual objects. Therefore, a randomization mechanism is required to generate varied puzzle arrangements. The Fisher–Yates Shuffle algorithm is widely applied because it can produce unbiased random permutations, allowing each element to have an equal probability of appearing in any position [12], [13]. By implementing this algorithm, the game can present different puzzle arrangements in each gameplay session and reduce repetitive patterns.

Several previous studies have investigated gamification, FSM, and Fisher–Yates Shuffle in educational game development. Gamification has been applied to increase learner motivation and participation [7], while FSM has been utilized to regulate character behavior and interactions in digital games [10]. Fisher–Yates Shuffle has also been implemented to randomize educational game content and reduce repetitive gameplay patterns [12].

However, most previous studies applied these approaches separately. Existing studies generally focused on character functionality or question randomization without integrating emotional feedback as part of the gamification experience. Moreover, studies that combine gamification, FSM-based emotional feedback, and Fisher–Yates Shuffle in an English vocabulary puzzle game specifically designed for elementary school students remain relatively limited.

Based on these considerations, this study proposes the development of an Android-based gamified English vocabulary puzzle game for sixth-grade elementary school students. The contribution of this study is threefold. First, it designs a gamified vocabulary puzzle game that integrates scores, levels, time limits, life indicators, and visual feedback to support vocabulary practice. Second, it implements an FSM-based emotional feedback mechanism that provides predefined character responses according to gameplay events. Third, it applies the Fisher–Yates Shuffle algorithm to randomize puzzle arrangements and reduce repetitive gameplay patterns. The game was developed using the Game Development Life Cycle (GDLC) method and evaluated through Black Box Testing, White Box Testing, and User Acceptance Testing involving 35 sixth-grade students of SD Negeri 2 Cikeusal. The proposed game is expected to serve as an engaging and interactive medium for English vocabulary practice and contribute to the development of educational game technology for elementary school students.

2. Method

This study employed an applied research and development approach because it focused on designing, implementing, and evaluating an Android-based educational game. The developed game is a gamified English vocabulary puzzle game for sixth-grade elementary school students that integrates gamification elements, an FSM-based emotional feedback mechanism, and the Fisher–Yates Shuffle algorithm. The game development process followed the Game Development Life Cycle (GDLC) method, which is commonly applied in educational game development because it provides systematic stages from concept formulation to testing and release [14], [15], [16]. System evaluation was conducted using Black Box Testing, White Box Testing, and User Acceptance Testing (UAT) to assess functionality, program logic, and user acceptance of the developed application.

2.1 Research Object and Data Collection

The object of this study is an Android-based English vocabulary puzzle game designed for sixth-grade elementary school students. The game was developed as an interactive medium for English vocabulary practice through drag-and-drop gameplay, FSM-based character feedback, and puzzle randomization mechanisms. The vocabulary materials implemented in the game were limited to three categories, namely animals, professions, and verb forms.

Data collection was conducted through observation, literature study, and questionnaire distribution. Observation activities were carried out at SD Negeri 2 Cikeusal, Kuningan Regency, Indonesia, to identify problems related to English vocabulary learning and determine the requirements for the proposed educational game. A literature study was conducted to obtain theoretical foundations and related research on educational games, gamification, Finite State Machine, Fisher–Yates Shuffle, and software testing techniques.

The evaluation stage involved 35 sixth-grade students of SD Negeri 2 Cikeusal. This number represented the entire population of sixth-grade students available during the implementation period. The evaluation was conducted with permission from the school and under teacher supervision. User responses were collected using a questionnaire consisting of ten statements grouped into four evaluation aspects, namely gamification, FSM-based emotional feedback, Fisher–Yates Shuffle randomization, and user engagement. The questionnaire items were developed based on the research objectives and the implemented game features. Before distribution, the questionnaire was reviewed by teachers to ensure that the statements were understandable and appropriate for elementary school students.

2.2 System Architecture

The developed application adopts a client-server architecture consisting of an Android-based game client and a cloud database service. The client application was developed using Unity and C#, while Firebase Realtime Database was used to store and retrieve user data, scores, and gameplay progress. The application is designed to run on Android devices and interact with the database through an internet connection.

The system architecture consists of four main modules. The Gamification Module manages gameplay elements, including scores, levels, time limits, and life indicators. The FSM Module regulates the rabbit character's visual feedback based on gameplay events, such as correct answers, incorrect answers, inactivity, winning conditions, and losing conditions. The Fisher–Yates Shuffle Module randomizes puzzle objects to reduce repetitive arrangements and prevent fixed answer patterns. The Database Module manages player data, score records, and progress information through Firebase Realtime Database. The overall system architecture is illustrated in Figure 1.

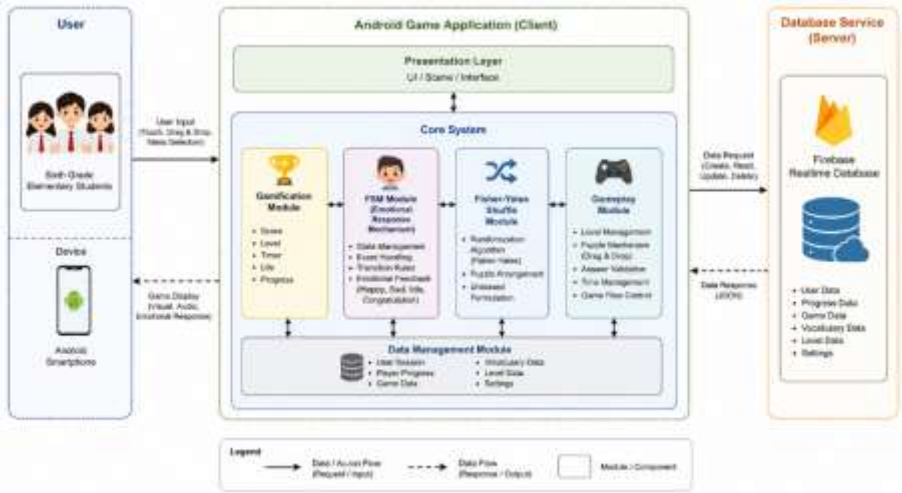


Figure 1. System Architecture

2.3 Game Development Method

The game was developed using the Game Development Life Cycle (GDLC) method [16]. In this study, the GDLC stages consisted of initiation, pre-production, production, testing, beta, and release. The initiation stage was conducted to identify vocabulary learning problems among sixth-grade students and formulate the initial concept of the game. The pre-production stage involved designing the gameplay mechanism, storyboard, interface layout, UML diagrams, FSM structure, and Fisher–Yates Shuffle flow.

The production stage focused on implementing the design into a functional Android game application using Unity and C#. At this stage, the drag-and-drop gameplay, gamification elements, FSM-based emotional feedback mechanism, Fisher–Yates Shuffle randomization, and Firebase integration were implemented. The testing stage was conducted to verify whether the application functions and program logic operated according to the specified requirements. The beta stage involved direct evaluation by students through UAT to determine user acceptance and obtain feedback on the developed game. Finally, the release stage represented the completion of the application after the testing and evaluation process had been carried out.

2.4 System Evaluation and Data Analysis

System evaluation was conducted using three testing techniques: Black Box Testing, White Box Testing, and User Acceptance Testing. Black Box Testing was used to evaluate whether each feature produced outputs that matched the expected results without examining the internal program structure [17]. The tested features included login, main menu navigation, level selection, dictionary access, drag-and-drop gameplay, score updates, life indicators, timer, FSM-based character feedback, Fisher–Yates Shuffle randomization, win and lose scenes, and audio settings. Each test case was evaluated based on input data, testing parameters, expected results, actual results, and test status.

White Box Testing was used to examine the internal control flow of the implemented FSM and Fisher–Yates Shuffle algorithm. The testing procedure included constructing a flowgraph, calculating cyclomatic complexity, identifying independent paths, and validating the execution paths using test cases [18], [19]. This test was conducted to ensure that the FSM transitions and randomization logic followed the designed program flow.

User Acceptance Testing was conducted to measure user acceptance of the developed game. The UAT instrument consisted of ten questionnaire statements grouped into four aspects: gamification, FSM-based emotional feedback, Fisher–Yates Shuffle randomization, and user engagement. Each item was assessed using a five-point Likert scale ranging from strongly disagree to strongly agree. The acceptance percentage was calculated using the following formula:

$$\text{Acceptance Percentage} = (\text{Total Score} / \text{Maximum Score}) \times 100\% \quad (1)$$

The resulting percentage was used to interpret the level of user acceptance toward the developed game. The UAT results were interpreted as indicators of usability, attractiveness, and user acceptance, not as direct evidence of vocabulary learning improvement.

3. Results and Discussion

This section presents the implementation results and evaluation findings of the developed gamified English vocabulary puzzle game. The discussion focuses on five main aspects: system implementation, gamification and FSM-based emotional feedback, Fisher–Yates Shuffle implementation, system testing, and user acceptance evaluation. The results are discussed in relation to the research objective, namely developing an Android-based vocabulary puzzle game that integrates gamification elements, rule-based character feedback using Finite State Machine, and randomized puzzle arrangements using the Fisher–Yates Shuffle algorithm.

The evaluation was conducted to verify whether the developed application operated according to the specified functional requirements, whether the implemented algorithms followed the designed control flow, and whether the application was accepted by the target users. Black Box Testing was used to examine application functionality, White Box Testing was used to evaluate the internal logic of the FSM and Fisher–Yates Shuffle implementations, and User Acceptance Testing was used to measure students' responses toward the developed game. The results are therefore interpreted as evidence of system functionality, implementation validity, and user acceptance, rather than as direct evidence of vocabulary learning improvement.

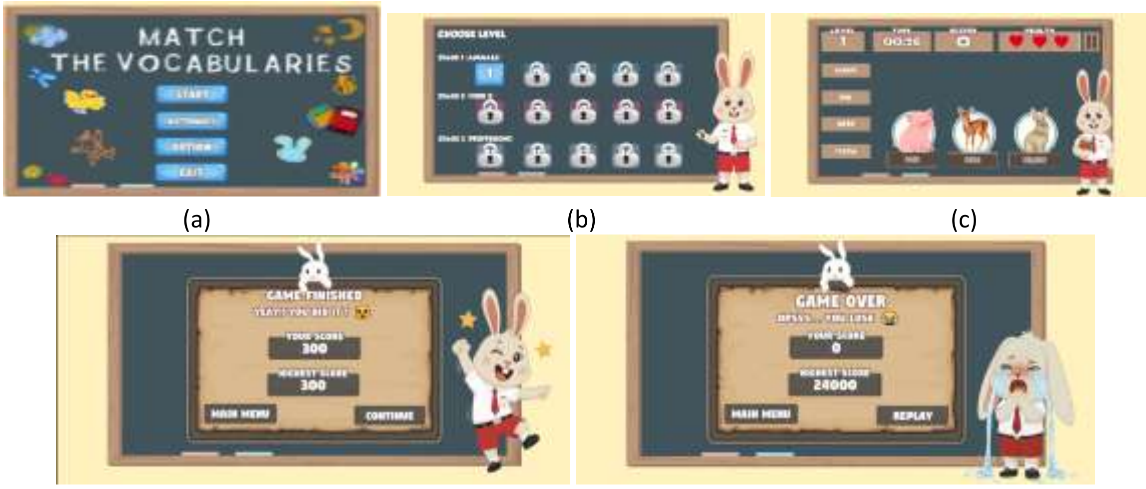
3.1 System Implementation

The developed application is an Android-based English vocabulary puzzle game designed for sixth-grade elementary school students. The application was implemented using Unity and C# and consists of several main scenes, including the login scene, main menu, level selection, dictionary, option menu, gameplay scene, win screen, and lose screen. Each scene was designed to support students in accessing vocabulary materials, selecting learning levels, adjusting audio preferences, and completing vocabulary matching activities through interactive gameplay.

The core gameplay adopts a drag-and-drop puzzle mechanism. In this activity, students are required to match English vocabulary items with corresponding images. The vocabulary materials are grouped into three categories, namely animals, professions, and verb forms. During gameplay, the system displays several interactive components, including score, level information, time limit, and life indicators. These components provide immediate information about students' progress and performance during each game session.

Gamification elements were integrated into the gameplay to create a more engaging practice environment. The score system rewards correct answers, the level system provides gradual challenges, the timer encourages students to complete tasks within a limited duration, and the life indicator provides consequences for incorrect answers. In addition, the rabbit character provides visual feedback based on gameplay conditions, while the puzzle objects are randomized to reduce repetitive arrangements. The implementation of these components is intended to support interaction and maintain student involvement during vocabulary practice.

The main interface and gameplay implementation are presented in Figure 2. The interface was designed using simple navigation, colorful visual elements, and clear object placement to make the application suitable for elementary school students. The gameplay screen serves as the central interaction area where students complete vocabulary-image matching tasks, receive feedback from the system, and proceed to the next challenge based on their performance.



(a) (b) (c)

(d) (e)

Figure 2. Main Interface and Gameplay Scene of the Developed Game. (a) Main game Scene, (b) Level Selection Scene, (c) Main Gameplay Scene, (d) Win Screen, (e) Lose Screen

3.2 Gamification and FSM-Based Emotional Feedback

Gamification elements were implemented to support student engagement during vocabulary practice. The developed game incorporates several game elements, including score accumulation, level progression, time limits, life indicators, and visual feedback. The score system provides rewards when students match vocabulary items correctly, while the level system introduces gradual challenges based on the selected learning stage. The timer encourages students to complete the puzzle within a limited duration, and the life indicator provides consequences for incorrect answers. These elements were designed to create a structured gameplay experience while maintaining student involvement during the learning activity.

In addition to these gamification elements, the game implements an FSM-based emotional feedback mechanism through a rabbit character. The character does not detect or interpret the actual emotional state of the player. Instead, it generates predefined visual responses based on gameplay events, such as correct answers, incorrect answers, repeated mistakes, inactivity, winning conditions, and losing conditions. Therefore, the character functions as a rule-based feedback component that responds to the current gameplay situation. This mechanism allows students to receive immediate visual feedback during interaction with the puzzle, thereby strengthening the gamification experience.

The FSM-based feedback mechanism was designed using thirteen states and seventeen events. The states represent both operational and feedback-related conditions. Operational states include idle, time checking, answer checking, correct response, and wrong response, while feedback-related states include happy, proud, sad, disappointed, encouraging, bored, win, and lose. The state transitions are triggered by specific events occurring during gameplay. For example, a correct answer triggers a transition toward positive feedback states, an incorrect answer triggers a transition toward negative feedback states, and inactivity triggers encouraging or bored responses. The complete FSM design is presented in Figure 3, while the state transition mechanism is summarized in Table 1.

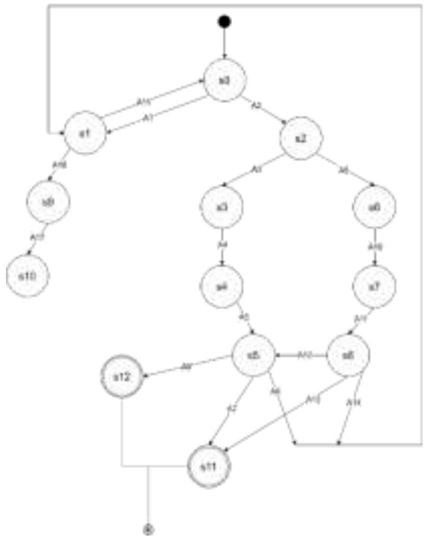


Figure 3. Finite State Machine Diagram

Table 1. State and Event Transition

Current State	*Trigger Event*	*Next State*	*Description*
S0 Idle	A1 Start Game	S1 Check Time	The game starts and the system begins the time-checking process.
S1 Check Time	A15 Time Available	S0 Idle	The game continues because the remaining time is still available.
S0 Idle	A2 Player Gives Answer	S2 Check Answer	The player's answer is submitted for evaluation.
S2 Check Answer	A3 Answer Correct	S3 Correct Response	A correct answer is detected by the system.
S3 Correct Response	A4 Show Happy	S4 Happy	The character displays a happy expression.
S4 Happy	A5 Repeated Success	S5 Proud	Consecutive correct answers lead the character to a proud state.
S5 Proud	A6 All Questions Completed	S12 Win	All puzzle questions have been completed successfully.
S5 Proud	A7 Game Over	S11 Lose	The game ends because the player fails to achieve the objectives.
S5 Proud	A8 Next Question	S2 Check Answer	The system proceeds to the next puzzle question.
S2 Check Answer	A9 Answer Wrong	S6 Wrong Response	An incorrect answer is identified.
S6 Wrong Response	A10 Show Sad	S7 Sad	The character displays a sad expression.
S7 Sad	A11 Repeated Mistakes	S8 Disappointed	Consecutive incorrect answers cause the character to become disappointed.
S8 Disappointed	A12 Recovery Correct	S5 Proud	Improved player performance restores a positive emotional state.
S8 Disappointed	A13 Fail Limit Reached	S11 Lose	The game reaches the failure condition.
S8 Disappointed	A14 Continue Game	S0 Idle	The game continues and returns to the idle state.
S1 Check Time	A16 Idle 8 Seconds	S9 Encouraging	Player inactivity for eight seconds triggers an encouraging response.
S9 Encouraging	A17 Idle 16 Seconds	S10 Bored	Continued player inactivity for sixteen seconds triggers the bored response.

The character expressions produced by the FSM-based feedback mechanism are shown in Table 2. These expressions function as visual feedback that reflects the current gameplay condition and supports interaction during vocabulary practice.

Table 2. Emotional Character Responses

Current State	***Character Expression***	***Description***
Idle		The character remains in the waiting state before receiving player interaction.
Happy		The character displays a happy expression when the player provides a correct answer.
Proud		The character displays a proud expression after repeated successful answers.
Sad		The character displays a sad expression when the player provides an incorrect answer.
Disappointed		The character displays a disappointed expression after repeated incorrect answers.
Encouraging		The character motivates the player after eight seconds of inactivity.
Bored		The character displays a bored expression after sixteen seconds of inactivity.
Win		The character celebrates after the player successfully completes the game.
Lose		The character displays a losing expression when the game ends unsuccessfully.

The implemented FSM enables the character to provide responses that are aligned with the player's actions and gameplay conditions. Positive expressions such as happy and proud act as reinforcement when students perform well, whereas sad and disappointed expressions indicate mistakes. Encouraging and bored expressions respond to inactivity, while win and lose expressions provide final feedback at the end of a level. Overall, the combination of gamification elements and FSM-based emotional feedback contributes to the interactive characteristics of the developed game and supports the objective of providing an engaging vocabulary practice medium for elementary school students.

3.3 Fisher–Yates Shuffle Implementation

The Fisher–Yates Shuffle algorithm was implemented to randomize the arrangement of puzzle objects before they were displayed to players. This mechanism was used to reduce repetitive gameplay patterns and prevent students from relying on fixed answer positions during vocabulary practice. In the developed game, the same vocabulary set may appear in different arrangements across gameplay sessions, allowing students to interact with the learning materials in a less predictable sequence.

The randomization process begins from the last index of the array. For each iteration, a random index j is generated within the range from zero to the current index i. The element at index i is then swapped with the element at index j, and the process continues decrementally until all elements have been processed. This procedure enables each puzzle object to have an equal opportunity to occupy any available position. The flow of the implemented Fisher–Yates Shuffle algorithm is presented in Figure 4.

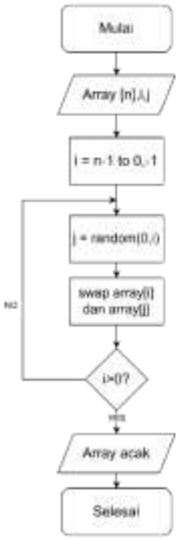


Figure 4. Fisher-Yates Shuffle Flowchart[20]

In this study, the algorithm was applied to the list of vocabulary puzzle objects before the gameplay scene was loaded. As a result, the order of puzzle objects was rearranged automatically in each game session. The implementation was tested by observing the shuffle process using a sample vocabulary array consisting of five objects. Table 3 presents an example of the Fisher–Yates Shuffle iteration process.

Table 3. Example of Fisher-Yates Shuffle Iterations

Iteration	*i Value*	*j Value (Random)*	*Array Before Swap*	*Array After Swap*
0	*4*	*2*	*[Cat, Dog, Rabbit, Bird, Cow]*	*[Cat, Dog, Cow, Bird, Rabbit]*
1	*3*	*1*	*[Cat, Dog, Cow, Bird, Rabbit]*	*[Cat, Bird, Cow, Dog, Rabbit]*
2	*2*	*0*	*[Cat, Bird, Cow, Dog, Rabbit]*	*[Cow, Bird, Cat, Dog, Rabbit]*
3	*1*	*1*	*[Cow, Bird, Cat, Dog, Rabbit]*	*[Cow, Bird, Cat, Dog, Rabbit]*
4	*0*	*–*	*[Cow, Bird, Cat, Dog, Rabbit]*	*[Cow, Bird, Cat, Dog, Rabbit]*

The example in Table 3 shows that the order of puzzle objects changes through a series of index exchanges. Although the vocabulary content remains the same, the arrangement presented to the player becomes different after the shuffle process. This result indicates that the implemented algorithm can generate varied puzzle arrangements and reduce fixed gameplay patterns. Therefore, Fisher–Yates Shuffle supports the gamification design by providing variation in repeated vocabulary practice sessions.

3.4 System Testing Results

System testing was conducted to verify whether the developed game operated according to the specified requirements and whether the implemented logic followed the designed program flow. The evaluation consisted of three testing approaches: Black Box Testing, White Box Testing, and User Acceptance Testing. Black Box Testing was used to examine the functional behavior of the application based on input and expected output. White Box Testing was applied to evaluate the internal control flow of the FSM-based emotional feedback mechanism and the Fisher–Yates Shuffle algorithm. Meanwhile, User Acceptance Testing was conducted to assess user responses toward the developed game after direct use by sixth-grade elementary school students.

The testing process was intended to ensure that the application features, gameplay mechanics, algorithmic logic, and user interaction components functioned properly. The results of these evaluations are presented in the following subsections.

3.4.1 Black Box Testing Results

Black Box Testing was conducted to evaluate the functional suitability of the developed application without examining the internal source code. The test focused on whether each feature produced outputs that corresponded to the expected behavior when given specific input conditions. The tested modules included login, menu navigation, level selection, dictionary access, drag-and-drop gameplay, score and life systems, timer, FSM-based character feedback, Fisher–Yates Shuffle randomization, win and lose conditions, and audio settings.

Each test case was arranged based on the feature module, test scenario, input or test data, testing parameter, expected result, and final status. This structure was used to provide a clearer basis for determining whether a feature passed the functional test. The results of Black Box Testing are presented in Table 4.

Table 4. Black Box Testing Results

No.	Feature Module	Test Scenario	Input/Test Data	Testing Parameter	Expected Result	Status
1	Login	Valid login	Registered student name and attendance number	Input validation and user access	The system accepts the input and displays the main menu.	Passed
2	Login	Invalid or empty login	Empty name field, empty attendance number, or unregistered data	Input validation and warning message	The system rejects the input and displays a warning message.	Passed
3	Main Menu	Selecting each menu button	Start, Dictionary, Option, and Exit buttons	Menu navigation accuracy	The selected menu or function is displayed according to the selected button.	Passed
4	Level Selection	Selecting available and locked levels	Available level button and locked level button	Level access control	Available levels can be accessed, while locked levels remain inaccessible.	Passed
5	Dictionary	Opening vocabulary materials	Selected vocabulary category	Vocabulary display accuracy	The system displays vocabulary materials according to the selected category.	Passed
6	Drag-and-Drop Gameplay	Correct word-image matching	Correct vocabulary object and corresponding image target	Answer validation, score update, and character feedback	The object is accepted, the score increases, and positive feedback is displayed.	Passed
7	Drag-and-Drop Gameplay	Incorrect word-image matching	Incorrect vocabulary object and non-corresponding image target	Answer validation, life reduction, and character feedback	The object is rejected, life decreases, and negative feedback is displayed.	Passed
8	Drag-and-Drop Gameplay	Object released outside the target area	Vocabulary object released outside any valid target	Object position validation	The object returns to its initial position.	Passed
9	Fisher–Yates Shuffle	Replaying the same level	Same vocabulary set played repeatedly	Puzzle arrangement variation	Puzzle objects are displayed in different arrangements across sessions.	Passed
10	FSM-Based Feedback	Correct, incorrect, idle, win, and lose conditions	Gameplay events triggered during play	State transition and character response accuracy	Character expressions change according to the corresponding FSM state.	Passed
11	Timer System	Time reaches zero	Remaining time equals zero	Time limit validation	The game displays the lose condition when the time limit is reached.	Passed
12	Score and Life System	Score increment and life reduction	Correct and incorrect answer events	Score and life value update	Score and life values are updated according to gameplay rules.	Passed
13	Win and Lose Conditions	Completing or failing the level	All questions completed, life depleted, or time expired	Game outcome validation	The system displays the appropriate win or lose screen.	Passed
14	Audio Settings	Adjusting sound controls	BGM and SFX slider values	Audio volume adjustment	Background music and sound effect volumes change according to slider values.	Passed

The results in Table 4 show that all tested modules produced outputs consistent with the expected functional behavior. Login validation, menu navigation, level access, dictionary display, gameplay interaction, score and life updates, character feedback, randomization, game outcomes, and audio settings operated according to the defined requirements. These findings indicate that the developed application met the functional specifications established during the design and implementation stages.

3.4.2 White Box Testing Results

White Box Testing was performed to analyze the internal logic and control flow of the implemented algorithms. This testing approach is commonly used to examine execution paths and support software reliability evaluation [20]. In this study, White Box Testing was applied to the FSM-based emotional feedback mechanism and the Fisher–Yates Shuffle algorithm. The testing process involved constructing control flowgraphs, identifying independent paths, and calculating cyclomatic complexity.

For the FSM-based emotional feedback mechanism, the complete design consists of thirteen-character states and seventeen event-driven transitions. However, the White Box Testing flowgraph was constructed based on the main executable control paths implemented in the game script. This abstraction was used to focus the analysis on the principal behavioral routes, including idle conditions, correct answer responses, incorrect answer responses, level completion, and game failure conditions. The flowgraphs of the FSM-based feedback mechanism and Fisher–Yates Shuffle algorithm are presented in Figure 5 and Figure 6.

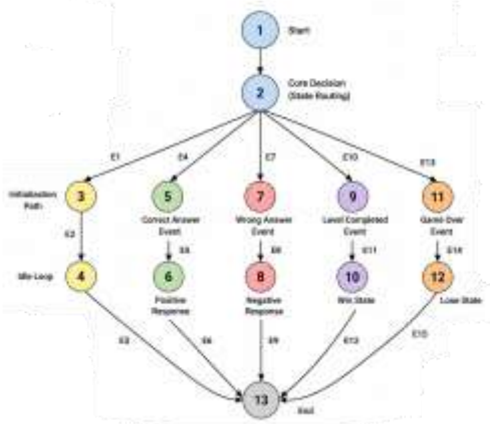


Figure 5. Finite State Machine Flowgraph

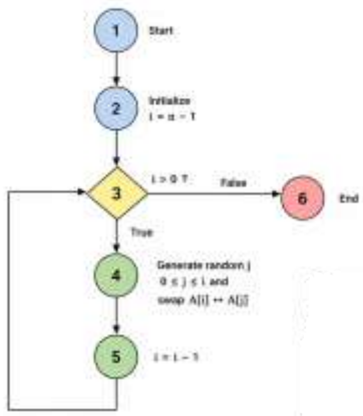


Figure 6. Fisher-Yates Shuffle Flowgraph

To verify the control flow rigorously, the Cyclomatic Complexity $V(G)$ for each graph was derived using the standard formula:

$$V(G) = E - N + 2 \quad (2)$$

Where E represents the number of edges and N represents the number of nodes. The step-by-step derivation and the full listing of independent execution paths are presented below:

1. **Finite State Machine (FSM) Logic:**
   - **Derivation:** With E = 16 edges and N = 13 nodes, the complexity is calculated as V(G) = 16 - 13 + 2 = 5. This indicates there are exactly 5 independent paths to verify.
   - **Independent Paths:**
     - *Path 1:* 1 — 2 — 3 — 4 — 13 (Initialization to Idle Loop)
     - *Path 2:* 1 — 2 — 5 — 6 — 13 (Correct Answer Response Path)
     - *Path 3:* 1 — 2 — 7 — 8 — 13 (Incorrect Answer Response Path)
     - *Path 4:* 1 — 2 — 9 — 10 — 13 (Level Completed Outcome)
     - *Path 5:* 1 — 2 — 11 — 12 — 13 (Game Over Outcome)
2. **Fisher-Yates Shuffle Logic:**
   - **Derivation:** With E = 6 edges and N = 6 nodes, the complexity is calculated as V(G) = 6 - 6 + 2 = 2. This indicates there are exactly 2 independent paths to verify.
   - **Independent Paths:**
     - *Path 1:* 1 — 2 — 3 — 6 (Array empty or single element condition, bypass loop)

- *Path 2:* 1 — 2 — 4 — 5 — 2 — 3 — 6 (Standard decremental swap loop iteration execution)

A summary of the structural metrics and the validation outcomes is compiled in Table 5.

Table 5. White Box Testing

No.	*Tested Logic*	*Nodes*	*Edges*	*Cyclomatic Complexity*	*Independent Path*	*Result*
1	Finite State Machine	13	16	5	Path 1, Path 2, Path 3, Path 4, Path 5	Passed
2	Fisher-Yates Shuffle	6	6	2	Path 1, Path 2	Passed

The results show that the FSM-based emotional feedback mechanism and the Fisher–Yates Shuffle algorithm followed the expected control flow and satisfied the identified independent paths. Therefore, the implemented program logic can be considered consistent with the designed gameplay behavior and randomization process.

3.4.3 User Acceptance Testing (UAT) Results

User Acceptance Testing was conducted to evaluate user responses toward the developed English vocabulary puzzle game after direct use. The evaluation involved 35 sixth-grade students of SD Negeri 2 Cikeusal, representing the target users of the application. The questionnaire consisted of ten statements grouped into four evaluation aspects: gamification, FSM-based emotional feedback, Fisher–Yates Shuffle randomization, and user engagement. The testing activity was carried out with permission from the school and under teacher supervision to ensure that the procedure and questionnaire items were appropriate for elementary school students.

Each questionnaire item was assessed using a five-point Likert scale, consisting of Strongly Agree = 5, Agree = 4, Neutral / Undecided = 3, Disagree = 2, and Strongly Disagree = 1. The response distribution obtained from the respondents is presented in Table 6.

Table 6. User Acceptance Testing Questionnaire Response Distribution

No.	*Statement*	*A*	*B*	*C*	*D*	*E*
Gamification Aspect						
1	I can easily use the buttons and menus in this game.	28	2	5	0	0
2	The text, images, and interface of the game are clear and easy to understand.	28	6	1	0	0
3	I can easily understand how to play this game.	28	3	4	0	0
Finite State Machine Aspect						
4	The rabbit character provides appropriate responses during gameplay.	29	4	2	0	0
5	The rabbit character provides interesting responses while playing the game.	32	3	0	0	0
Fisher-Yates Shuffle Aspect						
6	The arrangement of questions in the game feels varied during gameplay.	17	12	6	0	0
7	The questions do not appear in a monotonous or repetitive manner.	30	5	0	0	0
User Engagement Aspect						
8	Playing this game makes learning vocabulary more enjoyable.	25	7	3	0	0
9	I would like to play this game again in the future.	26	8	1	0	0
10	Overall, I am satisfied with using this game.	30	5	0	0	0

The total score was calculated by multiplying the number of responses in each category by its corresponding Likert value. The acceptance percentage was then calculated using the following formula:

$$\text{Acceptance Percentage} = \frac{Total\ Likert\ Score}{Maximum\ Likert\ Score}\ x\ 100\% \quad (3)$$

Based on the overall score, the calculation was performed as follows:

$$\text{Acceptance Percentage} = \frac{1651}{1750}\ x\ 100\%$$

Acceptance Percentage= 94,3 %

The recapitulation of the UAT score calculation is presented in Table 7.

Table 7. User Acceptance Testing Score Calculation

Aspect	*Total Score*	*Maximum Score*	*Acceptance Percentage*
Gamification	494	525	94.1%
Finite State Machine	339	350	96.8%
Fisher-Yates Shuffle	321	350	91.7%
User Engagement	497	525	94.7%
Overall Result	1651	1750	94.3%

The results in Table 7 show that the developed game obtained an overall acceptance percentage of 94.3%, which indicates a very positive level of user acceptance. The FSM-based emotional feedback aspect obtained the highest percentage, with a score of 96.8%. This result indicates that the rabbit character's responses were positively perceived by students during gameplay. The user engagement aspect also received a high score of 94.7%, suggesting that students responded favorably to the gameplay experience and expressed interest in using the game again.

The Fisher–Yates Shuffle aspect obtained an acceptance percentage of 91.7%, which was still categorized as positive but lower than the other aspects. In particular, Statement No. 6, "The arrangement of questions in the game feels varied during gameplay," received the lowest number of Strongly Agree responses, with 17 out of 35 students selecting this option. This finding may indicate that some elementary school students were less aware of changes in question order or that the number of vocabulary items in each level was still limited, making the variation less noticeable during play. Therefore, future development should consider increasing the number of vocabulary items, expanding level variations, and providing more diverse puzzle layouts to make the randomization effect more apparent to users.

Overall, the UAT results indicate that the developed game was well accepted by the target users in terms of gamification, character feedback, randomization, and user engagement. However, these findings should be interpreted as evidence of user acceptance and perceived interaction quality. Since this study did not employ pre-test and post-test measurements, the results cannot be used to conclude that the game directly improved students' vocabulary mastery.

3.5 Discussion, Implications, and Limitations

The results indicate that the integration of gamification elements, FSM-based emotional feedback, and Fisher–Yates Shuffle supports the development of an interactive vocabulary practice medium for elementary school students. Gamification elements such as scores, levels, timers, life indicators, and feedback provide a structured gameplay experience that encourages students to complete vocabulary-matching tasks. This finding is consistent with previous studies showing that gamification can support learner engagement and motivation in educational activities [4]-[7].

The FSM-based emotional feedback mechanism enables the rabbit character to respond to gameplay events through predefined visual expressions. The character does not recognize the actual emotional condition of students; instead, it provides rule-based feedback triggered by correct answers, incorrect answers, inactivity, and game outcomes. This implementation shows that FSM can be used to regulate character behavior in educational games without requiring complex machine learning models. Similar uses of FSM in game character behavior have been reported in previous studies [8]-[10]. Meanwhile, the Fisher–Yates Shuffle algorithm provides variation in puzzle arrangements by changing the order of vocabulary objects in each gameplay session. This supports previous findings that Fisher–Yates Shuffle can be applied to reduce repetitive patterns in educational games [11], [12].

From a practical perspective, the developed game can be used as an alternative medium to support English vocabulary practice through interactive and visual gameplay. From a technical perspective, the study demonstrates that FSM and Fisher–Yates Shuffle can be integrated with gamification elements to create responsive character feedback and varied puzzle arrangements. The UAT result of 94.3% indicates that the game was well accepted by the target users. However, this result should be interpreted as user acceptance and perceived interaction quality, not as evidence of improved vocabulary mastery.

Several limitations should be acknowledged. First, the vocabulary materials were limited to animals, professions, and verb forms. Second, the evaluation involved 35 sixth-grade students from one elementary school, which limits the generalizability of the results. Third, the study did not include pre-test and post-test measurements, so the learning effectiveness of the game was not directly examined. Fourth, the FSM-based feedback mechanism was limited to predefined states and events and did not recognize students' actual emotions. Future studies should involve larger samples, add more vocabulary categories, evaluate learning outcomes experimentally, and explore more adaptive feedback mechanisms.

4. Conclusion

This study developed a gamified English vocabulary puzzle game for sixth-grade elementary school students by integrating gamification elements, FSM-based emotional feedback, and the Fisher–Yates Shuffle algorithm. The game was implemented as an Android application using Unity and C#. Gamification elements, including scores, levels, time limits, life indicators, and visual feedback, were incorporated to support interactive vocabulary practice. The FSM-based feedback mechanism enabled the rabbit character to generate predefined visual responses based on gameplay events, while the Fisher–Yates Shuffle algorithm was applied to randomize puzzle arrangements and reduce repetitive gameplay patterns.

The evaluation results showed that the main application features operated according to the specified functional requirements based on Black Box Testing. White Box Testing indicated that the FSM-based feedback mechanism and Fisher–Yates Shuffle algorithm followed the expected control flow, with cyclomatic complexity values of 5 and 2, respectively. User Acceptance Testing involving 35 sixth-grade students of SD Negeri 2 Cikeusal produced an overall acceptance score of 94.3%, indicating that the developed game was well accepted by the target users.

Overall, the integration of gamification, FSM-based emotional feedback, and Fisher–Yates Shuffle provides a practical approach for developing an engaging vocabulary practice medium for elementary school students. However, this study focused on system development and user acceptance evaluation and did not directly measure vocabulary learning improvement through pre-test and post-test procedures. Future research is recommended to involve larger respondent groups, expand vocabulary categories, evaluate learning outcomes experimentally, and explore more adaptive feedback mechanisms to support personalized learning experiences.

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