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Dynamic Scoring for Quran Memorization Assessment in Journey of Ayat Educational Game Using the Fuzzy Tsukamoto Algorithm

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ABSTRAK

Conventional Qur'an memorization assessment in Madrasah Diniyah Takmiliyah (MDT) often relies on direct teacher evaluation and simple correct-or-wrong scoring, which may not fully represent students' memorization performance. At MDT An-Nidzom, preliminary assessment showed that students experienced difficulties in completing verse fragments of selected short surahs. Objective: This study aimed to develop Journey of Ayat, an Android-based educational game, and implement the Fuzzy Tsukamoto algorithm as a dynamic scoring mechanism for Qur'an memorization assessment. Methods: The study employed a Research and Development approach using the Game Development Life Cycle. The scoring model used three input variables, namely correct answers, completion time, and remaining lives, to generate a final score. The system was evaluated through black-box testing, white-box testing, Fuzzy Tsukamoto calculation validation, User Acceptance Testing, and pretest-posttest analysis involving 40 students and one teacher at MDT An-Nidzom. Results: The developed system provided memorization practice, gameplay interaction, score calculation, and teacher monitoring. The Fuzzy Tsukamoto calculation was consistent with manual calculation, with an error value of 0.00 in the validation scenario. Black-box testing showed that the main features operated as expected, while white-box testing produced a cyclomatic complexity value of 2. The UAT results indicated very feasible ratings of 92.00% from the teacher and 89.06% from students. The mean memorization score increased from 62.75 to 70.00, and the Wilcoxon signed-rank test showed a statistically significant difference in the observed sample ($p = 0.0237$). Conclusion: Journey of Ayat is feasible as a supporting medium for Qur'an memorization practice and preliminary assessment. However, further studies involving broader samples, control-group comparison, and oral recitation assessment are needed to strengthen evidence of learning effectiveness.

1 Introduction

Digital transformation in education has encouraged the development of interactive learning media that support motivation, engagement, feedback, and repeated practice. Educational games are increasingly used because they combine learning content with game elements such as challenges, levels, rewards, visual interaction, and scoring mechanisms. Recent studies show that digital educational games can improve students' motivation and engagement through active learning experiences [1], [2]. Broader studies on game-based learning and gamification also indicate positive effects on learning outcomes, motivation, and student participation when game activities are aligned with instructional objectives [3], [4], [5], [6]. In addition to functioning as learning media, educational games can support assessment activities by recording learner performance during gameplay.

Game-based assessment frameworks emphasize that learning evidence can be collected from observable player actions, embedded tasks, and gameplay behavior [7], [8], [9]. Therefore, educational games are relevant for learning domains that require repetition, performance tracking, and structured feedback.

Qur'an memorization, particularly short surahs in Juz 30, is an important learning component in Islamic non-formal education institutions such as Madrasah Diniyah Takmiliyah (MDT). Memorization learning requires repeated practice, recall accuracy, teacher guidance, and systematic evaluation. Previous studies on tahfidz learning show that memorizing short surahs requires structured learning activities and continuous guidance to strengthen memorization quality [10], [11]. From a cognitive perspective, Qur'an memorization is also related to memory development and learning achievement, indicating that memorization activities need appropriate instructional support [12], [13].

At MDT An-Nidzom, short-surah memorization is evaluated by asking students to complete missing fragments of Qur'anic verses. However, preliminary observation showed that the evaluation process was still conducted conventionally and depended heavily on direct teacher assessment. An initial pretest involving 40 students showed that only 17 students, or 42.5%, were able to complete the verse fragments correctly, while 23 students, or 57.5%, were unable to answer correctly. This condition indicates that students still experience difficulty in maintaining memorization consistency, particularly in the middle parts of surahs.

A simple correct-or-wrong scoring mechanism may not fully represent students' memorization performance. Two students with the same number of correct answers may have different levels of recall speed, error frequency, and gameplay consistency. In a memorization game, the number of correct answers can represent memorization accuracy, completion time can indicate recall speed, and remaining lives can reflect error tolerance and consistency during gameplay. Gamification studies suggest that enjoyment, self-efficacy, and engagement can influence students' participation in learning activities [14]. User evaluation studies in educational games also emphasize that usability, user acceptance, and player feedback are important to determine whether an educational game can be practically used and improved based on target users' responses [15], [16]. Therefore, a dynamic scoring mechanism is needed to process multiple performance indicators into a more proportional final score.

Fuzzy logic is one approach that can support decision-making under gradual and uncertain conditions. A recent scoping review of fuzzy logic in serious games shows that fuzzy systems have been widely applied in serious games, especially for adaptive mechanisms, feedback, difficulty adjustment, and performance-based decisions [17]. The Fuzzy Tsukamoto algorithm is suitable for score determination because it uses IF–THEN rules with monotonic membership functions and produces crisp output through weighted average defuzzification. Previous research has applied Fuzzy Tsukamoto in educational games, such as a Nusantara educational game that used Fisher-Yates Shuffle for question randomization and Fuzzy Tsukamoto for score calculation [18]. However, the context of that study focused on cultural knowledge, flora, fauna, and national figures, not on Quran memorization assessment. This shows that the research gap is not merely the use of Fuzzy Tsukamoto in educational games, but the adaptation of Fuzzy Tsukamoto for domain-specific Quran memorization assessment.

Based on this gap, this study proposes a dynamic scoring model for Qur'an memorization assessment in the Journey of Ayat educational game using the Fuzzy Tsukamoto algorithm. The novelty of this study lies in adapting Fuzzy Tsukamoto as a multi-parameter scoring mechanism for verse-fragment memorization practice. The proposed system was developed as an Android-based 2D adventure educational game equipped with learning materials, verse-fragment questions, level-based gameplay, dynamic scoring, and a teacher dashboard for monitoring student progress. This study aims to design and develop Journey of Ayat, implement the Fuzzy Tsukamoto algorithm as a dynamic scoring mechanism, and evaluate the system through black-box testing, white-box testing, calculation validation, User Acceptance Testing, and pretest-posttest analysis involving 40 students and one teacher at MDT An-Nidzom. The study focuses on system feasibility, scoring implementation correctness, user acceptance, and observed changes in students' memorization scores after using the game.

2 Method

This research adopted a Research and Development (R&D) approach to produce and evaluate an Android-based educational game entitled Journey of Ayat. The development process followed the Game

Development Life Cycle (GDLC), which provides systematic stages for game production, including initiation, pre-production, production, testing, beta, and release [19]. The evaluation was conducted through functional testing, logic testing, Fuzzy Tsukamoto calculation validation, User Acceptance Testing (UAT), and pretest-posttest comparison. These evaluation procedures were used to examine system feasibility, implementation correctness, user acceptance, and changes in students' memorization scores after using the game.

2.1 Research Object, Participants, and Data Collection

The object of this research was Journey of Ayat, an Android-based 2D adventure educational game designed to support the memorization of selected short surahs from Juz 30. The game presents verse-fragment completion tasks in which students answer Qur'anic verse continuation questions while completing game levels. The final score is calculated using the Fuzzy Tsukamoto algorithm based on three input variables: correct answers, completion time, and remaining lives.

The research was conducted at Madrasah Diniyah Takmiliyah (MDT) An-Nidzom, Ciniru Village, Ciniru District, Kuningan Regency, West Java. The participants consisted of 40 students from grades 3 to 5 and one teacher. The students served as game users, pretest-posttest respondents, and UAT respondents, while the teacher served as evaluator and dashboard user. The learning material was limited to nine selected short surahs from Juz 30: Al-Ma'un, Al-Quraisy, Al-Fil, Al-Humazah, Al-'Asr, At-Takatsur, Al-Qari'ah, Al-'Adiyat, and Az-Zalzalah. The assessment focused on students' ability to complete verse fragments. Tajwid, makharijul huruf, and oral recitation quality were beyond the scope of this research.

Data were collected through observation, interview, literature study, pretest-posttest, and UAT questionnaire. Observation was conducted on December 9, 2025, focusing on the memorization assessment process, teacher-student interaction, and students' difficulties in completing verse fragments. The interview involved the teacher responsible for memorization learning and assessment. The pretest and posttest were administered to 40 students using verse-fragment completion questions, while the UAT questionnaire used a five-point Likert scale to measure user acceptance and system feasibility. The game was developed using Unity 2D and C#, supported by Supabase/PostgreSQL for student data and score history, and a PHP-based web dashboard for teacher monitoring.

2.2 Game Development Procedure

The research procedure followed six GDLC stages: initiation, pre-production, production, testing, beta, and release [19], [20], [21]. Each stage generated outputs that became the basis for the next development phase. The GDLC model used as the game development procedure is illustrated in Figure 1, while the implementation of each stage and its corresponding research output is summarized in Table 1.

Figure 1. Game Development Life Cycle

Table 1. GDLC stages and research outputs

GDLC stage	Main activities	Research output
Initiation	Identifying memorization assessment problems through observation, interview, and pretest	User needs, problem statement, and initial game concept
Pre-production	Designing storyline, storyboard, game mechanics, level structure, UML model, interface design, and fuzzy variables	Game Design Document, storyboard, level design, UML diagrams, and fuzzy variable specification
Production	Developing the Android game, implementing scoring logic, integrating database, and building teacher dashboard	Android APK prototype, scoring module, database, and web dashboard

Testing	Conducting internal testing of features, gameplay, and scoring logic	Black box test design, white box test design, and fuzzy calculation validation scenarios
Beta	Testing the game with 40 students and one teacher at MDT An-Nidzom	UAT data, pretest-posttest data, and user feedback
Release	Preparing the final application after testing and revision	Final APK and dashboard implementation for MDT An-Nidzom

2.3 Fuzzy Tsukamoto Scoring Model

The dynamic scoring model in Journey of Ayat was designed using the Fuzzy Tsukamoto algorithm. The model processed three input variables obtained from gameplay performance: correct answers, completion time, and remaining lives. Correct answers represent memorization accuracy, completion time indicates recall speed, and remaining lives reflect error tolerance during gameplay. The output variable was the final score ranging from 0 to 100. The fuzzy variables and linguistic sets used in the scoring model are shown in Table 2.

Table 2. Fuzzy variables and linguistic sets

Variable	Type	Range	Linguistic sets
Correct answers	Input	0–5	Few, Medium, Many
Completion time	Input	0–180 seconds	Fast, Medium, Slow
Remaining lives	Input	0–100 HP	Low, Medium, High
Final score	Output	0–100	Low, Medium, High

The fuzzification process used linear and triangular membership functions. Linear functions were used for lower and upper linguistic sets, while triangular functions were used for middle linguistic sets. In general, the membership functions were formulated as follows:

$$\mu_{decreasing}(x) = \begin{cases} 1, & x \le a \\ fracb - xb - a, \quad a < x < b \backslash 0, & x \ge b \end{cases} \tag{1}$$

$$\mu_{increasing}(x) = \begin{cases} 0, & x \le a \\ fracx - ab - a, \quad a < x < b \backslash 1, & x \ge b \end{cases} \tag{2}$$

$$\mu_{triangular}(x) = \begin{cases} 0, & x \le a \text{ or } x \ge c \\ fracx - ab - a, & a < x < b \\ fracc - xc - b, & b \le x < c \end{cases} \tag{3}$$

The inference process used the logical AND operator by taking the minimum membership degree from each active rule:

$$\alpha_i = \min(\mu_A(x), \mu_B(y), \mu_C(z))) \tag{4}$$

Each rule produced a crisp consequent value (z_i) based on the monotonic membership function of the output variable. The final score was obtained using weighted average defuzzification:

$$Z = \frac{\sum_{i=1}^{n} \alpha_i z_i}{\sum_{i=1}^{n} \alpha_i} \tag{5}$$

The complete fuzzy rule base and calculation validation are presented in the Results and Discussion section to show the implementation correctness of the proposed scoring model.

2.4 Data Analysis and Evaluation Techniques

Data analysis was conducted to evaluate system functionality, scoring correctness, user acceptance, and learning score changes. Black box testing was used to verify whether each feature produced the expected output based on user input. White box testing was applied to examine the internal logic of the Fuzzy Tsukamoto scoring function using flowgraph analysis, cyclomatic complexity, and independent path testing.

The Fuzzy Tsukamoto calculation was validated by comparing the final score generated by the application with manual calculations. The validation result was reported using several input scenarios consisting of correct answers, completion time, and remaining lives. The error value was calculated using the absolute difference between the manual score and the system score:

$$Error = |Score_{manual} - Score_{system}| \quad (6)$$

User Acceptance Testing was used to measure user acceptance of the developed educational game. UAT is relevant for evaluating whether an educational game can be accepted by target users [22]. The questionnaire used a five-point Likert scale. The feasibility percentage was calculated using the following formula:

$$P = \frac{\sum Obtained\ Score}{\sum Maximum\ Score} \times 100 \quad (7)$$

The feasibility interpretation used five categories: 81–100% = very feasible, 61–80% = feasible, 41–60% = fairly feasible, 21–40% = not feasible, and 0–20% = very not feasible.

Pretest-posttest analysis was conducted to observe changes in students' memorization scores before and after using the game. The analysis included mean pretest score, mean posttest score, score difference, and the number of students whose scores increased, remained unchanged, or decreased. To support the interpretation of score changes, the data were analyzed using a statistical significance test. If the data distribution was normal, a paired sample t-test was used; otherwise, the Wilcoxon signed-rank test was applied.

3 Results and Discussion

This section presents the implementation and evaluation results of the Journey of Ayat educational game. The results are organized into system implementation, Fuzzy Tsukamoto scoring implementation, calculation validation, black-box testing, white-box testing, User Acceptance Testing (UAT), pretest-posttest analysis, and discussion of findings. These results demonstrate system functionality, scoring implementation correctness, user acceptance, and observed changes in students' memorization scores after using the game.

3.1 Presentation of Research Results

3.1.1 System Implementation Result

The development process produced Journey of Ayat, an Android-based 2D adventure educational game designed to support students in practicing selected short surahs from Juz 30 through verse-fragment completion tasks. The system consists of two main user environments: the Android game application for students and the web-based dashboard for teachers. Through the Android application, students can access learning materials, play levels, answer verse-fragment questions, and receive a final score. Meanwhile, the teacher dashboard supports student data management, score history monitoring, and learning progress observation.

The overall system architecture is shown in Figure 2. Student gameplay data are processed in the Android application and stored in Supabase/PostgreSQL, while the teacher accesses the web dashboard to monitor student progress and score history.

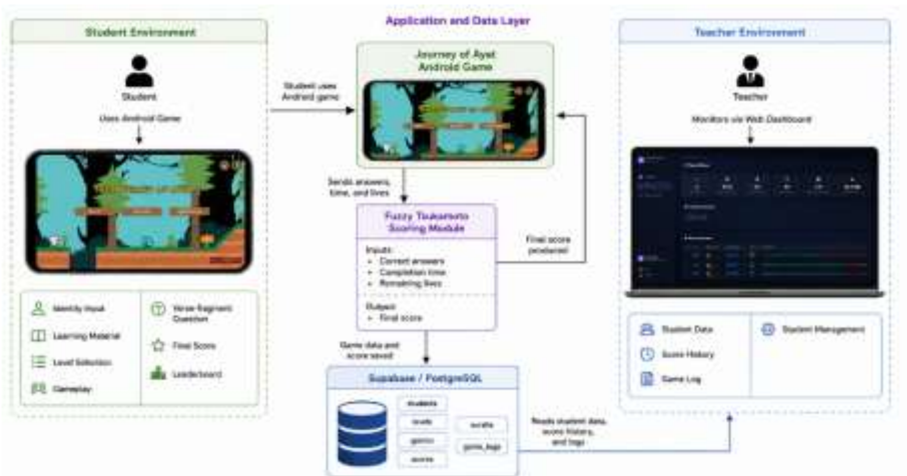

Figure 2. System architecture of Journey of Ayat

The gameplay and verse-fragment evaluation interface are shown in Figure 3. The interface combines movement control, lives, time indicator, and memorization questions. When a student reaches a question object, the system displays a verse-fragment question that must be completed correctly. The implemented student-side features include identity input, learning material access, level selection, gameplay, verse-fragment questions, final score display, and leaderboard.

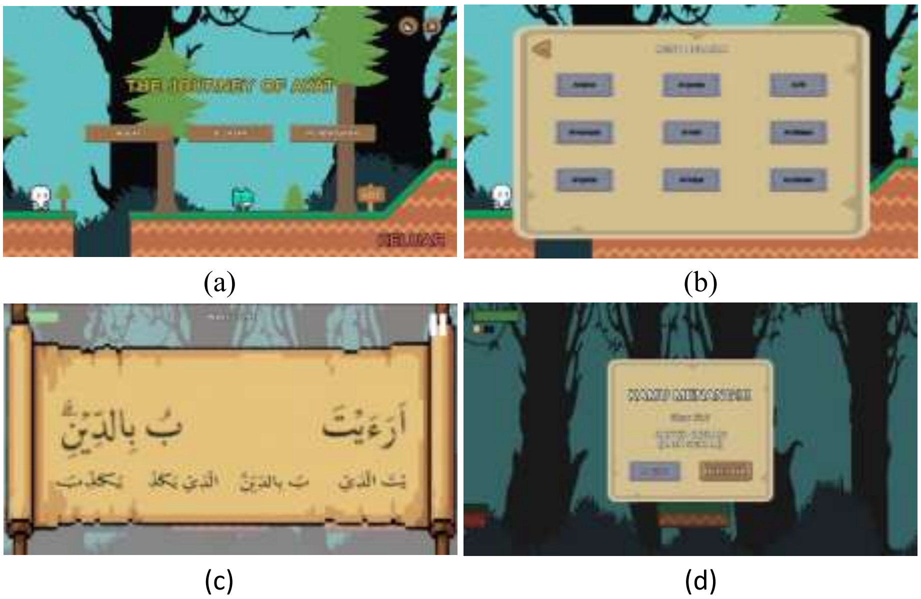

Figure 3. Gameplay and verse-fragment evaluation interface: (a) main game, (b) level game scene, (c) verse-fragment question, and (d) win condition scene.

The teacher monitoring interface is shown in Figure 4. The dashboard enables the teacher to view student data, monitor score history, and observe student game logs. This feature was designed to support a more structured evaluation process compared with conventional manual scoring.

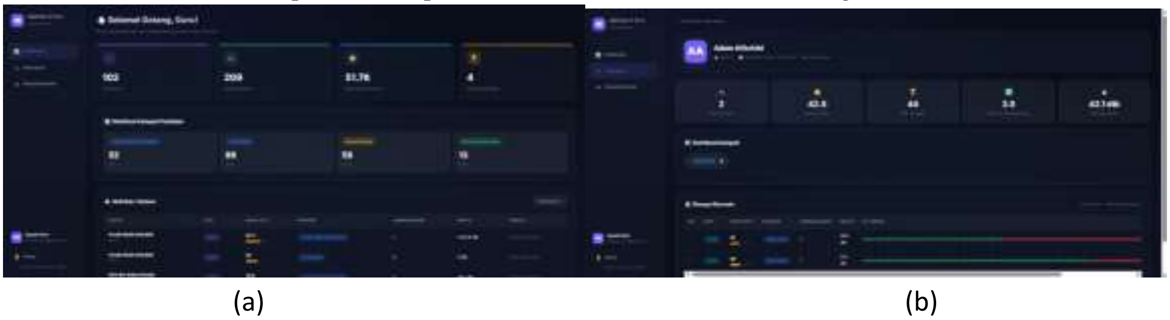

Figure 4. Teacher dashboard and score monitoring interface: (a) teacher dashboard and (b) student game log detail

3.1.2 Fuzzy Tsukamoto Rule Base and Scoring Implementation

The Fuzzy Tsukamoto algorithm was implemented as the dynamic scoring mechanism in Journey of Ayat. The scoring model used three input variables: correct answers, completion time, and remaining lives. These variables represent different aspects of gameplay-based memorization performance. Correct answers indicate memorization accuracy, completion time indicates recall speed, and remaining lives represent error tolerance during gameplay. The output variable was the final score, expressed as a crisp value from 0 to 100.

To improve reproducibility, the fuzzy set parameters used in the scoring model are presented in Table 3. The input variables were represented using linear and triangular membership functions. For the output variable, monotonic functions were used to comply with the Tsukamoto inference requirement.

Table 3. Fuzzy set parameters

Variable	Fuzzy set	Parameter/domain
Correct answers	Few	Decreasing [0, 3]
Correct answers	Medium	Triangular [1, 2.5, 4]
Correct answers	Many	Increasing [3, 5]

Completion time	Fast	Decreasing [0, 30]
Completion time	Medium	Triangular [30, 60, 90]
Completion time	Slow	Increasing [90, 180]
Remaining lives	Low	Decreasing [0, 30]
Remaining lives	Medium	Triangular [20, 40, 60]
Remaining lives	High	Increasing [50, 100]
Final score	Low	Decreasing [0, 50]
Final score	Medium	Increasing [40, 80]
Final score	High	Increasing [70, 100]

The rule base consisted of 27 rules generated from the combination of three linguistic sets for each input variable. The rules were arranged by prioritizing memorization accuracy while still considering completion time and remaining lives. In general, a higher number of correct answers, faster completion time, and higher remaining lives produce a higher final score. The complete rule base is presented in Table 4.

Table 4. Fuzzy Tsukamoto rule base

Rule	Correct answers	Completion time	Remaining lives	Final score
R1	Many	Fast	High	High
R2	Many	Fast	Medium	High
R3	Many	Fast	Low	Medium
R4	Many	Medium	High	High
R5	Many	Medium	Medium	Medium
R6	Many	Medium	Low	Medium
R7	Many	Slow	High	Medium
R8	Many	Slow	Medium	Medium
R9	Many	Slow	Low	Low
R10	Medium	Fast	High	Medium
R11	Medium	Fast	Medium	Medium
R12	Medium	Fast	Low	Low
R13	Medium	Medium	High	Medium
R14	Medium	Medium	Medium	Low
R15	Medium	Medium	Low	Low
R16	Medium	Slow	High	Low
R17	Medium	Slow	Medium	Low
R18	Medium	Slow	Low	Low
R19	Few	Fast	High	Medium
R20	Few	Fast	Medium	Low
R21	Few	Fast	Low	Low
R22	Few	Medium	High	Low
R23	Few	Medium	Medium	Low
R24	Few	Medium	Low	Low
R25	Few	Slow	High	Low
R26	Few	Slow	Medium	Low
R27	Few	Slow	Low	Low

The rule base was implemented in the scoring module by calculating the membership degree of each input, determining active rules using the minimum operator, obtaining the crisp consequent value from each active rule, and applying weighted average defuzzification to produce the final score.

3.1.3 Manual Calculation and Fuzzy Validation Result

The Fuzzy Tsukamoto calculation was validated to examine whether the scoring module produced results consistent with manual calculation. This validation focused on implementation correctness rather than the pedagogical effectiveness of the fuzzy model. The validation scenario used three input values: correct answers = 2, completion time = 58.78 seconds, and remaining lives = 75 HP.

Based on the fuzzy set parameters, the membership degrees for correct answers were Few = 0.3333, Medium = 0.6667, and Many = 0. The completion time belonged to the Medium set with a membership degree of 0.9593, while Fast and Slow were 0. The remaining lives variable belonged to the High set with a membership degree of 0.5000, while Low and Medium were 0. Therefore, only two rules had α-predicate values greater than zero, namely R13 and R22.

Table 5. Fuzzy Tsukamoto manual calculation

Active rule	Rule condition	α-predicate	Output set	zi	αi × zi

R13	Medium, Medium, High	0.5000	Medium	60.00	30.00
R22	Few, Medium, High	0.3333	Low	33.33	11.11
Total		**0.8333**			**41.11**

The final score was obtained using weighted average defuzzification:

$$Z = \frac{(0.5000 \times 60.00) + (0.3333 \times 33.33)}{0.5000 + 0.3333} \quad (8)$$

$$Z = \frac{41.11}{0.8333} = 49.33 \quad (9)$$

Thus, the manual calculation produced a final score of 49.33. The application output was then compared with this manual result. As shown in Table 9, the system produced the same raw score, resulting in an error value of 0.00. This indicates that the implemented scoring module was consistent with the designed Fuzzy Tsukamoto calculation.

Table 6. Manual and system score comparison

Scenario	Correct answers	Time (seconds)	Remaining lives	Manual score	System score	Error	Status
S1	2	58.78	75	49.33	49.33	0.00	Valid

The validation result should be interpreted as evidence of calculation correctness. It does not directly indicate learning effectiveness, because learning improvement must be examined through pretest-posttest analysis.

3.1.4 Black-Box Testing Result

Black-box testing was conducted to verify whether the main system features produced the expected output based on user input. The testing covered student-side features, gameplay mechanisms, scoring processes, data storage, and teacher dashboard functions. A summary of the black-box testing result is presented in Table 7.

Table 7. Summary of black-box testing

Feature	Test scenario	Expected output	Actual output	Status
Identity input	Student enters name and class	Student data are saved and the main menu opens	As expected	Valid
Learning material	Student opens the learning menu	Surah material is displayed	As expected	Valid
Level selection	Student selects an unlocked level	Gameplay scene opens	As expected	Valid
Gameplay control	Student moves, jumps, and attacks	Character responds according to input	As expected	Valid
Enemy and obstacle collision	Student collides with enemy or obstacle	Lives are reduced according to the rules	As expected	Valid
Question panel	Student reaches a question object	Verse-fragment question appears	As expected	Valid
Answer validation	Student selects an answer	Correct or incorrect response is processed	As expected	Valid
Final score	Student completes a level	Final score is displayed	As expected	Valid
Score saving	Student finishes a game session	Score data are stored in the database	As expected	Valid
Leaderboard	Student opens leaderboard menu	Highest scores are displayed	As expected	Valid
Teacher dashboard	Teacher logs in to dashboard	Student data and score history are displayed	As expected	Valid
Real-time monitoring	Student finishes a game while teacher opens dashboard	Latest score appears in the dashboard	As expected	Valid

The black-box testing result indicates that the main features operated according to their expected functions. Therefore, the developed application can be considered functionally valid for the tested scenarios.

3.1.5 White-Box Testing Result

White-box testing was conducted on the Fuzzy Tsukamoto scoring function because this function represents the core logic of the dynamic scoring model. The tested function processed three input variables, calculated membership degrees, evaluated fuzzy rules, handled the total α-predicate value, and returned the final score. The flowgraph of the scoring logic is shown in Figure 5.

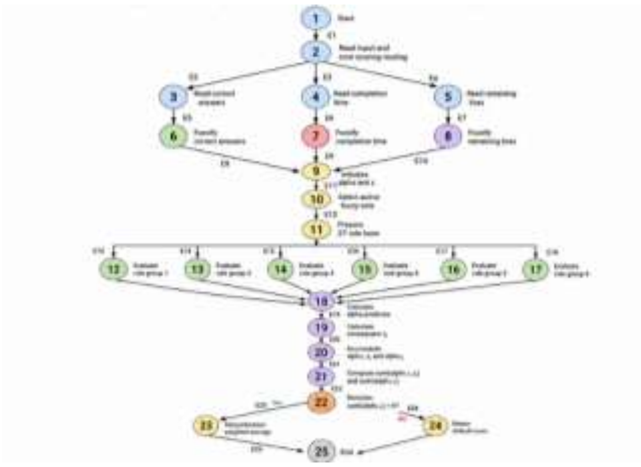

Figure 5. Flowgraph of the Fuzzy Tsukamoto scoring function

The cyclomatic complexity was calculated to determine the number of independent paths that needed to be tested. The white-box testing result is summarized in Table 8.

Table 8. White-box testing result

Component tested	**Number of nodes**	**Number of edges**	**Cyclomatic complexity**	**Independent paths**	**Status**
Fuzzy Tsukamoto scoring function	25	25	2	Path 1 and Path 2	Valid

The cyclomatic complexity value was calculated as follows:

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

$V(G) = 25 - 25 + 2 = 2$

Based on this result, two independent paths were tested:

Path 1: $(1 \rightarrow 2 - 10 \rightarrow 11 - 19 \rightarrow 20 \rightarrow 21 \rightarrow 22 \rightarrow 23 \rightarrow 25)$

Path 2: $(1 \rightarrow 2 - 10 \rightarrow 11 - 19 \rightarrow 20 \rightarrow 21 \rightarrow 24 \rightarrow 25)$

The result shows that the internal logic of the scoring function could be traced through the identified independent paths. This supports the logical correctness of the implementation at the code-structure level.

3.1.6 User Acceptance Testing Result

User Acceptance Testing was conducted to evaluate whether the developed system could be accepted by its target users. The UAT involved 40 students and one teacher. The questionnaire used a five-point Likert scale ranging from strongly disagree to strongly agree. The teacher questionnaire consisted of 15 items covering usability, monitoring features, scoring suitability, and overall application evaluation. The student questionnaire consisted of 18 items covering visual and usability aspects, memorization content, gameplay experience, and overall application evaluation.

The teacher evaluation obtained a total score of 69 out of 75, resulting in a feasibility percentage of 92.00%. Meanwhile, the student evaluation obtained a total score of 3206 out of 3600, resulting in a feasibility percentage of 89.06%. The student assessment showed that the memorization content aspect obtained the highest percentage at 90.88%, followed by overall application at 90.67%, gameplay experience at 89.63%, and visual and usability at 87.00%. The UAT results are visualized in Figure 6.

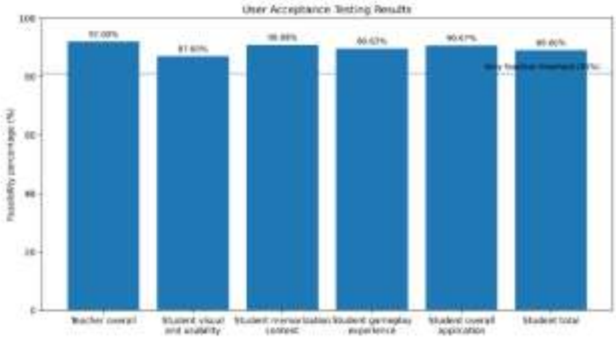

Figure 6. User Acceptance Testing results

Based on the feasibility category, both teacher and student results fall into the very feasible category. These findings indicate that *Journey of Ayat* was positively accepted by the target users. However, the UAT result should be interpreted as evidence of user acceptance and practical feasibility, not as direct evidence of learning effectiveness.

3.1.7 Pretest-Posttest Result and Statistical Analysis

The pretest-posttest evaluation was conducted to observe changes in students' memorization scores before and after using the Journey of Ayat educational game. The evaluation involved 40 students from grades 3 to 5 at MDT An-Nidzom. The test used verse-fragment completion questions with a comparable format before and after the game-based learning activity.

Based on the individual pretest-posttest data, 16 students experienced score improvement, 17 students maintained the same score, and 7 students experienced a decrease in score. The mean pretest score was 62.75, while the mean posttest score was 70.00. Therefore, the average score increased by 7.25 points after students used the game.

Table 9. Pretest-posttest descriptive and statistical result

Indicator	Result
Number of students	40
Mean pretest score	62.75
Mean posttest score	70.00
Mean difference	7.25
Students with increased score	16
Students with unchanged score	17
Students with decreased score	7
Shapiro-Wilk p-value	0.0012
Statistical test	Wilcoxon signed-rank test
Wilcoxon p-value	0.0237

The normality test showed that the difference scores were not normally distributed, as indicated by the Shapiro-Wilk p-value of 0.0012. Therefore, the Wilcoxon signed-rank test was applied to examine the pretest-posttest difference. The Wilcoxon test produced a p-value of 0.0237, which is lower than 0.05. This result indicates a statistically significant difference between the pretest and posttest scores in the observed sample.

Although the statistical result shows an increase in students' memorization scores after using the game, the interpretation should remain cautious. Since this research involved one group without a control group, the result is more appropriately interpreted as a significant improvement in the observed sample rather than definitive evidence that the game alone caused the learning improvement.

Figure 7. Statistical test result

3.2 Analysis of Findings

The findings indicate that Journey of Ayat was successfully implemented as an Android-based educational game that integrates memorization practice, gameplay interaction, dynamic scoring, and teacher monitoring. The system architecture supports two main user roles: students as game users and teachers as evaluators through the dashboard. This structure allows memorization activities to be recorded as learning data, so the assessment process becomes more structured than conventional manual recording.

The implementation of the Fuzzy Tsukamoto algorithm contributes to the scoring mechanism by combining three indicators: correct answers, completion time, and remaining lives. This approach provides a more proportional scoring mechanism than simple correct-or-wrong accumulation because students with similar answer accuracy may still differ in recall speed and gameplay consistency. The calculation validation showed that the system score was consistent with the manual calculation. However, this result should be interpreted as implementation correctness of the scoring algorithm, not as direct evidence of learning effectiveness.

The technical testing results support the feasibility of the developed system. Black-box testing showed that the main features operated according to their expected functions, while white-box testing confirmed that the scoring logic could be traced through two independent paths. The UAT results also showed positive acceptance from both user groups, with feasibility scores of 92.00% from the teacher and 89.06% from students. These results indicate that the application was considered practical and acceptable by its target users.

The pretest-posttest analysis showed an increase in the mean score from 62.75 to 70.00. The Wilcoxon signed-rank test produced a p-value of 0.0237, indicating a statistically significant difference between the pretest and posttest scores in the observed sample. Nevertheless, the interpretation should remain cautious because the study used a one-group design without a control group. Therefore, the result indicates a significant improvement in the tested sample, but it cannot be used as definitive evidence that the game was the only factor causing the improvement.

Compared with previous studies that applied Fuzzy Tsukamoto in educational games, this research extends the application context to Qur'an memorization assessment. For example, Karim et al. applied Fisher-Yates Shuffle and Fuzzy Tsukamoto in a Nusantara educational game, but the learning domain focused on cultural knowledge rather than memorization assessment [18]. A scoping review by Rechy-Ramirez also showed that fuzzy logic has been widely used in serious games for adaptive mechanisms and decision-support processes [17]. In this study, the fuzzy model was adapted specifically as a dynamic scoring mechanism for memorization performance by considering accuracy, recall speed, and error tolerance. This domain-specific adaptation represents the main contribution of the proposed system.

3.3 Implications of the Results

The results provide practical, educational, and technical implications. From a practical perspective, the teacher dashboard can help teachers monitor student score history and game logs more systematically. This feature may reduce dependence on fully manual recording and support teachers in reviewing students' memorization progress.

From an educational perspective, Journey of Ayat provides students with an interactive medium for practicing selected short surahs through gameplay and immediate score feedback. The game does not replace direct teacher guidance in Qur'an memorization, but it can function as a supporting medium for independent practice and preliminary assessment.

From a technical perspective, the study shows that the Fuzzy Tsukamoto algorithm can be applied as a dynamic scoring model in an educational game by combining multiple performance indicators. The scoring concept can be adapted to other educational games that require multi-criteria assessment rather than binary scoring.

3.4 Limitations of the Study

This study has several limitations. First, the evaluation involved only 40 students and one teacher from a single institution, namely MDT An-Nidzom. Therefore, the findings may not fully represent students from other madrasah or broader educational contexts. Second, the learning material was limited to nine selected short surahs from Juz 30, so the system has not yet covered wider Qur'an memorization content.

Third, the assessment focused only on verse-fragment completion and did not evaluate tajwid, makharijul huruf, or oral recitation quality. Fourth, the pretest-posttest analysis used a one-group design without a control group, so the observed improvement should be interpreted as an improvement within the tested sample rather than definitive causal evidence. Fifth, the UAT questionnaire was used to measure user acceptance, but future studies should strengthen the validity and reliability testing of the instrument.

Future research should involve a larger sample, multiple institutions, control-group comparison, broader surah materials, and additional assessment indicators related to oral recitation quality. Further development may also integrate adaptive difficulty, question randomization, and long-term retention analysis to evaluate the sustainability of memorization improvement.

4 Conclusion

This study developed Journey of Ayat, an Android-based 2D educational game designed to support Qur'an memorization practice through verse-fragment completion tasks. The game was developed using the GDLC method and integrated the Fuzzy Tsukamoto algorithm as a dynamic scoring mechanism based on three performance indicators: correct answers, completion time, and remaining lives. The calculation validation showed that the implemented scoring module was consistent with the manual Fuzzy Tsukamoto calculation, indicating the correctness of the algorithm implementation.

The evaluation results showed that the main system features operated properly based on black-box testing, while white-box testing confirmed that the scoring logic could be traced through two independent paths. The UAT results indicated that the system was categorized as very feasible, with feasibility scores of 92.00% from the teacher and 89.06% from students. The pretest-posttest analysis also showed an increase in the mean score from 62.75 to 70.00, and the Wilcoxon signed-rank test indicated a statistically significant difference in the observed sample with a p-value of 0.0237.

Based on these findings, Journey of Ayat can be considered feasible as a supporting medium for Qur'an memorization practice and preliminary assessment at MDT An-Nidzom. However, the findings should be interpreted within the study limitations, including the use of one institution, a limited number of participants, selected short surah materials, and a one-group pretest-posttest design without a control group. Future research should involve broader participants, multiple institutions, expanded Qur'an memorization materials, oral recitation assessment, and control-group comparison to provide stronger evidence of learning effectiveness..

Data and Software Availability Statements

The software application build (.apk) and the dataset supporting the experimental pre-test and post-test results generated during this study are publicly archived and can be accessed via the repository hyperlink at GitHub: https://github.com/aysyahns/journey-of-ayat.

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