ISSN 2355-0082

Enhancing Public Knowledge on Sugar Consumption Limits Through Educational Games with Fuzzy Logic Implementation

Alexander Christian Jauwandi [1], Wirawan Istiono[2]
[1,2] Department of Informatics, Universitas Multimedia Nusantara, Indonesia
[1]alexander.djauwandi@student.umn.ac.id, [2]wirawan.istiono@umn.ac.id

Accepted 09 June 2026
Approved 29 June 2026

***Abstract*— The creation of educational games utilising fuzzy logic to increase public awareness of Banten's daily sugar consumption restriction is predicated on the fact that there will be around 536 million instances of diabetes mellitus by 2021. By 2030, it is expected to reach 642 million. With a frequency of 10.6%, or around 19.4 million cases, Indonesia is among the top five countries in the world for the most instances of diabetes mellitus. In Indonesia, the prevalence of Banten is approximately 2.2%. An educational game is used in this study. Based on the results of the first and second pre-test quizzes, fuzzy logic will be employed in the game to calculate the player's additional time. According to the analysis's findings, of the 33 respondents, around 57,57% or 19 had increased their knowledge, whereas roughly 42,42% or 14 did not. Furthermore, the average GUESS-18 user satisfaction score is 77.84%, indicating that users "agree/satisfied" with the game. Based on the findings, it can be concluded that creating educational games with fuzzy logic to increase public awareness of Banten's daily sugar consumption limit can be an alternate method of learning.**

***Index Terms*— Banten Indonesia; Daily Sugar Consumption; Fuzzy Logic; Education Game;**

I. INTRODUCTION

Diabetes mellitus (DM), commonly known as diabetes, is a severe chronic disease characterized by the body's inability to regulate blood sugar levels [1]. DM occurs when the pancreas fails to produce sufficient insulin or when the body cannot use insulin effectively. Insulin is a hormone produced by the pancreas that acts as a key to process glucose from the bloodstream into body cells for energy production [2], [3]. The body breaks down all carbohydrates into glucose in the bloodstream, and insulin facilitates glucose uptake into the cells. If left untreated, DM can lead to various health complications, including nerve damage, vision impairment, kidney failure, and organ dysfunction [4].

Type 1 diabetes is marked by the pancreas's inability to produce insulin or producing it in insufficient amounts. This type of diabetes can affect individuals of all ages but is most commonly diagnosed in children and young adolescents [5]. Patients with type 1 diabetes require insulin injections to regulate blood sugar levels, as the absence of insulin can be fatal. The most common symptoms of type 1 diabetes include excessive thirst, dry mouth, sudden weight loss, frequent urination, fatigue, persistent hunger, and vision problems [6], [7].

According to the International Diabetes Federation (IDF), approximately 90% of diabetes cases are type 2 diabetes. Type 2 diabetes occurs when the body cannot effectively use insulin, a condition known as insulin resistance [8], [9]. When insulin fails to function properly, blood sugar levels rise, prompting the pancreas to produce more insulin. This overproduction can overwork and eventually damage the pancreas, leading to a reduced ability to produce insulin, which in turn results in persistently high blood sugar levels [10].

There are several risk factors that contribute to diabetes. The exact cause of type 1 diabetes remains unknown, whereas type 2 diabetes is influenced by genetic factors, metabolic conditions, family medical history, age, overweight status, unhealthy diet, lack of physical activity, and smoking habits. Additionally, the frequent consumption of foods and beverages high in added sugar increases the risk of developing type 2 diabetes [2], [6].

According to the International Diabetes Federation (IDF), in 2021, the number of diabetes cases worldwide among individuals aged 20-79 years reached 536 million, accounting for 9.8% prevalence (the total number of disease cases occurring at a specific time in a given region) [10], [11]. The IDF also projects that this number will continue to rise, with an estimated 642 million cases or 10.8% prevalence by 2030. In 2021, Indonesia ranked fifth among countries with the highest number of diabetes cases, with 19.4 million people affected, representing a 10.6% prevalence rate. Specifically, the Banten province recorded a prevalence rate of 2.2% [10], [12], [13].

In designing educational game mechanisms, feedback in the form of extra time is generally determined using crisp logic rules, such as standard *if-else* conditional structures. However, this conventional approach has limitations as it creates rigid boundaries (the cliff effect), where negligible score differences can result in drastically different time allocation decisions. The justification for implementing fuzzy logic in this study is to overcome this rigidity. Fuzzy logic is selected due to its capability to model gradual human reasoning and to handle the uncertainty of player performance in a more adaptive manner [14], [15]. Consequently, the calculation of additional game time based on pre-test quiz 1 and pre-test quiz 2 scores can operate with smoother transitions, higher flexibility, and proportionality relative to each player's baseline understanding.

Based on these issues, this study aims to develop an educational game to enhance public knowledge regarding the daily sugar consumption limit in Tangerang, utilizing fuzzy logic. The objectives of this research are to design and develop an educational game to raise public awareness about daily sugar intake limits in Banten using fuzzy logic and to measure the improvement in public knowledge regarding daily sugar consumption limits in Banten.

The selected learning medium for this study is a game-based educational tool. Educational games can incorporate text, animations, videos, images, and sound, which can effectively enhance interest and engagement in learning. Game-based learning has been proven to increase motivation, interest, and active participation in educational activities, making it an effective method for disseminating health-related information.

II. Related Work

In the study conducted by Puja [16], it was stated that fuzzy logic is used to determine the difficulty level of quizzes based on the player's status. By utilizing fuzzy logic, various difficulty levels can be created, making the assessment not limited to binary correct or incorrect results. In a study conducted by Jonathan [17], [18], it was also stated that fuzzy logic is used to determine the movement speed of opponents , which is influenced by the player's health points and the opponent's health points.

Unlike previous studies that utilized fuzzy logic to determine quiz difficulty levels or to control the movement speed of non-player characters (NPCs), this research applies fuzzy logic to determine the duration of additional time awarded to players based on their pre-test quiz 1 and pre-test quiz 2 scores [19]. Utilizing this fuzzy-based approach provides a significant competitive advantage over conventional game-balancing systems (non-fuzzy baselines), which tend to be rigid, as fuzzy logic can dynamically evaluate a combination of multiple input variables without being constrained by binary true-false decisions [15], [20], This study specifically employs the Sugeno fuzzy logic method, as it yields a crisp constant output that can be directly integrated into the game's time computation system to establish a precise amount of bonus time for the player.

III. Methodology

A. Problem Identification

At this stage, problem identification process will be carried out. This problem identification is obtained from various internet resources. Some of the sources used for problem identification such as, World Health Organization (WHO), the International Diabetes Federation (IDF), journals, websites, and others.

B. Data Collection and Processing

At this stage, the main focus on data collection such as nutrients fact from food and drinks especially sugars. This data collection is obtained from internet sources. Some of the sources that used for searching data such as, National Health Agency, Worldh Health Organization (WHO), Food and Agriculture Organization (FAO), journals, and others. The data that has been collected will then be processed to remove none relevant data for the research. This process is carried by checking the data from 1 source with other different sources.

C. Fuzzy Design

In this research, fuzzy logic is used to determine the additional time that players will receive based on the score from pre test quiz 1 and pre test quiz 2. The type of fuzzy that being used for this study is fuzzy sugeno. The difference between fuzzy sugeno and fuzzy mamdani lies in the output that produced. In fuzzy mamdani, the output is a decision set, whereas in fuzzy sugeno, the output is a crisp constant [9]. The steps for designing the fuzzy system are as follows:

D. Fuzzy Variables and Linguistic Value

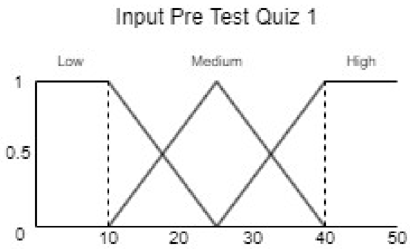
This research will use three fuzzy variables consisting of two input variables and one output variable [21], [22]. The variables for input and output for the fuzzy are as follows:

- Input Variables, pretest quiz 1 score divided into 3 (low, medium, and high).
- Input Variables, pretest quiz 2 score divided into 3 (low, medium, and high).
- Output Variables, total extra time for players divided into 3 (many (represented by the constant value of 10), intermediate (represented by the constant value of 7), and little (represented by the constant value of 5)).

E. Fuzzyfication

Fuzzyfication is done to mapping crisp value into fuzzy set for determine memberships value for each variables. The steps for fuzzyfication are as follows [23], [24]:

Input variables pre test quiz 1 score, low = 0-25, medium = 10-40, high = 25-50. In Figure 1, the graph of the input variable for pre test quiz 1 value range from 0-50. The set of pre test quiz 1 is divided into low has score value range from 0-25, medium has score value range from 10-40, and high has score value range from 25-50.



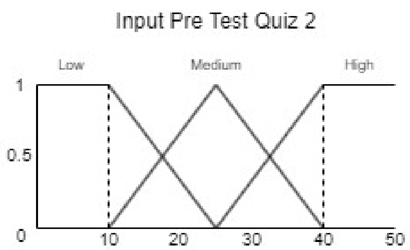
$$\mu_{low}(x) = \begin{cases} 1 : x \leq 10 \\ \frac{25 - x}{25 - 10} : 10 < x < 25 \\ 0 : x \geq 25 \end{cases}$$

$$\mu_{medium}(x) = \begin{cases} 0 : x \leq 10 \\ \frac{x - 10}{25 - 10} : 10 < x < 25 \\ \frac{40 - x}{40 - 25} : 25 < x < 40 \\ 0 : x \geq 40 \end{cases}$$

$$\mu_{high}(x) = \begin{cases} 0 : x \leq 25 \\ \frac{x - 25}{40 - 25} : 25 < x < 40 \\ 0 : x \geq 40 \end{cases}$$

Fig. 1. Pre Test Quiz 1 Input Graph

Input variables pre test quiz 2 score, low = 0-25, medium = 10-40, high = 25-50. In Figure 2, the graph of the input variable for pre test quiz 1 value range from 0-50. The set of pre test quiz 1 is divided into low has score value range from 0-25, medium has score value range from 10-40, and high has score value range from 25-50.



$$\mu_{low}(x) = \begin{cases} 1 : x \leq 10 \\ \frac{25 - x}{25 - 10} : 10 < x < 25 \\ 0 : x \geq 25 \end{cases}$$

$$\mu_{medium}(x) = \begin{cases} 0 : x \leq 10 \\ \frac{x - 10}{25 - 10} : 10 < x < 25 \\ \frac{40 - x}{40 - 25} : 25 < x < 40 \\ 0 : x \geq 40 \end{cases}$$

$$\mu_{high}(x) = \begin{cases} 0 : x \leq 25 \\ \frac{x - 25}{40 - 25} : 25 < x < 40 \\ 0 : x \geq 40 \end{cases}$$

Fig. 2. Pre Test Quiz 2 Input Graph

Output variables total extra time for players, many (represented by the constant value of 10), intermediate (represented by the constant value of 7), and little (represented by the constant value of 5).

F. Fuzzy Rules

This rules will be created based from two fuzzy input variables and the result from output variables. The variables for input such as, pre test quiz 1 and pre test quiz 2. The output variable for the fuzzy rules is total extra time for players. Table 1 provides an illustration of the fuzzy rules.

TABLE I. TABLE FUZZY RULES

IF	Pre test quiz 1	And	Pre test quiz 2	Then	Extra times
IF	Low	AND	Low	THEN	Little
IF	Low	AND	Medium	THEN	Little
IF	Low	AND	High	THEN	Intermediate
IF	Medium	AND	Low	THEN	Little
IF	Medium	AND	Medium	THEN	Intermediate
IF	Medium	AND	High	THEN	Many
IF	High	AND	Low	THEN	Intermediate
IF	High	AND	Medium	THEN	Many
IF	High	AND	High	THEN	Many

G. Inference and Defuzzification

In this research, the inference used is the maximal function or MAX. During the defuzzification stage, the weighted average method will be employed, using Equation 1 as follows:

$$Output = \frac{\sum_{i=1}^{n}(Membership\ Function\ x\ Constant\ Value_i)}{\sum_{i=1}^{n} Membership\ Function_i}$$

Equation 1. Equation for Output

H. Game Design

The educational tool developed in this study is a 3D single-player serious game. The core gameplay loop is structured into three sequential phases to measure knowledge acquisition systematically: a pre-test assessment phase, an educational intervention segment, and a post-test evaluation phase. The game environment is bound by invisible walls to maintain a controlled testing environment and ensure players remain focused on the designated tasks. To isolate the learning process, character movement and standard navigation features are temporarily restricted during assessment segments, requiring players to complete each evaluation phase before progressing further in the game.

I. Player

In this game, which is an offline single-player game, the player will strive to complete all the given missions. These missions consist of two pre-test quizzes, followed by an educational segment, and then the player will complete two post-test quizzes.

J. Objective

The player aims to complete the quizzes by answering all the provided questions. The player must complete the game in stages, starting with the 2 pre-tests, followed by the educational segment, and then completing the post-tests. The player will receive a score for each quiz, except for the educational segment.

K. Game Explanation

- Controls:

Character Movement: The player can control the character using the left joystick to move in the desired direction.

Camera Control: The player can control the character's camera view to look left or right using the right joystick.

- Pause Menu:

Pause button is located at the top left corner, which can be pressed to bring up the pause menu.

The pause menu includes options such as resume (to continue the game), settings (to adjust music, sound, etc.), restart (to restart the game), and quit (to exit the game).

Players can also open doors by approaching them.

L. Quiz Rules

- First Quiz:

Players answer multiple-choice questions, earning 10 points for each correct answer.

- Second Quiz:

Players are presented with different types of food and their nutritional content.

Players must label the food items with options such as "very good," "good," "fair," "poor," and "very poor."

- Timer:

A timer is present during the quizzes. If the timer reaches zero, the game will stop, and the player must restart the game.

M. Boundaries

- Invisible Walls:

There are invisible walls that limit how far players can walk within the game area.

- Quiz Restriction:

Once a quiz starts, the player cannot move the character or access a back button, meaning the player must complete the quiz before proceeding.

IV. Result and Discussion

A. Fuzzy Implementation

The fuzzy logic used in this game will be employed to provide additional time for the players. This additional time will be based on the scores of pre-test quiz 1 and pre-test quiz 2. Time will only decrease when the player is taking a quiz. If the time runs out, the player will lose and have to restart the game from the beginning.

In this game, players will be given a timer of 10 minutes at the start of the game, which will run while the player is taking quizzes. The fuzzy logic system will take two input values, namely the scores of pre-test quiz 1 and pre-test quiz 2, and will produce an output value in the form of additional time based on these input values. Figure 3 illustrates the timer application in the game.

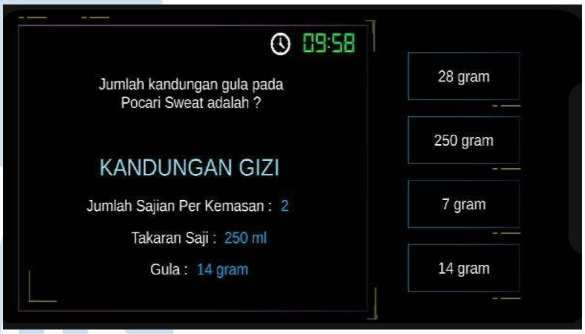


Fig. 3. Timer Application in Game

The next stage, after the player successfully completes pre-test quiz 1 and pre-test quiz 2, the scores from each quiz will be used as input variables to generate an output in the form of additional time for the players using the fuzzy method. Figure 4 shows the additional of time after the player successfully completes the pre-test quizzes.

If the timer reaches zero, the game will automatically stop, and a game over menu will appear. In the game over menu, the player can select the restart button to restart the game from the beginning. The addition of the timer system is expected to make the game more challenging for the players. Figure 5 illustrates the game over menu that appears when the timer reaches zero.

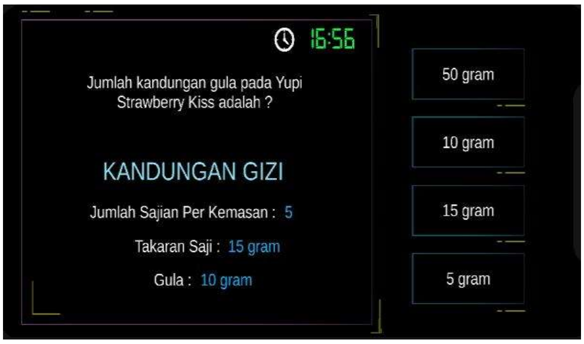


Fig. 4. Additional Time for Player

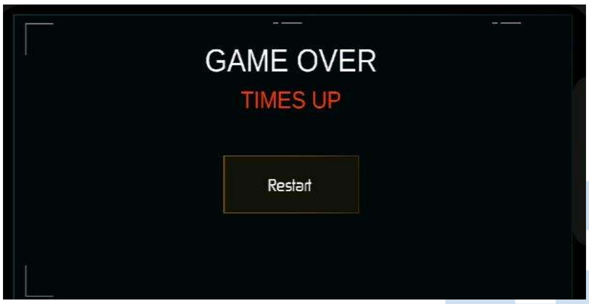


Fig. 5. Game Over Screen

B. Respondent Result

At this stage, testing will be conducted with respondents. The respondent testing process will follow these steps:

1. Respondents will download the game via the provided link.
2. After downloading, respondents will install the game.
3. Respondents will play the game according to the given missions.
4. After playing, respondents will be directed to a Google Form to fill out a survey.
5. The final step is for respondents to complete all the questions in the survey and submit it.

The data to be used will come from individuals aged 5 to 55 years. According to the Regional Health Research Report (Riskesdas), based on doctor diagnoses among residents of all ages by characteristics in the Banten province in 2018, the highest number of diabetes diagnose were recorded in the 5 to 55 age group. In this survey stage, 35 respondents were successfully gathered. Out of these 35 respondents, data from 33 respondents will be used, as 2 of the 35 respondents did not meet the data usage criteria. According to Mizanur [25], [26], a suitable sample size for research ranges from 30 to 500. Table 2 below shows the pre-test and post-test scores of the 33 respondents.

Based on the data in Table 2, the following average calculation will be conducted. According to the survey conducted, it was found that 19 out of 33 respondents showed improvement, while 14 out of 33 respondents showed no improvement. From this data, a calculation will be carried out to determine the percentage of respondents who improved versus those who did not. The percentage of respondents who showed improvement is 57.57%, while the percentage of respondents who showed no improvement is 42.42%.

TABLE II. SCORE OF 33 RESPONDENTS

No	Pre test	Post test	Result
1	70	80	Increase
2	80	90	Increase
3	60	80	Increase
4	10	70	Increase
5	80	90	Increase
6	30	80	Increase
7	100	100	Not Increase
8	90	70	Not Increase
9	60	90	Increase
10	100	90	Not Increase
11	50	50	Not Increase
12	80	90	Increase
13	90	100	Increase
14	100	100	Not Increase
15	50	70	Increase
16	80	90	Increase
17	30	50	Increase
18	80	100	Increase
19	50	90	Increase
20	70	100	Increase
21	70	70	Not Increase
22	60	70	Increase
23	30	90	Increase
24	80	80	Not Increase
25	10	0	Not Increase
26	60	50	Not Increase
27	70	80	Increase
28	60	90	Increase
29	80	90	Increase
30	80	80	Not Increase
31	80	70	Not Increase
32	80	70	Not Increase
33	70	70	Not Increase

Next is the calculation of the average score from GUESS-18 for each subscale from a total of 33 respondents shown at Table 3.

TABLE III. AVERAGE SCORE GUESS-18

Subscale	Average
Usability	76,19%
Narratives	80,95%
Play Engrossment	61,26%
Enjoyment	79,65%
Creative Freedom	72,73%
Audio Aeshetics	84,85%
Visual Aesthetics	84,20%
Personal Gratification	82,90%
Total Average	77,84%

A deeper analysis of the GUESS-18 subscale scores reveals critical implications for the game's design and educational efefficacy. The dimensions that received the highest satisfaction scores were Audio Aesthetics (84.85%) and Visual Aesthetics (84.20%), followed closely by Personal Gratification (82.90%). These high metrics indicate that the 3D environment, interface design, sound effects, and rewarding mechanics were highly successful in creating an appealing and immersive atmosphere for learning. Visually and audibly stimulating elements are vital in serious games, as they directly lower cognitive load and sustain players' initial interest when absorbing complex health data, such as daily sugar intake limits.

Conversely, the Play Engrossment dimension recorded the lowest score at 61.26%, falling into the 'tend to agree/satisfied' category. This lower rating implies that while players found the game visually appealing, their deep absorption or state of 'flow' within the gameplay loop was occasionally disrupted by external factors or the rigid pacing of the mandatory quiz blocks. For future game design iterations, this indicates a clear need to improve narrative integration and introduce more fluid, dynamic interaction mechanics rather than abrupt assessment transitions. Enhancing Play Engrossment is essential to ensure that players remain deeply focused on the educational content for longer durations, thereby maximizing knowledge retention.

V. CONCLUSION

Based on the research conducted, it was concluded that the design and development of an educational game to increase public knowledge about daily sugar consumption limits in Banten using fuzzy logic was successfully designed and built. Through the respondent trials of the successfully designed and developed game, several values such as pre-test, post-test, and GUESS-18 scores were obtained. Based on the calculations from a total of 33 respondents, it was found that 19 respondents, or 57.57%, showed an increase in knowledge scores, while 14 respondents, or 42.42%, did not show an increase in knowledge scores.

This study successfully designed and developed a 3D educational serious game implementing Sugeno fuzzy logic to enhance public knowledge regarding daily sugar consumption limits in Banten. Experimental evaluations yielded definitive quantitative support for the game's efficacy as an alternative learning medium. Specifically, post-test analysis demonstrated a measurable knowledge improvement in 57.57% of the respondents (19 out of 33 participants). Furthermore, evaluation of user experience via the GUESS-18 framework resulted in an overall satisfaction score of 77.84%, confirming that users were highly satisfied with the game's usability, engagement, and aesthetic design. Future work should focus on optimizing narrative elements to further elevate player engrossment and maximize long-term knowledge retention.

ACKNOWLEDGMENT

Thank you to Universitas Multimedia Nusantara in Indonesia for providing a space for academics to conduct this journal research. Hopefully, this research will contribute significantly to the growth of technology in Indonesia

REFERENCES

[1] M. Nassar *et al.*, "Diabetes Mellitus and COVID-19: Review Article," *Diabetes Metab. Syndr. Clin. Res. Rev.*, vol. 15, no. January, 2021.

[2] F. Sugandh *et al.*, "Advances in the Management of Diabetes Mellitus: A Focus on Personalized Medicine," *Cureus*, vol. 15, no. 8, 2023, doi: 10.7759/cureus.43697.

[3] D. Tomic, J. E. Shaw, and D. J. Magliano, "The burden and risks of emerging complications of diabetes mellitus," *Nat. Rev. Endocrinol.*, vol. 18, no. 9, pp. 525–539, 2022, doi: 10.1038/s41574-022-00690-7.

[4] M. A. Darenskaya, L. I. Kolesnikova, and S. I. Kolesnikov, "Oxidative Stress: Pathogenetic Role in Diabetes Mellitus and Its Complications and Therapeutic Approaches to Correction," *Bull. Exp. Biol. Med.*, vol. 171, no. 2, pp. 179–189, 2021, doi: 10.1007/s10517-021-05191-7.

[5] C. G. Yedjou *et al.*, "The Management of Diabetes Mellitus Using Medicinal Plants and Vitamins," *Int. J. Mol. Sci.*, vol. 24, no. 10, 2023, doi: 10.3390/ijms24109085.

[6] I. W. Suryasa, M. Rodríguez-Gámez, and T. Koldoris, "Health and Treatment of Diabetes Mellitus," *Int. J. Health Sci. (Qassim).*, vol. 5, no. 1, pp. I–V, 2021, doi: 10.53730/IJHS.V5N1.2864.

[7] Y. An *et al.*, "The role of oxidative stress in diabetes mellitus-induced vascular endothelial dysfunction," *Cardiovasc. Diabetol.*, vol. 22, no. 1, pp. 1–17, 2023, doi: 10.1186/s12933-023-01965-7.

[8] P. Aschner *et al.*, "The International Diabetes Federation's guide for diabetes epidemiological studies," *Diabetes Res. Clin. Pract.*, vol. 172, p. 108630, 2021, doi: 10.1016/j.diabres.2020.108630.

[9] T. Chivese *et al.*, "IDF Diabetes Atlas: The prevalence of pre-existing diabetes in pregnancy – A systematic review and meta-analysis of studies published during 2010–2020," *Diabetes Res. Clin. Pract.*, vol. 183, p. 109049, 2022, doi: 10.1016/j.diabres.2021.109049.

[10] H. Sun *et al.*, "IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045," *Diabetes Res. Clin. Pract.*, vol. 183, pp. 1–23, 2022, doi: 10.1016/j.diabres.2021.109119.

[11] H. Wang *et al.*, "IDF Diabetes Atlas: Estimation of Global and Regional Gestational Diabetes Mellitus Prevalence for 2021 by International Association of Diabetes in Pregnancy Study Group's Criteria," *Diabetes Res. Clin. Pract.*, vol. 183, p. 109050, 2022, doi: 10.1016/j.diabres.2021.109050.

[12] T. Tönnies, W. Rathmann, A. Hoyer, R. Brinks, and O. Kuss, "Quantifying the underestimation of projected global diabetes prevalence by the International Diabetes Federation (IDF) Diabetes Atlas," *BMJ Open Diabetes Res. Care*, vol. 9, no. 1, pp. 9–10, 2021, doi: 10.1136/bmjdrc-2021-002122.

[13] G. D. Ogle *et al.*, "Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition," *Diabetes Res. Clin. Pract.*, vol. 183, p. 109083, 2022, doi: 10.1016/j.diabres.2021.109083.

[14] S. Papadimitriou and M. Virvou, "Fuzzy Logic and Applications in Education and Games: Theory, Practical Implementations and a Literature Review," in *Intelligent Systems Reference Library, vol 93. Springer, Cham*, 2025, ch. Artificial, pp. 95–127. doi: https://doi.org/10.1007/978-3-031-77464-5_4.

[15] D. T. Muhamediyeva, L. U. Safarova, and N. Tukhtamurodov, "Building a fuzzy sugeno model for diagnosing cattle diseases on the basis of developing a knowledge base," *AIP Conf. Proc.*, vol. 2817, 2023, doi: 10.1063/5.0148278.

[16] P. Angga Firmansyah, K. Auliasari, and Y. Agus Pranoto, "Penerapan Metode Fuzzy Logic Pada Game 3D 'Aliester,'" *JATI (Jurnal Mhs. Tek. Inform.*, vol. 7, no. 5, pp. 3098–3105, 2024, doi: 10.36040/jati.v7i5.7607.

[17] R. Dimas Hariyanto, "Penerapan Metode Fuzzy Logic Untuk Pembentukan Perilaku Non Player Charakter Pada Game Petualang Finding Chiko," *J. Mhs. Tek. Inform.*, vol. 3, no. 1, pp. 251–256, 2019.

[18] I. Tisna Kusuma, A. Kusnadi, and F. Adline Twince Tobing, "Implementation Of Fuzzy Multi-Criteria Decision Making To Design An Expert System For Prediction Of Digestive Diseases At Dogs," *Ceddi J. Inf. Syst. Technol.*, vol. 2, no. 2, pp. 34–43, 2023, doi: 10.56134/jst.v2i2.50.

[19] Y. R. Kaesmetan and M. V. Overbeek, "Digital Image Processing using Texture Features Extraction of Local Seeds in Nekbaun Village with Color Moment, Gray Level Co Occurance Matrix, and k-Nearest Neighbor," *Ultim. J. Tek. Inform.*, vol. 13, no. 2, pp. 81–88, 2022, doi: 10.31937/ti.v13i2.2038.

[20] A. Hussain and K. Ullah, "An Intelligent Decision Support System for Spherical Fuzzy Sugeno-Weber Aggregation Operators and Real-Life Applications," *Spectr. Mech. Eng. Oper. Res.*, vol. 1, no. 1, pp. 177–188, 2024, doi: 10.31181/smeor11202415.

[21] C. Engineering, T. Study, C. Engineering, and T. Study, "Fuzzyfication Optimization of Crude Cassava Starch Processing into Tapioca Flour with the Mamdani Approach Extracting starch from cassava is the essence of the tapioca processing process . The basic stages of this process include peeling , washing yams ," *J. Appl. Sci. Technol. Humanit.*, vol. 1, no. 5, pp. 477–492, 2024, doi: https://doi.org/10.62535/4bra8966.

[22] X. Yang, J. Zou, S. Yang, J. Zheng, and Y. Liu, "A Fuzzy Decision Variables Framework for Large-Scale Multiobjective Optimization," *IEEE Trans. Evol. Comput.*, vol. 27, no. 3, pp. 445–459, 2023, doi: 10.1109/TEVC.2021.3118593.

[23] A. Acikgoz, "Fuzzyfication of new open set types," *Filomat*, vol. 39, no. 1, pp. 131–143, 2025, doi: 10.2298/FIL2501131A.

[24] F. Sbiaa, S. Kotel, R. Mghirbi, and A. G. Blaeich, "Revolutionizing Dyslexia Diagnosis: An Intelligent Model Featuring Machine Learning and Fuzzyfication," *Procedia Comput. Sci.*, vol. 246, no. C, pp. 3624–3633, 2024, doi: 10.1016/j.procs.2024.09.195.

[25] M. M. Rahman, "Sample Size Determination for Survey Research and Non-Probability Sampling Techniques: A Review and Set of Recommendations," *J. Entrep. Bus. Econ.*, vol. 11, no. 1, pp. 42–62, 2023, [Online]. Available: www.scientificia.comS

[26] H. Taherdoost, "What are Different Research Approaches? Comprehensive Review of Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and Limitations," *J. Manag. Sci. Eng. Res.*, vol. 5, no. 1, pp. 53–63, 2022, doi: 10.30564/jmser.v5i1.4538.