RESEARCH ARTICLE

BORNEO SCIENCE
THE JOURNAL OF SCIENCE & TECHNOLOGY

Journal homepage: https://jurcon.ums.edu.my/ojums/index.php/borneo-science

STUDENTS' LEARNING PERFORMANCE EVALUATION USING FUZZY LOGIC

Suriana Lasaraiya*[1] and Suzelawati Zenian[2]

[1] Preparatory Centre for Science and Technology, Universiti Malaysia Sabah, UMS, Malaysia.
[2] Faculty of Science and Technology, Universiti Malaysia Sabah, UMS, Malaysia.

***Correspondence:**
suriana@ums.edu.my

Received: 5 May 2025
Revised: 29 December 2025
Accepted: 29 December 2025
Published online:
1 March 2026

Doi:
10.51200/bsj.v47i1.6353

Keywords:
Fuzzy inference; fuzzy logic; fuzzy number; fuzzy rules; triangular membership function

ABSTRACT. *In Malaysia, students' performance at school, foundation, and university levels is traditionally assessed using a classical evaluation method, which aggregates scores from various assessments, such as assignments and exams, and assigns grades based on predefined thresholds (e.g., A, A-, B+, B). This study evaluates the mathematics performance of foundation students using a fuzzy logic approach and compares it with the conventional classical grading method. A Mamdani-type fuzzy inference system was developed using three input variables, that is, assignment, midterm, and final examination scores, and one output variable, namely students' performance grade. All variables were modeled using triangular membership functions, and a total of 12 fuzzy if-then rules were constructed based on common academic grading practices. The centroid defuzzification method was applied to obtain crisp performance scores. The proposed model was tested using data from 49 foundation students at the Preparatory Centre for Science and Technology, Universiti Malaysia Sabah. The results indicate that while extreme performances remain consistent across both methods, the fuzzy logic approach provides a more nuanced evaluation for borderline cases, leading to differences in grade classification for several students. These findings suggest that fuzzy logic offers a more flexible and informative alternative to classical grading systems in educational assessment. This study aims to analyze the differences between the classical and fuzzy logic methods, highlighting the potential benefits or limitations of adopting fuzzy logic in educational assessments.*

INTRODUCTION

Enhancing students' learning performance is a fundamental objective in educational systems. To achieve this, a fair and comprehensive evaluation system is essential to ensure all students receive equitable assessments. Traditionally, educational performance is measured numerically based on examination grades. The most common method involves summing the total marks from various assessments, including assignments, midterm exams, and final exams, to determine students' grades. However, this classical approach often relies on rigid scoring criteria, which may not accurately reflect students' true abilities and learning progress.

The fuzzy evaluation method in fuzzy logic has been shown to be effective for assessing student academic performance, as highlighted by Biswas (1995), Chang and Sun (1993), and Law (1996). Their research demonstrated that the fuzzy logic approach offers several advantages over traditional evaluation methods. Semerci (2004) introduced an experimental method utilizing fuzzy logic to explore its impact on student achievement. This study laid the groundwork for understanding how fuzzy logic could influence educational outcomes. Building on this, Saleh and Kim (2009) proposed a method for evaluating student performance using fuzzy logic. Their approach involved fuzzification and defuzzification processes based on the difficulty, importance, and complexity of questions, which proved to be straightforward and yielded fair and accurate results.

Gokmen *et al*. (2010) found that fuzzy logic assessment effectively classified students' learning groups by adapting to their individual characteristics and real-time performance. It was as accurate as the traditional t-score method, making it a viable alternative for educational evaluations. Sripan and Suksawat (2010) propose a study on students' learning assessment by fuzzy logic. Their study concludes that fuzzy logic provides a strong framework for personalized student assessment in computer disciplines, improving educational outcomes by accommodating diverse learning styles and enabling tailored instructional strategies. Petrudi *et al*. (2013) also introduced a new performance evaluation method using fuzzy logic systems. In this study, they consider three aspects of an academic course: exam 1, theoretical exam 2, and practical exam 3. The results indicated that the fuzzy logic method could effectively evaluate students' learning levels in real-time, outperforming the t-score method in terms of accuracy and consistency.

Meanwhile, Yadav *et al*. (2014) introduce a new fuzzy expert system for evaluating students' academic performance using fuzzy logic techniques. Unlike the rigid classical method, the proposed system offers greater flexibility and reliability. Their comparison of the classical method with Fuzzy-1, Fuzzy-2, and the proposed system shows that the new fuzzy expert system is more effective for assessing student performance. Patel *et al*. (2014) developed a fuzzy logic-based expert system that assists the process of decision-making of students' performance evaluation within a data grid environment. Barlybayev *et al.* (2016) describe a technology for online training and assessment that focuses on qualitatively evaluating student competence without relying on formulas for calculating performance. Electronic university tutors assign grades and maintain records, providing an easy way to calculate students' average progress. It emphasizes the importance of considering the type and value of assessments and their overall impact on performance.

Lee *et al.* (2019) propose using a fuzzy modelling approach to consider these performance predictors and predict student performance at the start of a semester. Early predictions enable adjustments and interventions in course design to achieve the desired learning outcomes. Wen and Liu (2021) offer a more transparent and equitable approach to assessing student performance. It enhances the current system by providing a clearer analysis of how students' scores relate directly to the attributes of each question. This method helps to better reflect the intended teaching design and objectives behind each question. Tengku Petra and Ab. Aziz (2021) proposes a fuzzy expert system that significantly aids in investigating and analyzing student performance. Their study demonstrates the flexibility of fuzzy logic, highlighting its ability to assign different weightages to attributes based on the specific needs and requirements of educational institutions. Additionally, the system allows for further refinement of fuzzy rules and membership functions to optimize the results of fuzzy controllers. Dokare *et al.* (2021) showed the difference between the traditional approach and the inference in assessing the student's performance. Fuzzy logic facilitates the creation of systems with complex, human-like logical abilities. It can handle data representing subjective or ambiguous human thoughts, allowing computers to process information that is neither entirely true nor false, akin to human thinking. This model can thus be employed to improve evaluation systems in educational institutions, enabling better tracking of performance and monitoring of individual growth over time.

Kumar and Singh (2023) modelled students' performance using fuzzy logic. However, in this study, they are comparing the results obtained while using type-I fuzzy and type-2 fuzzy in the model. Jan *et al.* (2023) focus on using the artificial intelligence (AI) technique of fuzzy logic to develop a student monitoring system based on the Outcome-Based Education (OBE) system for quality education. We identified three key factors from the literature: direct assessment, indirect assessment, and stress. Stress has been added as an additional factor to gain more insight into student monitoring. This approach highlights student stress and aims to provide a comprehensive view of academic performance. The latest study was done by Loan *et al.* (2024). In this study, they employ a combination of fuzzy logic and hierarchical linear regression to analyze students' performance. The findings in this study revealed the following: 1) There are differences in students' performance between traditional and fuzzy evaluation methods; 2) The learning method has an impact on students' fuzzy grades; 3) Students studying online do not perform better than those studying onsite. In this paper, a fuzzy logic approach is employed to assess students' performance in Mathematics, focusing on scoring and grading. The evaluation utilizes three key input variables: scores from assignments, midterm exams, and final exams. A total of 12 fuzzy rules are established to implement the fuzzy logic model.

Although numerous studies have applied fuzzy logic to student performance evaluation, many focus primarily on proposing fuzzy models without clearly detailing their inference structure, rule justification, or membership function parameters. Furthermore, limited studies provide a direct comparison using real foundation-level mathematics data while explicitly addressing borderline grading issues inherent in classical assessment methods. This creates a gap in terms of transparent methodological reporting and practical implementation in foundation mathematics courses.

Therefore, the objectives of this study are to develop a Mamdani fuzzy inference system for evaluating foundation students' mathematics performance using assignment, midterm, and final examination scores, construct and justify a 12-rule fuzzy rule base using triangular membership functions and finally to compare the grades obtained using the classical grading method and the fuzzy logic approach, with particular emphasis on borderline performance cases. This study contributes by providing a fully specified fuzzy inference framework, including membership function definitions, rule justification, and defuzzification procedures, applied to real academic data at the foundation level.

MATERIALS AND METHODS

Fuzzy logic, introduced by Zadeh in 1975 through his work on fuzzy sets, offers a mathematical framework to express linguistic variables, vagueness, and uncertainty. Unlike traditional binary logic, fuzzy logic handles non-digital, continuous systems without crisp boundaries, making it effective for representing knowledge and human reasoning. This approach uses variables such as "Low," "High," and "Normal" to capture degrees of truth, rather than simple "Yes/No" or "True/False" values. Data within fuzzy sets are represented by membership functions, where the degree of belongingness to a set is expressed as a value between 0 and 1. A higher membership value indicates a stronger association with a particular set, as described by Timothy (2004) and Zimmermann (2001).

This research focuses on the fuzzy inference system (FIS), a common application of fuzzy logic and set theory. FIS is a rule-based system that utilizes if-then rules, which are derived from human knowledge and experience, to process linguistic variables like "poor," "average," and "good." These rules enable FIS to handle vague systems effectively. Sen & Cenkci (2009) note that fuzzy sets can be characterized by various membership functions; in this study, we use a triangular membership fuzzy number $\mu = (\gamma, \alpha, \beta)$ with $\alpha > 0$ and $\beta > 0$, as illustrated by Zadeh (1965) in Equation 1.

$$\mu_\mu(x) = \begin{cases} \dfrac{x-\gamma}{\alpha} + 1, & \gamma - \alpha \leq x \leq \gamma \\ \dfrac{\gamma - x}{\beta} + 1, & \gamma \leq x \leq \gamma + \beta \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

The model follows five main stages,

1. Data Collection:
   Gather raw scores from assignments, midterm exams, and final exams.

2. Fuzzification:
   The fuzzification of students' scores was performed by incorporating input variables and their corresponding membership functions into fuzzy sets. In this study, the input variables consist of assignment scores, midterm exam scores, and final exam scores, while the output variable represents the students' performance grade. Both input and output variables are modelled using triangular membership functions as shown in Figures 1, 2, 3, and 4.

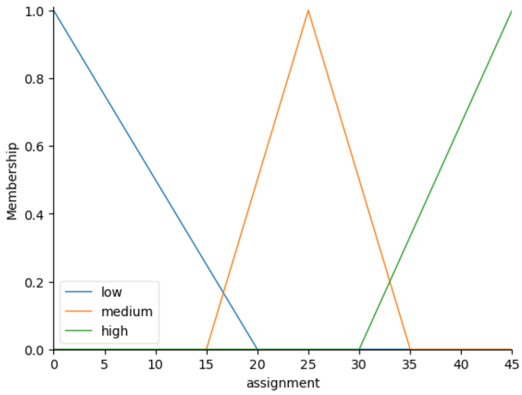

Figure 1. Membership function of the input variable for the assignment.

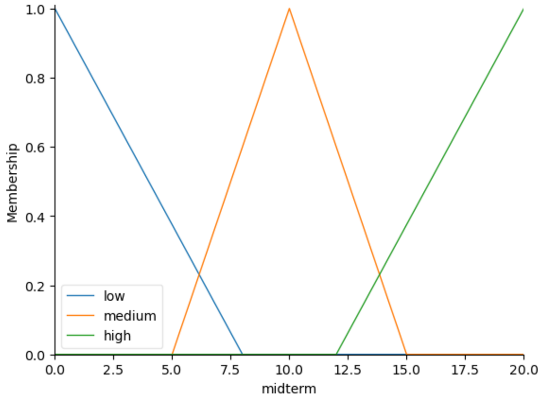

Figure 2. Membership function of the input variable for the midterm.

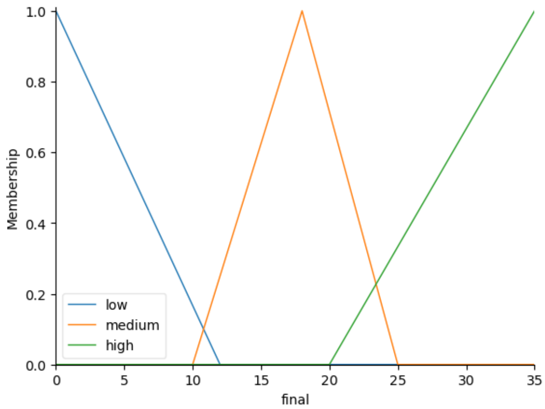

Figure 3. Membership function of the input variable for the final term.

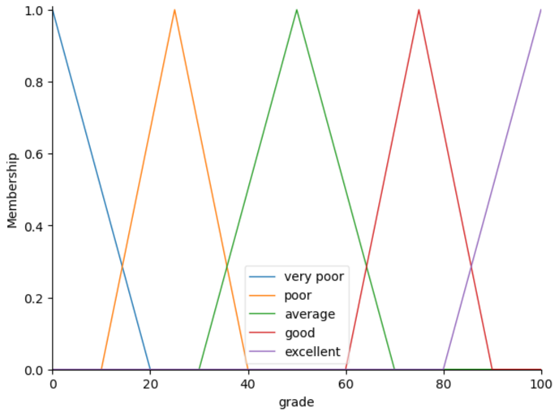

Figure 4. Membership function of output variables for student performance grades.

3. Rule Application:
   The fuzzy inference system was constructed by defining a set of rules that govern how the input variables (Assignment, Midterm, Final Term) combine to produce an output (Final Grade). A total of 12 rules were defined, capturing all possible combinations of inputs across the three linguistic terms. The rules were designed to reflect common grading practices, ensuring that students with consistently low scores received lower grades, while those with higher scores were rewarded accordingly. These rules, known as If-Then rules, are based on the works of Altrock (1995) and Semerci (2004). These rules were carefully designed to account for different performance scenarios, ensuring that the grading system was fair and accurate. Although three input variables with three linguistic terms each could theoretically produce 27 rules, this study adopts 12 dominant rules to represent realistic and pedagogically meaningful grading scenarios. Redundant and impractical combinations, such as simultaneously high assignment performance with consistently poor examination results, were excluded. The selected rules focus on dominant performance patterns commonly observed in foundation-level mathematics assessments, thereby improving interpretability while maintaining adequate decision coverage.

4. Defuzzification:
   Transform the fuzzy output into a crisp performance value. The membership interval is shown in Table 1. The defuzzification process was carried out using the centroid method, which is the most widely used method in fuzzy systems due to its effectiveness in capturing the center of the area under the curve. This method provided a crisp output that represented the final grade for each student. The crisp value is obtained and calculated as Equation 2.

$$z^* = \frac{\int \mu_c(z) \times z \times dz}{\mu_c(z) \times dz} \quad (2)$$

Table 1: The if-then rules assign for the input variables.

Output Variables	Input Variables		
	Assignment	Midterm	Final term
Very Poor (VP)	Low	Low	Low
Poor (Po)	Low	Low	Medium
Average (Av)	Medium	Medium	Medium
	High	Medium	Medium
	High	Medium	Low
	High	Low	Low
	High	Low	Medium
Good (Go)	High	Medium	Medium
	High	Medium	High
	High	High	Medium
	High	Low	Medium
Excellent (Ex)	High	High	High

Source: (If-then Rules as in Altrock (1995) and Semerci (2004))

5. Comparison and Analysis:
   Compare the fuzzy logic results with traditional grading methods and analyze the differences.

Table 2. Output variables in the fuzzy logic system according to the membership function (Performance)

Linguistic Expression	Symbol	Interval
Very Poor	VP	[0, 0, 20]
Poor	Po	[10, 25, 40]
Average	Av	[30, 50, 70]
Good	Go	[60, 75, 90]
Excellent	Ex	[80, 100, 100]

RESULTS AND DISCUSSION

Table 3 presents the scores obtained by 49 foundation students in three key assessments: the assignment, midterm examination, and final term examination. Additionally, the table includes the final marks each student achieved, along with their corresponding grades. This comprehensive data provides a clear overview of the students' performance across different evaluation components, offering insight into their overall academic achievements for the semester. To validate the fuzzy logic system, the grades obtained through the fuzzy logic method were compared with those derived from the classical grading system.

In classical students' evaluation performance, the grading relies on a fixed threshold for assigning grades. For example, if a student's total score is 65, they may get a "B," while a score of 64 could result in a "B-," even though the difference in their performance is very minimal. In this case, sometimes the students on the borderline between two grades are not captured. Meanwhile, in fuzzy logic, this system evaluates students' performance better by considering the degree of membership to the different grade categories, where, in this case, for example, excellent, good, average, poor, and very poor. For example, a student with a score of 65 might have a grade "B" but with more nuanced reflection of their performance (e.g., 60.6), where this student might be closer to "B-".

Table 3. The input variables and the grade comparison by the classic method and fuzzy logic.

Student	Input variables			Grade comparison		Student	Input variables			Grade comparison	
	A	M	F	C	Fu		A	M	F	C	Fu
Stud 1	40.5	13.7	14.5	B	B-	Stud 26	40.5	11.7	17.5	B+	B-
Stud 2	41.1	8.0	15.5	B	B-	Stud 27	41.0	10.7	28.5	A	A-
Stud 3	40.8	6.8	12.5	B-	B-	Stud 28	40.6	11.0	15.5	B	B-
Stud 4	39.6	3.7	9.5	C	C	Stud 29	41.0	10.0	13.5	B	B-
Stud 5	40.5	10.0	27.5	A-	A-	Stud 30	40.6	8.3	20.0	B	B-
Stud 6	40.8	19.3	28.0	A	A-	Stud 31	37.2	4.3	4.0	C-	C
Stud 7	40.5	3.7	10.5	C+	C+	Stud 32	37.2	16.3	20.5	A-	A-
Stud 8	41.1	11.3	14.5	B	B-	Stud 33	41.0	13.3	30.0	A	A-
Stud 9	41.5	16.3	20.0	A-	A-	Stud 34	41.0	5.3	19.5	B	B-
Stud 10	39.6	10.3	12.5	B-	B-	Stud 35	41.1	6.3	16.5	B-	B-
Stud 11	39.1	5.3	5.0	C	C	Stud 36	40.8	4.3	15.0	B-	B-
Stud 12	41.5	3.7	5.0	C	C	Stud 37	41.0	5.0	1.5	C-	C
Stud 13	39.6	9.0	12.5	B-	B-	Stud 38	40.5	13.7	21.0	A-	B-
Stud 14	40.6	4.0	8.5	C	C	Stud 39	37.2	5.3	4.5	C-	C
Stud 15	41.5	9.3	14.0	B	B-	Stud 40	41.1	8.3	14.0	B-	B-
Stud 16	39.6	12.7	25.0	A-	A-	Stud 41	40.5	2.0	5.5	C-	C
Stud 17	40.8	6.0	2.0	C-	C	Stud 42	40.6	11.0	23.5	A-	B-
Stud 18	41.0	6.8	5.5	C	C	Stud 43	37.2	7.7	10.0	C+	C
Stud 19	40.5	8.3	9.5	C+	C	Stud 44	40.5	7.7	9.5	C+	C
Stud 20	40.6	15.3	20.0	A-	A-	Stud 45	40.6	10.0	15.5	B	B-
Stud 21	40.5	18.0	26.5	A	A	Stud 46	41.5	13.7	21.0	A-	B-
Stud 22	40.5	4.0	10.5	C+	C+	Stud 47	39.6	1.0	3.5	C-	C
Stud 23	40.8	13.0	20.0	B+	B-	Stud 48	40.5	6.0	18.5	B	B-
Stud 24	37.2	7.7	7.0	C	C	Stud 49	41.5	6.8	10.0	C+	C
Stud 25	37.2	8.3	26.0	B+	A-						

Source: Mathematics Course File, Semester 2, Session 2023/2024.
(Stud – Student; A - Assignment ; F – Final Term ; C – Classical ; Fu – Fuzzy Logic)

Evaluation using fuzzy logic shows the potential benefit in the student assessment as it provides a more flexible evaluation, especially for those marks that are close to the grade boundary. For example, in Table 3, Student 16 or Student 23 obtained a more accurate reflection of their performance under the fuzzy grading system. This is good in capturing small differences in student performance that are not noticed in the classical way. In addition, with fuzzy logic, students who might narrowly miss a grade cutoff in the classical system, such as Student 17 (C in classical, C in fuzzy), receive grades that more accurately reflect their capabilities without the harsh consequences of a cutoff. By avoiding sudden shifts in grades, fuzzy logic reduces the instances where students feel unfairly rewarded or penalized based on slight differences in their scores. Besides that, the fuzzy logic approach evaluates student performance based on degrees of membership across multiple grade categories (Very Poor, Poor, Average, Good, and Excellent), rather than relying on fixed cut-off values. This allows borderline cases to be assessed more gradually, avoiding abrupt grade transitions. As observed in Table 3, several students experienced grade adjustments under the fuzzy logic system, particularly those whose scores were close to conventional grade boundaries. This indicates that the fuzzy approach is more sensitive to small variations in performance that are not captured by the classical grading method.

The results further show that students with consistently high or consistently low performance generally retained the same grades under both evaluation methods. For example, students such as Student 6 (high performance) and Student 47 (low performance) received identical grades using both classical and fuzzy evaluations. This suggests that the impact of the fuzzy logic approach is more pronounced for borderline and mid-range performances, while extreme cases remain largely unaffected. Overall, these findings demonstrate that fuzzy logic provides a more flexible and informative assessment framework by reducing sudden grade changes and offering smoother transitions between grade categories. However, one limitation of this approach is the increased complexity in interpreting fuzzy output values, which may be less intuitive for educators and students accustomed to traditional letter grades. Therefore, appropriate guidelines or conversion schemes may be required to support the practical implementation of fuzzy-based grading systems.

However, there are a few limitations that need to be considered as well. For example, the grade obtained by Student 6 is A in both classical and fuzzy. The example is shown by Student 47, whose grade is C- in both classical and fuzzy as well. This shows that fuzzy logic might have less impact on the students' marks with extreme scores. Besides that, adopting fuzzy logic is the potential complexity in interpreting the results. Unlike the clear-cut "A," "B," or "C" grades in the classical system, fuzzy grades (e.g., 60.5) might seem less intuitive for students and educators accustomed to discrete letter grades. There may need to be a guideline to help interpret these nuanced scores.

CONCLUSION

This study's comparison of the classical grading method with fuzzy logic revealed that fuzzy logic offers a more nuanced and flexible evaluation of student performance. Unlike the classical method, which relies on fixed cutoffs and may overlook subtle differences in student capabilities, the fuzzy logic approach accounts for the degree to which students meet each performance criterion. While fuzzy logic can enhance fairness and accuracy, it may require additional support and understanding from educators and students to fully realize its benefits. This results in a more detailed and accurate reflection of their abilities. The fuzzy logic system's ability to handle uncertainties and subjective assessments makes it a valuable alternative in educational settings. The findings suggest that adopting fuzzy logic in educational assessments could enhance the accuracy of performance evaluations, though further research may be needed to address potential challenges in its implementation. While this study does not introduce a new fuzzy algorithm, it provides a transparent and fully specified implementation of a Mamdani fuzzy inference system for foundation-level mathematics assessment, supported by real institutional data.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support provided by the Preparatory Centre for Science and Technology (PPST), Universiti Malaysia Sabah, throughout this study.

REFERENCES

Zadeh, L.A. 1975. *The Concept of a Linguistic Variable and Its Application to Approximate Reasoning-III*. Information Sciences, 9(1): 43–80.

Biswas, R. 1995. An application of fuzzy sets in students' evaluation. *Fuzzy Sets and Systems*, 74(2): 187-194.

Altrock, V.C. 1995. Fuzzy Logic Application in Europe, In J. Yen, R. Langari, & L. A. Zadeh (Eds). *Industrial Applications of Fuzzy Logics and Intelligent Systems*, Chicago: IEEE Press

Chang, D.F. & Sun, C.M. 1993. Fuzzy assessment of learning performances of junior high school students. *In Proceedings of the 1993 1st National Symposium on Fuzzy Theory and Applications*, 1-10.

Law, C.K. 1996. Using fuzzy numbers in educational grading system. *Fuzzy Sets and Systems*, 83(3), 311-323.

Zimmermann, H.J. 2001. *Fuzzy Set Theory and Its Applications*. London. Kluwer Academic Publisher.

Semerci, C. 2004. The influence of fuzzy logic theory on students' achievement. *The Turkish Online Journal of Educational Technology TOJET*, 3(2:9): 56-61.

Timothy, J.R. 2004. *Fuzzy Logic with Engineering Applications*. Chichester, West Sussex. UK: McGraw-Hill, Inc.

Saleh, I. & Kim, S.I. 2009. A fuzzy system for evaluationg students' learning achievement. *Journal of Expert Systems with Application*, 36: 6236-6243.

Sen, C.G. & Cenkci, D. 2009. An integrated approach to determination and evaluation of production planning performance criteria. *Journal of Engineering and Natural Science*, 27: 4-5.

Gokmen, G., Akinci, T.C., Tektas, M., Onat, N., Kocyigit, G. & Tektas, N. 2010. Evaluation of students performances in laboratory applications using fuzzy logic. *Procedia Social and Behavioral Science* 2: 902-209.

Sripan, R. & Suksawat, B. 2010. Propose of fuzzy logic-based students' learning assessment. *International Conference on Control, Automation and Systems*. 414-417.

Petrudi, S.H.J., Pirouz, M. & Pirouz, B. 2013. Application of fuzzy logic for performance evaluation of academic students. *13th Iranian Conference on Fuzzy Systems (IFSC).*

Yadav, R.S., Soni, A.K. & Pal, S. 2014. A study of academic performances evaluation using fuzzy logic techniques. *International Conference on "Computing for Sustainable Global Development*, 54-59.

Patel, S., Sajja, P. & Patel, A. 2014. Fuzzy logic-based expert system for students' performance evaluation in data grid environment. *International Journal of Scientific & Engineering Research*, 5(1): 36-40.

Barlybayev, A., Sharipbay, A., Ulyukova, G., Sabyrov, T., & Kuzenbayev, B. 2016. Students' Performance by Fuzzy Logic. *Procedia Computer Science,* 102, 98-105.

Lee, S.H., The, C.S. & Barawi, M.H. 2019. Predicting students' course performance based on learners' characteristics via fuzzy modelling approach. *International Advanced Science Engineering Information Technology*, 9(6): 1944-1949.

Wen, S. & Liu, D. 2021. Students' learning performance evaluation using a new fuzzy inference system. *2nd International Conference on Artificial Intelligence and Education*, 650-656.

Tg. Petra, T.Z. & Ab. Aziz, M.J. 2021. Analysing Student performance in higher education using fuzzy logic evaluation. *International Journal of Scientific & Technology Research*, 10(1): 322-327.

Dhokare, M., Teje, S., Jambukar, S. & Wangikar, V. 2021. Evaluation of academic performance of students using fuzzy logic. 978-982.

Kumar, P. & Singh, G. 2023. Modelling student's performance evaluation using fuzzy logic techniques. *International Journal of Creative Research Thought (IJCRT),* 2320-2882.

Jan, N.U., Naqvi, S. & Ali, Q. 2023. Using fuzzy logic for monitoring students academic performance in higher education. *Engineering Proceedings*. 46 (21) doi: https://doi.org/10.3390/engproc2023046021.

Loan, D.T.T., Tho, N.H., Nghia, N.N., Chien, V.D. & Tuan, T.A. 2024. Analyzing students' performance using fuzzy logic and hierarchical linear regression. *I.J. Modern Education and Computer Science,* 1: 1-10.