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Modeling Mathematics Performance Between Rural and Urban School Using a Fuzzy Logic Approach

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HIGHLIGHTS

- Fuzzy logic was used to determine which schools perform better in mathematics .
- Midterm and trial SPM results are defuzzified to generate academic performance value.
- Students can be classified according to their performance.

ABSTRACT

This study concerns competitiveness in Sijil Pelajaran Malaysia (SPM) performance between two different schools in Kedah, Malaysia, focusing on Mathematics scores. There are two different schools selected namely SMK Sungai Layar and SMK Bandar Sungai Petani. SMK Sungai Layar is a rural school while SMK Bandar Sungai Petani is an urban school. The objectives are to determine which schools between urban and rural schools perform better in mathematics subjects and classify students' performance on Mathematics subject using Fuzzy Logic. It is found that the performance of urban school was better than the rural school. As for rural school, the performance was moderate. The percentage of Mathematics value for SMK Bandar Sungai Petani is higher than SMK Sungai Layar. The number of students from an urban school who got a good score was double from the number of students from rural schools. The results show that the students from the urban school have excellent flexibility and reliability in Mathematics subject.

Keywords: *Sijil Pelajaran Malaysia, mathematics, urban school, rural school, fuzzy logic*

INTRODUCTION

Students in Malaysia begin their learning at the early age of four at kindergarten, even though it is unnecessary. The government offers free education of six years at the primary level and five years at the secondary level. Primary education starts when children reach the age of seven. Secondary Education in Malaysia is a continuation of primary education. The Sijil Pelajaran Malaysia (SPM), or the Malaysian Certificate of Education, is a national examination taken by all fifth-form secondary school students in Malaysia. SPM is the penultimate examination sat by secondary school students before entry into sixth form or technical education.

In Malaysia, mathematics is one of the compulsory subjects for primary and secondary school, and the most important criteria to enter universities. According to Dr Habibah Abdul Rahim (2020), SPM 2019 shows

the results for three core subjects of Bahasa Melayu, English and Moral Education showed an increase in performance while the other core subjects of Islamic Studies, History, Mathematics and Science declined. The performance of candidates in urban areas is better than that of candidates in rural areas. This difference causes the achievement gap between urban and rural areas to increase by 0.01 in 2019 compared to 2018 (Bernama, Khamis, 05 Mac 2020). According to Hassan and Rasiah (2011), urban schools in Malaysia remain much better serviced with good infrastructure support facilities and classrooms. It can be an influence of inequality performance between urban and rural areas. To improve Mathematics achievement among students, the Ministry of Education should take a course of action. One of them that should be concerned is about education delivery between rural schools and urban schools.

An analysis is needed to determine competitiveness between rural schools and urban schools regarding Mathematics subjects. This study aims to identify the schools with the highest Form Five SPM Mathematics achievement in Kedah's urban and rural areas and classify students' mathematics performance. As a result, fuzzy logic techniques were proposed in this study.

This paper is structured as follows; a literature review section, followed by a methodology section that describes the methodology for applying fuzzy logic to find the performance value. The discussion section discusses the working model of the analysis tool. Finally, the last section summarizes the result of the study and future works for extending this study.

LITERATURE REVIEW

There are many prediction model approach in students' performance was stated by researcher, however there is no certainty if there are predictors that precisely can verify whether a student will be an academic brilliant, a drop out, or a standard performer (Mohamed Shahiri et al., 2015). Several studies focused on students' performance using fuzzy logic approach (Kraoska et al., 2019; Kharola et al.,2015; Arora et al.,2014; Jamsandekar, 2013; Sakthivel et al., 2013; Yadav et al., 2011).

The fuzzy set concept has developed in various ways and many disciplines (Zimmermann, 2010). The set of the real numbers that characterize the class of objects is a fuzzy set. A fuzzy set has a graphical explanation that describes how the transition from one to another takes place. The graphic is called a membership function. A membership function is a curve that describes how every point in the input space is mapped to a membership value ranging between zero and one. In fuzzy sets, the set theoretic operations include intersection, union and complement, which correspond to the logical operators (AND, OR). In fuzzy set theory, the linguistic terms are used to elucidate an expert's knowledge and are also the most significant element in fuzzy (Nguyen, 2013).

The advantage of using fuzzy set theory is it can be easily evaluated and dealt with uncertainty. The majority of problems in this real world are dealing with uncertainty. However, the uncertain knowledge can be classified into incomplete important knowledge that uses probability techniques and imprecise information. A fuzzy set theory can give verbal statements numerical clarity without losing their imprecise qualities. The linguistic term by fuzzy set theory is easier to measure the performance of the school. For example, the terms of very good, good, average, low and very low are easier to analyze rather than the overall score of the student's performance. It can be created using the linguistic rating to the school's performance related to students' results in their examinations.

Performance Evaluation using Fuzzy Logic

Lotfi Zadeh formalized the fuzzy logic tool at the University of California in 1965 which is a mathematical tool for dealing imprecision and information granularity (Sakthivel, 2013). What Lotfi Zadeh suggested is

extremely a paradigm change that first gained acceptance in the Far East, and its successful method has guaranteed its implementation around the world.

Ingoley et al. (2012) directed a study to investigate the significance and complexity of the examination questions. By using Fuzzy Logic, they had taken accuracy and time rate to get the complexity. Total time allocated by the students in universities or institution to complete answering the questions was fixed. How much time exactly needed by a student to answer the questions, was difficult to determine. Therefore they considered the importance and complexity of the question in order to carry the study. The difficulties of questions imply the capability of the students to give the correct answers.

A fuzzy rule-based approach has been applied to model academic performance evaluation of the students. Yadav et al. (2013) studied about fuzzy to implement the use of membership values and clarify whether the decision of the result was helpful to be understood or not. Their objectives were to help the students in the educational processes and improve their academic performance in the future. The data had been classified into five possible outcomes that were Unsatisfactory, Satisfactory, Average, Good and Excellent. Data collected starts from semester 1, semester 2 and semester 3. They designed a fuzzy-rule based system by using the Fuzzy Logic ToolboxTM 2.2.7 by MathWorks.

Kharola et al. (2015) used Mathlab-Simulink model using fuzzy logic toolbox to evaluate performance of the students. The outcomes proved that the advantage of suggested method rather than using traditional average method. They considered focusing more on students' performance instead of attributes that may affect student academic performance. Fuzzy model that had been presented by them closely imitate the performance of traditional average method. Next, further improvement and modification can be used by using fuzzy controllers. The model also can be used to evaluate teachers' performance, employees, faculties and others. They used Stage-wise fuzzy reasoning methodology to reduce issue regarding rule explosion.

A fuzzy Expert System experimented with 20 students' marks that they obtained in semester1 and semester2 examinations. Both inputs had similar Triangular Membership Functions. They suggested using fuzzy logic method for students' academic performance evaluation that used a proper fuzzy inference mechanism and associated rule (Yadav, 2011). Some researchers stated that some students frequently got low grades in their first examination results. Even worst, few of them were dismissed or expelled due to low grades. Ajiboye et al. (2013) stated that they used fuzzy logic to prevent the students from being expelled by forecasting the students' risk status based on certain predictive reasons. Their research had allowed the teachers to focus more on students' weaknesses and helped the management in decision-making by offering scholarships to brilliant students to minimize the risk of failures. While those who obtained low grades, should be motivated and enhanced their studies.

METHODOLOGY

The data collected are from two schools located in Kedah were SMK Bandar Sungai Petani (urban school) and SMK Sungai Layar (rural school). The data consists of the midterm and trial examination Mathematics results of 120 Form 5 students from the science and civil engineering classes. This data used to find out and determine which schools performed better based on Mathematics subjects. The Fuzzy Logic ToolboxTM by MathLab was used to analyze the results.

Fuzzy Logic System

The actual mapping process from a given set of input variables to output depends on a set of fuzzy rules. The general fuzzy system's main process includes fuzzification, fuzzy rule-based, fuzzy inference engine, and defuzzification.

Fuzzification is the first step in the fuzzy inferencing process. Fuzzification is the process of converting a crisp quantity into fuzzy quantity. Once the input, output variables and membership functions are identified, the next stage is to design the rule-based decision matrix. Fuzzy rule-based keeps the input variables and rules before getting the outputs. These rules are expressed in the If-Then form. The fuzzy inference engine is responsible for taking the human feelings, thought, and logical inference to obtain a rational and reasonable result from fuzzy rule-based. The last stage in fuzzy inference system is defuzzification. Defuzzification is the process of converting or transforming the fuzzy output into a crisp output. Figure 1 shows the process of the fuzzy system.

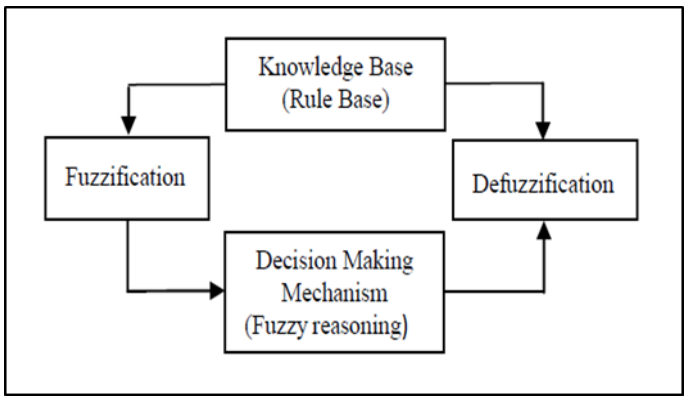

Figure 1: Basic structure of a fuzzy system (Yadav and Singh, 2012)

Fuzzy Logic for Academic Performance Evaluation

In this paper, the two inputs included consist of a midterm examination and trial examination. The output variable is called the school's performance, which is determined by fuzzy logic. Figure 2 shows the Fuzzy Logic for student academic performance evaluation.

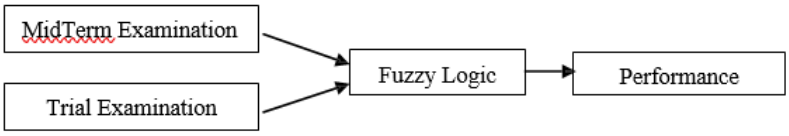

Figure 2: Fuzzy logic for academic performance evaluation

Evaluation of Academic Performance with Fuzzy Logic

Academic performance evaluation with fuzzy logic consists of three steps.

Step 1: Fuzzification of Midterm and Trial examination, trial examination performance value.

Step 2: Determine input and output membership functions in rules and inference process.

Step 3: Defuzzification of performance value.

Step 1: Fuzzification of Midterm and Trial Examination and Performance Value

Fuzzification of examination results was performed using input variables and fuzzy set membership functions. Each school involved in this project had two examination results, both of which came from fuzzy logic input variables. There are five triangular membership functions for each input variable as shown in Table 1, and different types of inputs membership functions are shown in figure 3.

Table 1: Fuzzy set of input variable

Lingusitic Variable	Interval
Very Low (VL)	(0, 0, 25)
Low (L)	(0, 25, 50)
Average (A)	(25, 50, 75)
High (H)	(50, 75, 100)
Very High (VH)	(75, 100, 100)

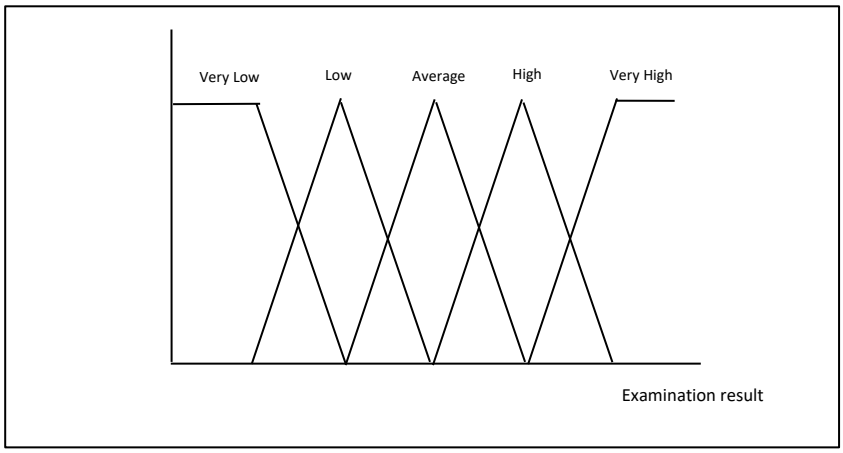

Figure 3: Membership function of midterm and trial examination

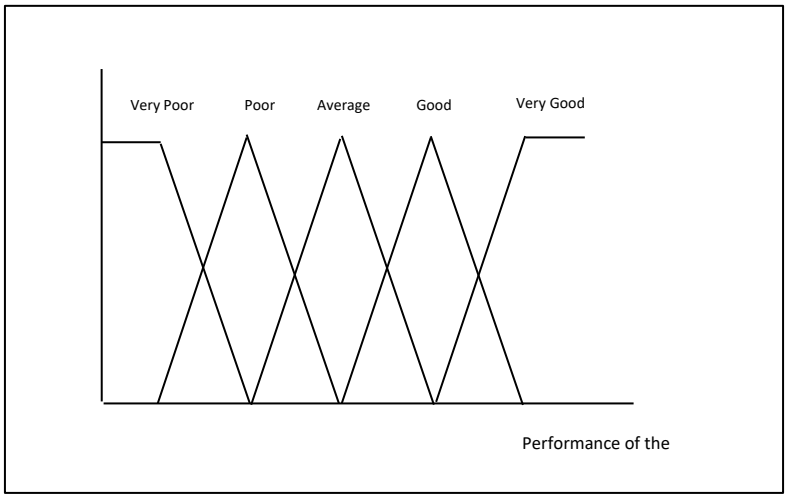

Figure 4 : Membership function of performance of the schools

There are five membership functions for the output attribute, which is the success value. Next, Figure 4 present the five membership function of performance value as an output variable. Table 2 shows the fuzzy set of output variables.

Table 2 : Fuzzy set of output variable

Lingusitic Variable	Interval
Very Poor (VP)	(0, 0, 0.25)
Poor (P)	(0, 0.25, 0.50)
Average (A)	(0.25, 0.50, 0.75)
Good (G)	(0.50, 0.75, 1)
Very Good (VG)	(0.75, 1, 1)

To determine their membership function, insert the range for the linguistic variables for both input and output variables into Mathlab-Simulink. Figure 5 illustrates the examination results based on five linguistic variables: very low, low, average, high, and very high. The school's performance is demonstrated in Figure 6 based on five linguistic variables: very poor, poor, average, good, and very good.

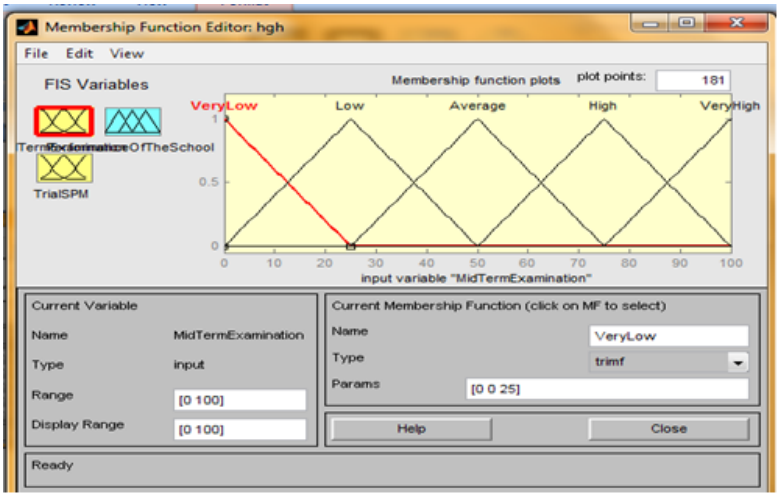

Figure 5: Membership function for result examination

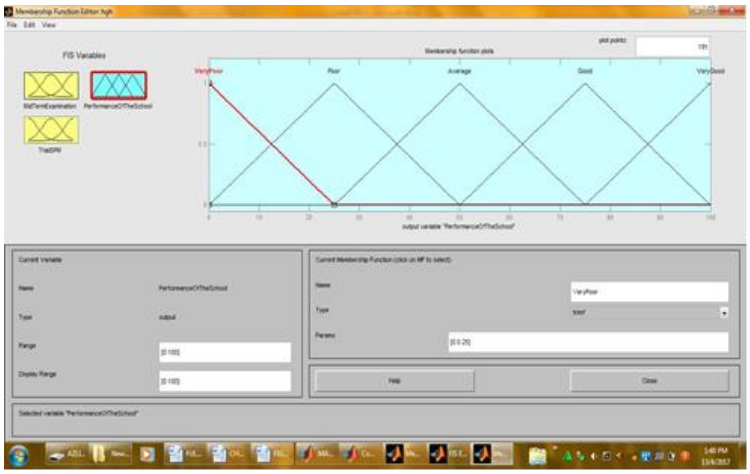

Figure 6: Membership function for performance value

Step 2: Rules and Inference

The rules determine input and output membership functions that will be used in the inference process. These rules are linguistic and are entitled "IF-THEN" RULES:

1. If Midterm is VL and Trial is VL then Performance is VP.
2. If Midterm is L and Trial is VL then Performance is P.
3. If Midterm is A and Trial is VL then Performance is P.
4. If Midterm is H and Trial is VL then Performance is A.
5. If Midterm is VH and Trial is VL then Performance is A.
6. If Midterm is VL and Trial is L then Performance is P.
7. If Midterm is L and Trial is L then Performance is P.
8. If Midterm is A and Trial is L then Performance is A.
9. If Midterm is H and Trial is L then Performance is A.
10. If Midterm is VH and Trial is L then Performance is G.
11. If Midterm is VL and Trial is A then Performance is P.
12. If Midterm is L and Trial is A then Performance is A.
13. If Midterm is A and Trial is A then Performance is A.
14. If Midterm is H and Trial is A then Performance is G.
15. If Midterm is VH and Trial is A then Performance is G.
16. If Midterm is VL and Trial is H then Performance is A.
17. If Midterm is L and Trial is H then Performance is A.
18. If Midterm is A and Trial is H then Performance is G.
19. If Midterm is H and Trial is H then Performance is G.
20. If Midterm is VH and Trial is H then Performance is VG.
21. If Midterm is VL and Trial is VH then Performance is A.
22. If Midterm is L and Trial is VH then Performance is G.
23. If Midterm is A and Trial is VH then Performance is G.
24. If Midterm is H and Trial is VH then Performance is VG.
25. If Midterm is VH and Trial is VH then Performance is VG.

If some rules are active for the same output membership function, only one membership value must be chosen. This method is called "fuzzy decision" or "fuzzy inference". In this paper, the method proposed by Mamdami, is given below:

$$\mu_c(y) = \max_k[\min[\mu_A(input(i), \mu_B(input(j))]], \qquad k = 1,2,3,4 \dots r \qquad (1)$$

This expression decides an output membership function value for every active rule. While one rule is active, an AND operation is used connecting inputs. The smaller input value is selected and its membership value is decided as membership value of the output for that rule. This procedure is continued, so that output membership functions are verified for every rule. To conclude, AND (min) operations are used between inputs and OR (max) operations are used between outputs.

Step 3: Academic Performance Evaluation with Fuzzy Logic

Once completing the fuzzy decision process, the fuzzy number acquired have to convert to a crisp value. This process is known as Defuzzification. Many techniques have been developed for Defuzzification. In this paper, a centre of area called Centroid method was used.The crisp value is computed using the formula given:

$$z = \frac{\int u_c(z) \times x \times dz}{\int u_c(z) \times dz} \quad (2)$$

RESULTS

In this paper, the application of Fuzzy Logic for students' Mathematics performance evaluation had been implemented in MATLAB (version 7.6). Fuzzy Logic ToolBox has been used for this research work. The proposed Fuzzy Logic was analyzed based on 60 students' marks from both schools obtained from their midterm and trial SPM examinations. Based on the data, the student's performance value and performance according to their school are calculated, then clusters them into their classes based on random data. 120 students were clustered into five classes which are Very Good, Good, Average, Poor and Very Poor.

Both examination scores were fuzzified by means of the triangular membership functions for each student. Active membership functions, using the Mamdami Fuzzy Decision Techniques, were determined according to the rule table. By measuring the centre (centriod) of the resulting geometric shape, the output (performance value) was measured and then defuzzified. This series was replicated for each student using the Midterm and Trial Mathematics scores.

Both inputs had same Triangular Membership Functions. For example, let's take the calculated midterm and trial performance 90 and 79. The result shows performance value is 0.797, close to 1. It shows that the more the performance value is close to 1, the better is the result. Figure 7 shows the membership functions for the example given, while Figure 8 shows the surface viewer for students' Mathematic performance evaluation.

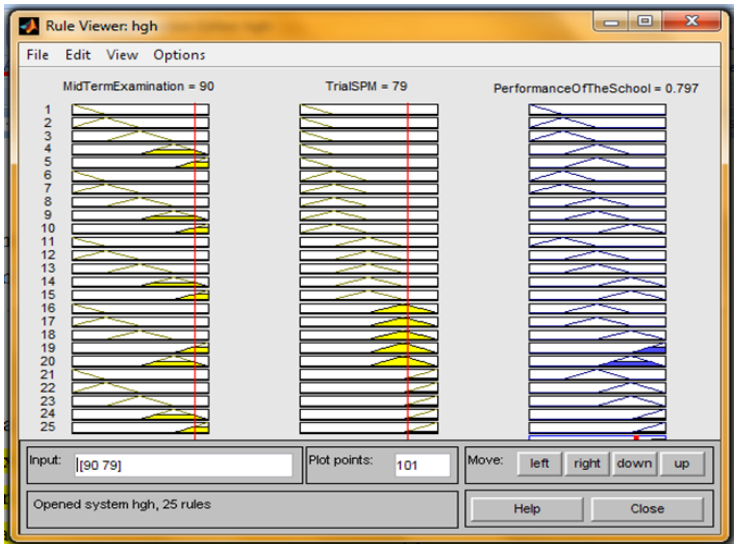

Figure 7: Performance value for Mathematic scores of 90 and 79

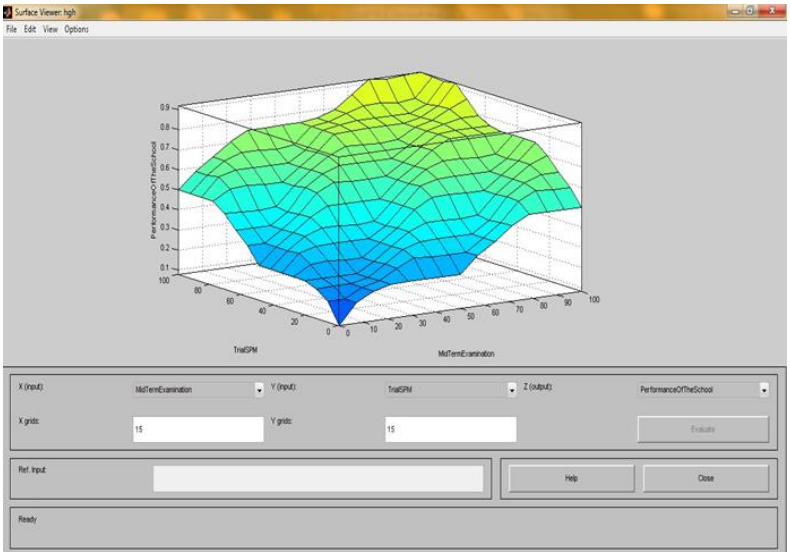

Figure 8: Surface viewer of Mathematics performance evaluation

Table 3 and Table 4 show the classification of student's mathematics performance for both schools.

Table 3: Result overall for SMK Bandar Sungai Petani

Average Percentage Mathematics Performance Value	**71.32 %**
Very Good	0 student
Good	38 student
Average	21 student
Poor	1 student
Very Poor	0 student

Table 4: Result overall for SMK Sungai Layar

Average Percentage Mathematics Performance Value	**62.04 %**
Very Good	1 student
Good	19 student
Average	30 student
Poor	10 student
Very Poor	0 student

Fuzzified was applied to generate the output. The average percentage for the performance value was used to compare the result. The average used because the method is easy to understand for plotting and comparing data (Jawahar and Seema, 2009). Table 3 and 4 show that students from urban school performed better than students from rural school. The percentage of mathematics value for SMK Bandar Sungai Petani is higher than that of SMK Sungai Layar by 9.28%.

The number of students from urban school that got a Good score is 38, which was double the number of students from rural schools that only had 19 students getting similar scores. Information from Table 3 also shows that 21 of the students from urban school achieved an average score while one of them achieved a low score. However, from Table 4, 30 students achieved an average score while ten students scored low results. This category of students deserves special attention so that they can cope well with their studies. Generally, cases with values above 0.5 defuzzied value have satisfactory academic achievement, while cases with values less than 0.5 need to do extra work and efforts to meet the challenges ahead.

CONCLUSION

This study aims to determine which schools between rural and urban schools perform better in mathematics subjects and classify students' performance based on Mathematics subject using fuzzy application. During the evaluation of students', the result's from urban school and rural school, the urban school were discovered to have great flexibility and reliability in Mathematics subject. The defuzzied or the performance value obtained from the midterm and trial examination result from each student shows the students' performance according to Mathematics subject. It means that by using fuzzy application, the students can be classified according to their performance. Using these results, students with low achievement should get more attention and extra practices and work.

Gaps or variations in outcomes can be seen between urban and rural schools during the fuzzy logic process. Both schools used the same membership features in this article, although their mid-term and trial examination as an input variable and performance value as output variables were used. In conclusion, the performance assessment using fuzzy logic is not only relevant for the subject of mathematics, but can also be extended to the performance assessment of theoretical lessons by students such as history and geography subjects.

RECOMMENDATION

For a recommendation to future researchers, they can combine the methods between fuzzy logic and artificial neural networks, named Neuro-Fuzzy Systems to get better results and evaluate students' performance. These techniques can be applied to other subjects too.

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