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Fuzzy Logic to Evaluate Significant Factors Affecting Students' Academic Performance Through Online Distance Learning

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HIGHLIGHTS

- Fuzzy logic was used to evaluate the factors that affect students' academic performance through online distance learning.
- Respondents are students from Universiti Teknologi MARA who experienced online distance learning.
- The MATLAB Fuzzy Inference System editor was used as a tool to conduct a comprehensive analysis.

ABSTRACT

Online distance learning is becoming more and more popular and more preferred among students. In order to develop efficient strategies and solutions for introducing online distance learning, higher education institutions should be aware of the needs and expectations of their students. In the current study, students from University of Technology MARA will investigate which factors that affect the execution of online distance learning for academic performance. Time management, learning environment, internet connection, and learning method are among the factors under consideration, as determined by a literature review. The information was gathered through an online survey of 331 students whose academic performance is affected by online distance learning. An expert system based on fuzzy logic has been developed to determine which factors have the greatest influence on students' academic performance in online distance learning. According to the results obtained using the MATLAB software, one of the most important factors influencing students' academic performance in online distance learning is time management. The findings of this study will help students to improve time management in order to improve students' academic performance.

Keywords: *online distance learning, students' academic performance, fuzzy logic, time management*

INTRODUCTION

Typically, in Malaysia's higher schools, Hijazi and Naqvi (2006) argued there is a growing trend of falling grades. The deteriorating academic performance of students is therefore the problem that seeks solutions. This study analyses the factors that affect academic performance. It also looked at possible factors that affect the academic performance of students to a certain degree. In previous studies, solutions that could help solve problems could be suggested.

The classroom instruction Sun (2010) revealed has a certain influence upon the performance of students. More time was spent presenting lectures as an important determining factor which affects the performance and quality of teachers (Schwerdt & Wuppermann, 2008). Basile and D'Aquila (2002) have determined that technology has helped to teach a positive study attitude leading to higher qualifications. George et al. (2008) found that good timing can reduce stress and improve academic performance. Good time management practices can be central and strategies for improving the effective use of time are often recommended as a contribution to improving students' performance (Misra & McKean, 2000).

According to the study by Anand (2007), the internet connection has an adverse impact on students. These studies are based on studies conducted by scientists on the connection to the Internet and which give students from rural countries an impact on their performance. It is also the result of research by Kubey et al. (2001), that the decline in the academic performance of college students is due to the use of synchronous contacts such as chats, allowing students to remain at night late and to decrease their academic performance. Accordingly, the internet connection can influence academic performance. Social media affects the university performance of students (Asemah et al., 2012). At the same time, Shakir Ullah et al. (2014) shows that the facts about electronic media can educate the public, make it clear, and help students better than anyone else.

In connection with this study, Williams et al. (2008) reported that safe and proper classroom conditions (aspect of education) and school facilities (accessories) were very significantly related to academic achievements in schools. The report states that this study is related to international occurrences. The three researchers, Glassman (1994), also quoted, argued that a comfortable, caring environment among other treatments contributed to the academic performance of students. There are several effects on teachers, students, and the learning process on the physical properties of the school. Poor lighting, noise, high carbon dioxide in classrooms and inconsistent temperatures make it difficult to teach and learn. Poor maintenance and inefficient systems of ventilation lead to poor health for students and teachers, resulting in poor performance and higher absentee rates (Frazier, 2002).

Increasing integration of mobile technology has led instructors to take on their role in assisting and generating innovative learning methods for students from afar. The increase in mobile technology integration has led teachers to play their part in helping students from afar and generating innovative learning methods. Some students have a severely deficient degree of mobile-assisted learning supplemented with tutoring and speech. Kent (2013) discovered that students use the social media platform through mobile learning, such as Blackboard discussions and Facebook, to post content and encourage discussions. This work has a significant effect on the self-reporting and academic outcomes of students. Their full potential and capacity building are therefore not possible for the students. Content delivery is still deficient, although the content is perfectly designed. Students cannot ask questions and participate actively in virtual learning. Teachers who can stimulate students to get the best understanding of the lesson can address the problems (Mazzolini & Maddison, 2007).

METHODOLOGY

Method of Data Collection

Primary data was gathered using a Google form questionnaire that was distributed via social media. Two parts of the questionnaire apply the procedure for this analysis. Section A provides a summary of population variables, including gender, age, university, and faculty. While section B includes the modified e-learning scale. The focus group of the analysis is the 331 current students from Universiti Teknologi MARA (UiTM) with various programmes and faculty. Closed questions with multiple answers yielded answers. The data can only be considered if the respondents have completed at least six months of online distance learning

that affect student academic performance. The received data were filtered before being used to build the model.

Fuzzy System Design

The fuzzy logic was used to develop a system of experts to assess which factors affect students' academic performance on online distance learning. MATLAB software was used as a tool for using the fuzzy system to evaluate the factors. It consists of two concepts for the design of a fuzzy system. The first was a linguistic variable, and the second was a fuzzy IF-THEN rule base. The main part of the system was the decision making using Fuzzy Inference Systems (FIS). FIS is a mechanism for the assessment of input value computing fuzzy systems. In essence, FIS formulates the right decision-making rules. Figure 1 depicts the structure of a fuzzy system.

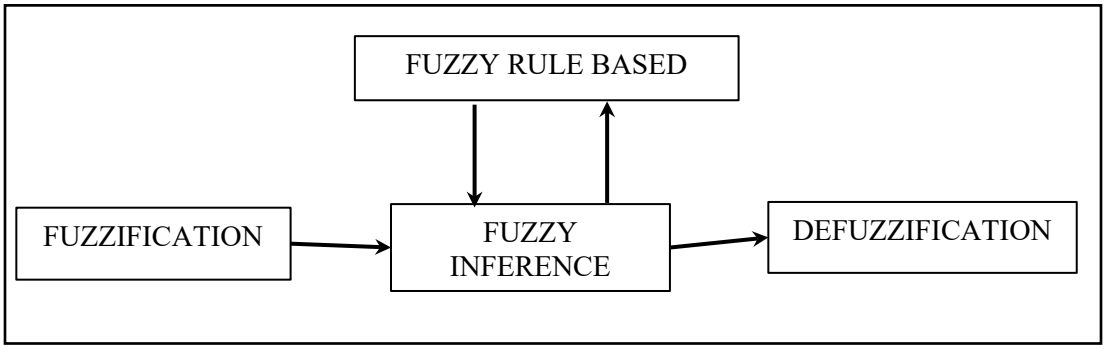

Figure 1: Structure of a fuzzy system

The membership function for input and output in the fuzzy model are shown in Table 1. The input membership functions have been used for fuzzification, while the output membership functions have been used for defuzzification. Gaussian and triangular membership functions are often used as membership functions in a fuzzy logic system.

Table 1: Information of membership functions for input and output in the fuzzy model.

	Variables	Types of Membership function
Inputs	Time Management	Gaussian
	Learning Environment	Gaussian
	Internet Connection	Gaussian
	Learning Method	Gaussian
Output	Student Academic Performance	Triangular

Fuzzification

Fuzzification represents the conversion into a fuzzy value of a true scalar value. A fuzzification is used in a set of input values to determine the level of membership for each value. The procedure starts with the definition of each input variable using membership sets based on the equation 1:

$$f(x, c, \sigma) = e^{-\frac{(x-c)^2}{2\sigma^2}} \quad (1)$$

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In the following equation, x is the input variable, c is the center while σ is the width.

Fuzzy sets consist of a linguistic form and membership value. The following linguistic variables for all input variables are used in Table 2 and the gaussian membership function with a bell-shaped distribution is defined in Figure 2.

Table 2: Fuzzy set input of factors

Linguistic Variable	Symbols
Low	L
Moderate	M
High	H

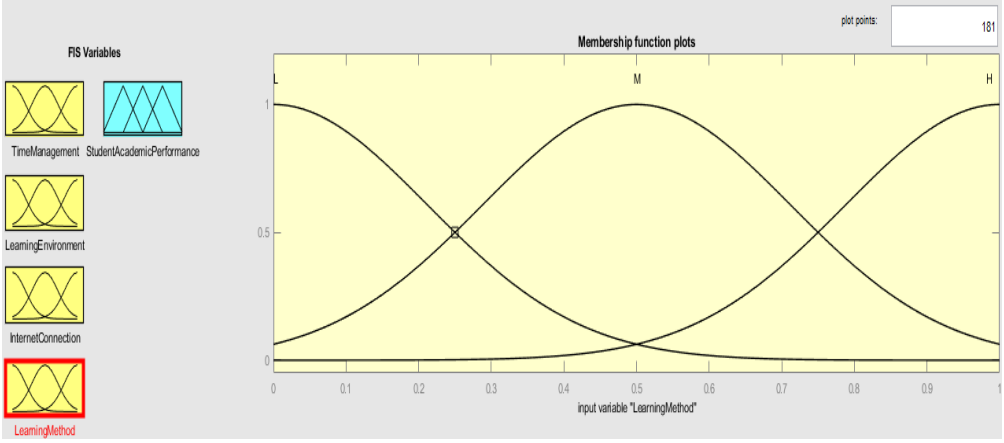

Figure 2: Gaussian membership function.

Membership function in Fuzzy Logic for four inputs is represented as follows:

i. Low

$$\mu_L(x) = \left\{ e^{-\frac{x^2}{50}}, 0 \leq x \leq 10 \quad 0 \quad , otherwise \right\}$$

ii. Moderate

$$\mu_M(x) = \left\{ e^{-\frac{(x-5)^2}{50}}, 0 \leq x \leq 10 \quad 0 \quad , otherwise \right\}$$

iii. High

$$\mu_H(x) = \left\{ e^{-\frac{(x-10)^2}{50}}, 0 \leq x \leq 10 \quad 0 \quad , otherwise \right\}$$

Fuzzy Inference

The input and output membership functions relate to fuzzy inference rules. The inference engine consists of a basis of knowledge and rules for generating output. "IF-THEN" statements are used in the linguistic

rules to formulate conditional statements consisting of the fuzzy logic. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion.

Two methods are available in the FIS: the Mamdani method and the Sugeno method. Sugeno is good for mathematical analyses, while Mamdani is good for human input. In this research, the Mamdani model is used to determine the output of membership function in each rule to interpret the human perception. The structure of the Mamdani is as follows:

IF x_1 is A_{i1} and x_2 is A_{i2} …….. and x_n is A_{in}, THEN y is C_i (2)

where x_j ($j = 1,2, \ldots, n$) are the input variables, y is the output variable and A_{in} and C_i are fuzzy sets for x_j and y.

There are four inputs with three linguistic expressions and one output with five linguistic expressions for this study. Based on data from 331 respondents, a total of 12 sub-factors are derived from the four main factors, with each main factor containing three sub-factors. The main factors and subfactors of the expert assessment system are shown in Table 3.

Table 3: Main factors and subfactors used in the expert assessment system

	Main Factors	**Sub-Factors**
Input	Time Management	1. This online distance learning provides divided time. 2. This online distance learning provides a structured schedule. 3. This online distance learning provides enough rest.
	Learning Environment	1. This online distance learning provides a calm environment. 2. This online distance learning is not disrupted during lessons. 3. This online distance learning provides a place to study.
	Internet Connection	1. This online distance learning is suitable for all areas. 2. This online distance learning provides data that does not deplete. 3. This online distance learning is suitable for all weather conditions.
	Learning Method	1. This online distance learning provides an additional note from another website. 2. This online distance learning provides a self-study method. 3. This online distance learning provides an understanding of the method.
Output	Student Academic Performance	

The data collected from this group are used in the fuzzy logic-based evaluation model. Mamdani modelling used to determine the output membership functions of each rule for fuzzy inferences and fuzzy decision-making.

Defuzzification

The total result is a fuzzy value when the fuzzy rule-based system is applied to MATLAB software's fuzzy logic toolbox. The defuzzification step must be implemented to achieve the final crisp output from the overall result.

The defuzzification process transforms the fuzzy output into a crisp output. For any type of fuzzy set, the most common defuzzification method is a centroid. The centre of the area is called the centroid method and the formula for the centroid method is provided below:

$$z = \frac{\int \mu_C(x).xdx}{\int \mu_C(x).dx} \quad (3)$$

where z is the crisp output, μc is the aggregated membership function, while x is the output variable. After each unit has been tested, all units established during the implementation stage are integrated into the system. In order to reveal the factors that affect students' academic performance, the results of the defuzzification stage are then used.

The output variable is assigned to the triangular membership function defined by the lower limit a, upper limit c, and value b for the linguistic variables, where a < b < c, as shown below:

$$f(a,b,c) = \left\{0, \quad x \le a \ \frac{x-a}{b-a}, \ a \le x \le b \ \frac{c-x}{c-b}, \ b \le x \le c \quad 0, \ otherwise \right\} \quad (4)$$

Table 4 shows the linguistic variables for the output variables used which are very low, low, moderate, high, and very high with their symbol and Figure 3 illustrates the membership function for the output of the factors that affect students' academic performance on online distance learning.

Table 4: Fuzzy set output of degree of student academic performance.

Linguistic Variable	Symbol
Very Low	VL
Low	L
Moderate	M
High	H
Very High	VH

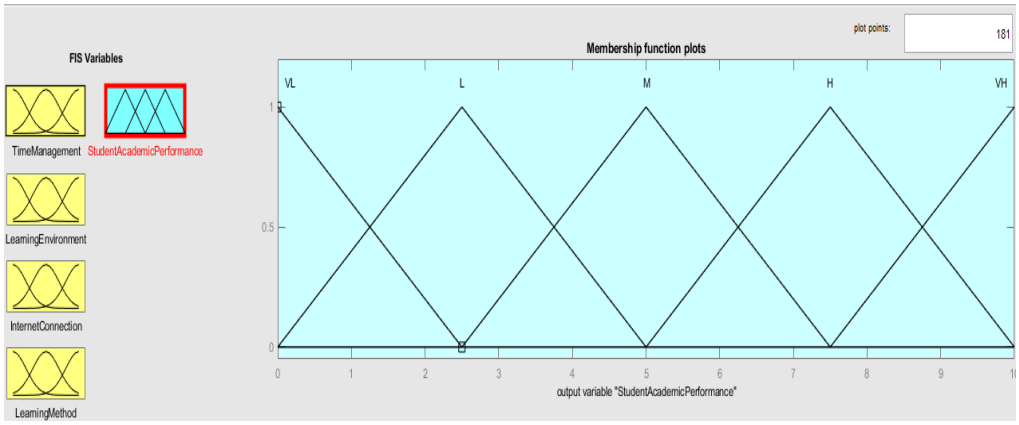

Figure 3: MATLAB-membership function of student academic performance

Membership function in Fuzzy Logic for output is represented as follows:

(i) Very Low

$$\mu_{VL}(y) = \left\{\frac{2.5-y}{2.5},\ 0 \le y \le 2.5\ 0,\ otherwise\right\}$$

(ii) Low

$$\mu_{L}(y) = \left\{\frac{y}{2.5},\ 0 \le y \le 2.5\ \frac{5-y}{2.5},\ 2.5 \le y \le 5\ 0,\ otherwise\right\}$$

(iii) Moderate

$$\mu_{M}(y) = \left\{\frac{y-2.5}{2.5},\ 2.5 \le y \le 5\ \frac{7.5-y}{2.5},\ 5 \le y \le 7.5\ 0,\ otherwise\right\}$$

(iv) High

$$\mu_{H}(y) = \left\{\frac{y-5}{2.5},\ 5 \le y \le 7.5\ \frac{10-y}{2.5},\ 7.5 \le y \le 10\ 0,\ otherwise\right\}$$

(v) Very High

$$\mu_{VH}(y) = \left\{\frac{y-7.5}{2.5},\ 7.5 \le y \le 10\ 0,\ otherwise\right\}$$

FINDINGS AND DISCUSSIONS

Result from Extracted Rules Base

1. Identify the linguistic variables that have been updated.

The updated linguistic variable for each input factor. The four key factors are time management (TM), learning environment (LE), internet connectivity (IC) and learning method (LM). There are three sub-factors for each main factor and different linguistic variables may exist for each sub-factor. The new data have been collected on the base of three sub-factors to emphasize how students' academic performance affects these factors. The updated linguistic variable is created as shown in Table 5.

Table 5: Obtaining the updated linguistic variable.

Respondent 1	TM			LE			IC			LM			Output
	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Moderate
Response	M	L	L	M	L	M	M	M	M	M	L	M	
Updated Data	Low			Moderate			Moderate			Moderate			

2. Combine input and output variables to form a rule base.

Input and output variables are combined in order to create an "IF-THEN" rule base. The questionnaire provided the output variable, while the first step shows the updated linguistic variable, the input variable. Table 6 displays the input and output obtained from Respondent 1 in Table 5.

Table 6: Simplification of the updated linguistic variable and form of rules base.

IF	TM	AND	LE	AND	IC	AND	LM	THEN	Output
	L		M		M		M		Moderate

*The rules base was formed this way: **IF** Time Management "Low" and Learning Environment "Moderate" and Internet Connection "Moderate" and Learning Method "Moderate", THEN Output is "Moderate".*

3. Select the rules based on the highest number of respondents selected.

Table 7: Overall results from the responses of respondents.

Rule	IF	TM	AND	LE	AND	IC	AND	LM	THEN	Output	Total
1		H		M		L		L		H	2
2		H		M		M		M		H	2
3		H		L		L		M		H	2
4		H		M		M		L		M	4
5		H		L		L		L		VH	1
6		M		M		M		L		H	14
										VH	2
										M	4
7		M		L		M		M		H	8
										VH	1
										M	5
8		M		L		L		M		VH	3
										M	12
										H	8
9		M		M		L		M		H	24
										VH	2
										M	20
10		M		M		M		M		M	11

										H	15
11		M		M		L		L		M	5
										H	13
12		M		L		L		L		H	10
										M	13
13		M		L		L		H		M	2
14		M		L		M		L		M	6
										H	3
15		L		M		L		L		M	6
										H	11
										VH	1
16		L		L		M		L		H	8
										M	3
17		L		L		L		M		H	15
										VH	2
										M	14
18		L		M		M		M		M	8
										H	10
										VH	2
19		L		M		L		M		VH	3
										H	16
										M	8
20		L		L		M		M		M	5
										H	4
21		L		L		L		L		H	6
										VL	7
22		L		M		M		L		M	4
										H	6
										Total	331

Only 22 unique rules base are generated from a total of 331 respondents. Table 8 displays the simplified rules base based on the respondents' highest responses from Table 7.

Table 8: Extracted rule base

Rule	IF	TM	AND	LE	AND	IC	AND	LM	THEN	Output
1		H		M		L		L		H
2		H		M		M		M		H
3		H		L		L		M		H
4		H		M		M		L		M
5		H		L		L		L		VH
6		M		M		M		L		H
7		M		L		M		M		H
8		M		L		L		M		M
9		M		M		L		M		H
10		M		M		M		M		H

11		M		M		L		L		H
12		M		L		L		L		M
13		M		L		L		H		M
14		M		L		M		L		M
15		L		M		L		L		H
16		L		L		M		L		H
17		L		L		L		M		H
18		L		M		M		M		H
19		L		M		L		M		H
20		L		L		M		M		M
21		L		L		L		L		VL
22		L		M		M		L		H

Overall Evaluation of the Factors that affect Students' Academic Performance

The combination of the inputs and outputs of the extracted rules base as shown in Table 8 and it can produce a correlation between the input and the output using MATLAB. The illustration of the relationship between input and output is critical in explaining how online distance learning affects students' academic performance. The interdependence of students' academic performance and four key factors are shown in Figures 4, 5, 6 and 7. These curves represent students' academic performance with respect to factors in online distance learning.

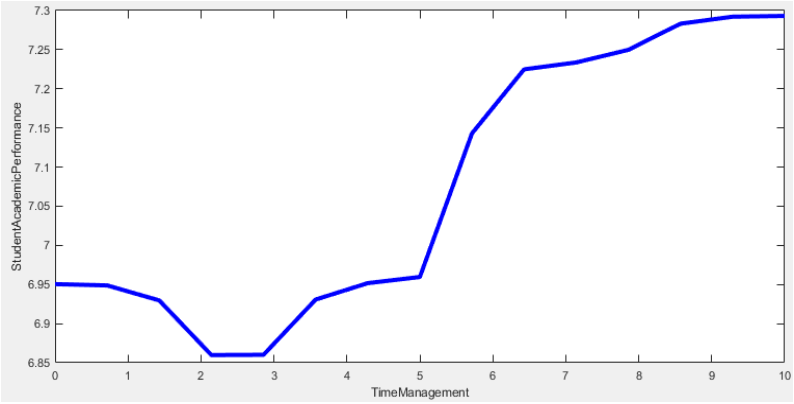

Figure 4: Students' academic performance for time management.

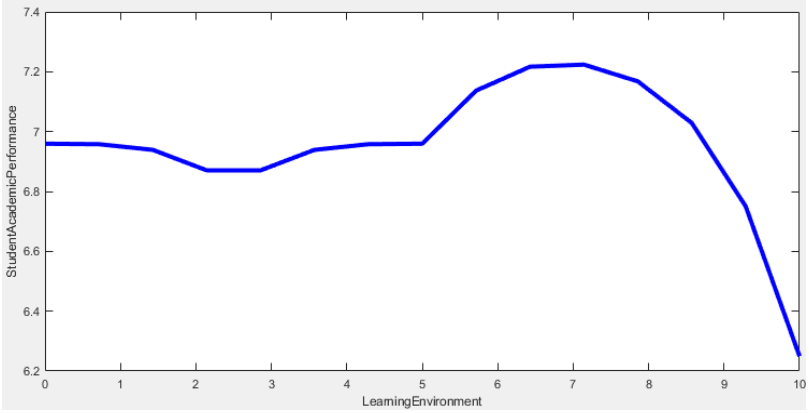

Figure 5: Students' academic performance for learning environment.

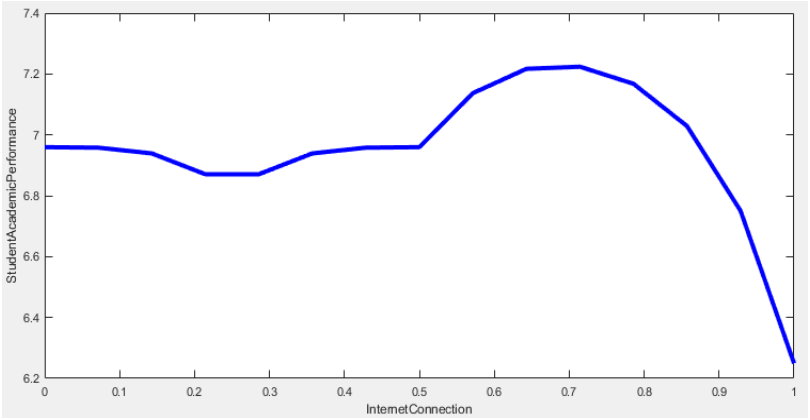

Figure 6: Students' academic performance for internet connection.

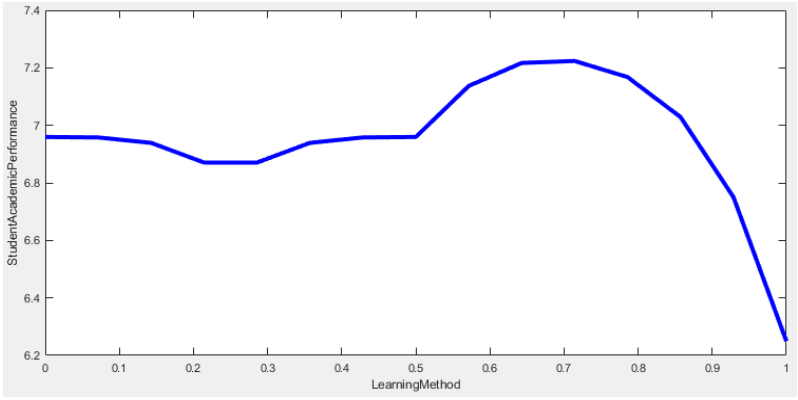

Figure 7: Students' academic performance for learning method.

Table 9: Final assessment weight for the factors that affect students' academic performance on online distance learning.

Factors	Maximum Weight
Time Management	7.30
Learning Environment	7.21
Internet Connection	7.21
Learning Method	7.21

Table 9 shows the maximum weight of students' academic performance for time management, learning environment, internet connection, and learning method, which are 7.30, 7.21, 7,21, and 7.21. If the curves are examined and the rules of time management can be found to have a greater impact on students' academic performance than other factors with the same maximum weight which are the learning environment, the internet connection, and the learning method. It shows that online distance learning with satisfying time management has the biggest impact on students' academic performance as compared to the other factors.

CONCLUSION AND RECOMMENDATIONS

To evaluate the four factors, a fuzzy logic assessment system was developed using its FIS. For all input variables the FIS model used gaussian membership functions, while triangular output models were used. The extracted rules base was found to be used in the FIS. Fuzzy logic can estimate the factors which affect the academic performance of students in online distance learning, as expert results show. The results also indicated that time management is greater than other factors, with a maximum level of about 7.30 that affects students' academic performance on online distance learning.

Several recommendations for future studies are proposed. First, consider including an additional input variable in the assessment of online distance learning to reflect factors influencing students' academic performance. Next, increase the number of participants in the study to obtain a larger sample size for more accurate analysis of correlations impacting academic performance in online distance learning. Lastly, encourage future researchers to investigate the relationship between these factors and the academic performance of tertiary education students.

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CONFLICT OF INTEREST DISCLOSURE

All authors declare that they have no conflicts of interest to disclose.

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