Implementation of Mamdani Fuzzy Logic in The Assessment System of Merdeka Belajar Kampus Merdeka (MBKM) Activities: Case Study of Mathematics Study Program at Bangka Belitung University

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***Abstract*— This study aims to apply Mamdani fuzzy logic in the assessment system of the Merdeka Belajar Kampus Merdeka (MBKM) activity to evaluate the effectiveness of student participation. This study was conducted on students of the Mathematics Study Program, Bangka Belitung University, class of 2021, involving four aspects of assessment: teamwork, basic skills, problem solving, and technological innovation. The method used is a descriptive quantitative approach with data processing using MATLAB software. Each input variable is converted into a fuzzy value through triangular and trapezoidal membership functions, followed by the preparation of if-then rules, Mamdani inference, and defuzzification using the centroid method. The results of the analysis show that the fuzzy system is able to produce an objective final assessment and in accordance with the assessor's policy, where students with dominant values at a high level get a final score of 83.7 and are categorized as "good". This study proves that Mamdani fuzzy logic is effective as a tool in the evaluation process of MBKM based on soft skills and hard skills in a comprehensive and measurable manner.**

Keywords*— *Mamdani Fuzzy Logic, MBKM, Assessment System, MATLAB, Defuzzification

I. INTRODUCTION

The transformation of higher education in Indonesia has experienced quite rapid acceleration since the introduction of the Merdeka Belajar Kampus Merdeka (MBKM) policy from the Ministry of Education and Culture. This policy provides students with the opportunity to study outside their study program for three semesters, with the aim of improving the quality of graduates so that they are better prepared to adapt and meet the demands of the industrial world and global society [1] [2]. Through MBKM, students are expected to gain a more flexible learning experience that is in line with the real-world context, through activities such as internships, teaching in schools, research, and humanitarian projects [3] [4].

Since the launch of the Merdeka Belajar Kampus Merdeka (MBKM) policy, the participation of students and universities in Indonesia has increased significantly. By the end of 2023, more than 1.2 million students and 5,200 industry partners have been involved in the Kampus Merdeka platform, which now covers more than 1,000 universities across Indonesia [5] [6]. One of the flagship programs, the Magang dan Studi Independen Bersertifikat (MSIB), has successfully involved more than 36,000 students from 800 campuses in its fifth batch in 2023, with support from 222 companies across sectors. Meanwhile, the sixth batch of the Kampus Mengajar program recorded the highest number of registrants in its history, with more than 43,000 participants registering [6] [7]. This achievement shows the high enthusiasm of all stakeholders in the world of higher education towards MBKM, while also illustrating the great potential for educational transformation in Indonesia towards a more adaptive system that is oriented towards direct experience.

However, the implementation of the MBKM program in the field still faces several challenges, especially in assessing the performance and learning achievements of the students involved. The variety of MBKM activities that are very diverse and contextual make the assessment process not easy. Creating a fair, objective, and consistent evaluation system between various types of activities is quite a complicated job [8] [9]. Evaluation approaches that still rely on traditional logic are often not flexible enough to capture the complexity and uncertainty in assessing non-academic aspects such as the level of participation, creativity, and soft skills of students [10] [11].

Fuzzy logic, especially the Mamdani method, has been

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widely used as an alternative approach to evaluate subjective and uncertain matters. This method allows for a decision-making process based on natural language and if-then rules that are more flexible and contextual [12] [13]. Several studies have shown that Mamdani fuzzy logic is able to provide a more comprehensive and human-oriented assessment, both in the fields of education, human resource management, and project management [14] [15].

In the world of higher education, fuzzy logic has been utilized for various purposes, from assessing lecturer performance, evaluating the quality of online learning, to determining the feasibility of students' final assignments [16] [17]. However, its use specifically to assess MBKM activities is still relatively minimal. Research by Utti and colleagues (2024), which is one of the main references, shows that Mamdani fuzzy logic has great potential in designing an MBKM assessment system that considers many aspects and is based on expert evaluations. However, the study is still limited to certain cases and has not made a comparison with other assessment approaches that are also relevant.

The gap in current research lies in the unavailability of a general and flexible MBKM assessment model for use in various study programs. In addition, aspects of model validation and sensitivity analysis of fuzzy parameters are also rarely explored in depth [18]. This study aims to conduct a comprehensive literature review related to the application of Mamdani fuzzy logic in the MBKM activity assessment system, as well as to identify the main parameters, rule structures, and inference methods used in previous studies.

This study aims primarily to evaluate and summarize the findings of previous studies that discuss the use of Mamdani fuzzy logic in educational assessment, especially within the MBKM framework. In addition, this study also seeks to uncover the challenges and opportunities in its wider application in the future. Thus, this study not only addresses the gaps in the literature but also becomes an important basis for the development of a more humane educational evaluation system supported by artificial intelligence technology.

This study aims to develop a Mamdani fuzzy logic-based assessment model by referring to established concepts in educational evaluation. Rather than using a separate literature review section, relevant theories and prior studies are integrated throughout the manuscript to support model development within the MBKM framework.

II. Research Methods

This study uses a descriptive quantitative approach with the aim of evaluating the assessment of the Merdeka Belajar Kampus Merdeka (MBKM) activities, especially using the Mamdani fuzzy logic approach. The main focus of this study is to develop a fuzzy logic-based assessment system to measure the level of effectiveness of student participation in MBKM activities.

A. Types and Approaches of Research

This type of research is included in quantitative research with a descriptive approach, which aims to describe the results of student assessments of the MBKM program based on linguistic input such as "good", "sufficient", "very good", and so on. The input is then processed using the Mamdani fuzzy logic system. This approach was chosen because it is able to manage qualitative data in linguistic form and convert it into numeric information that can be measured.

B. Population and Sample

The population in this study includes all students of the 2021 intake from the Mathematics Study Program, Bangka Belitung University who have participated in at least one activity in the MBKM program, such as internships, independent projects, campus teaching, and others. The research sample was taken using a purposive sampling technique, with a total of 25 students selected based on their active involvement in MBKM activities.

C. Data Collection Technique

Data collection in this study was carried out through a closed questionnaire or questionnaire arranged in the form of a 5-point Likert scale, with statements that measure several aspects of MBKM activities, such as:

- Teamwork
- Basic Skills
- Problem Solving
- Technological Innovation

The questionnaire was distributed online via Google Form, then the results were compiled and analyzed using the Mamdani fuzzy logic system.

D. Mamdani Fuzzy Logic

In addition to being represented in the form of ordered pairs, fuzzy sets can also be represented through membership functions. A membership function is a mapping that associates each element in a set with a particular membership value. Some common forms of fuzzy membership functions include linear increasing functions, triangular functions, and linear decreasing functions. The linear increasing function describes a gradual increase in membership values from low to high levels. The mathematical equation of the linear increasing membership function in a fuzzy set can be described through the following equation:

$$\mu(x) = \begin{cases} 0; x < a \\ \dfrac{x-a}{b-a}; a \le x \le b \\ 1; x \ge b \end{cases} \qquad (1)$$

The membership function with a linear decreasing form describes a condition where the membership value starts from a high level and then decreases gradually. The form of a fuzzy set that uses a membership function like this can be explained through the following mathematical equation:

$$\mu(x) = \begin{cases} 0; x > b \\ \dfrac{b-x}{b-a}; a \le x \le b \\ 1; x \le a \end{cases} \qquad (2)$$

The triangular membership function is formed from a combination of an increasing linear function on the left side and a decreasing linear function on the right side, forming a peak

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pattern in the middle. Fuzzy sets with this function have a triangular graphic shape and can be mathematically formulated as follows:

$$\mu(x) = \begin{cases} 0; x < a \\ \dfrac{x-a}{b-a}; a \leq x \leq b \\ \dfrac{c-x}{c-b}; b \leq x \leq c \\ 0; x > c \end{cases} \quad (3)$$

E. Data Analysis Technique

This research began with a literature review to gain an in-depth understanding of the basic principles of fuzzy logic, especially the Mamdani method, and its application in evaluation systems in the field of education. After the theoretical understanding stage was completed, the process continued by analyzing the data obtained through student questionnaires. The data collected from the student questionnaires were first converted from numerical Likert scale values (ranging from 1 to 5) into linguistic categories. The classification was carried out as follows: a score of 1 was categorized as 'very low', 2 as 'low', 3 as 'sufficient', 4 as 'good', and 5 as 'very good'. This mapping allowed the conversion of quantitative inputs into fuzzy linguistic values suitable for fuzzification using the Mamdani method. Each category was then mapped into a triangular or trapezoidal fuzzy membership function.

The next analysis process was carried out using MATLAB software, especially through the Fuzzy Logic Toolbox feature. The analysis steps include:

- Fuzzification: The Likert scale values from the questionnaire were converted into fuzzy values using membership functions.
- Rule Base: A number of IF-THEN logic rules were compiled to combine various MBKM assessment variables.
- Mamdani Fuzzy Inference: MATLAB runs the inference process based on the Mamdani method, processing existing rules to determine fuzzy output.
- Defuzzification: The resulting fuzzy values are converted back into numeric numbers using the centroid method, to obtain the final score of MBKM effectiveness from each respondent.

The final results of this analysis are then discussed descriptively to see the distribution of the effectiveness of student participation in the MBKM program. MATLAB also provides visual displays such as surface graphs, rule diagrams, and membership curves that help clarify the overall interpretation of the results. The flowchart of this research can be seen in Figure 1. below.

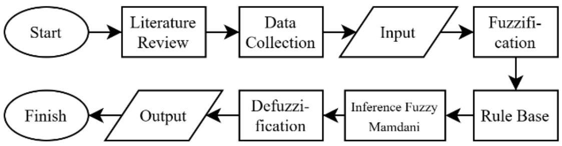

Fig.1. Research Flow Chart

III. Results and Discussion

Before determining the input and output variables in the fuzzy set, the first step that needs to be taken is to design an assessment rubric. This rubric includes assessment elements along with the value range for each component. In this study, the preparation of the rubric was carried out through a mapping process between courses and graduate learning outcomes (LO). The courses referred to here refer to courses taken in the current semester according to the semester taken by students participating in the MBKM program. From the results of the mapping between courses and graduate learning outcomes (LO), a number of abilities will be identified, both in the form of hard skills and soft skills, which are then used as indicators or assessment elements. This mapping process is shown in Figure 2. below.

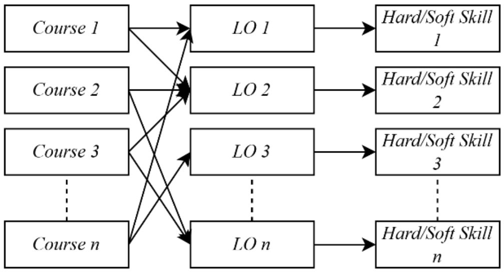

Fig.2. Mapping Graduate Learning Achievements with Hard Skills and Soft Skills

The assessment rubric guide for MBKM activities is compiled using the free form method, which is based on the results of mapping between courses and graduate learning outcomes. The assessment rubric is presented in full in Table 1. and can be used as a reference in evaluating student achievement during the MBKM program.

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TABLE. I. TABLE STYLES

Level	Score Range	Assessment Components			
		Teamwork	***Basic Abilities***	***Solution to Problem***	***Technological Innovation***
1	0– 20	Work individually	Does not understand basic concepts of science and technology	No issues were rasied	Doesn't understand technological innovation
2	21– 40	Work as a team	Know what science and technology are	Explain the problem clearly	Understanding innovation technology
3	41– 60	Can get the job done	Can use basic science and technology	Can formulate problem	Providing appropriate technology for problems faced
4	61– 80	Share roles/tasks whitin the team	Can apply basic concepts of science and technology	Can provide solutions to problem faced	Provide breakthroughs to the problems faced
5	81 – 100	Be the responsible person in the team	Can carry out scientific and technological enginering	Can explain the results of the solutions providded	Able to develop technology to addres problems faced

The initial stage in the application of fuzzy logic begins with identifying the input and output variables that will be used in the system. After that, the variables are set using MATLAB software. In this study, the approach used is the Fuzzy Mamdani method, with the configuration settings shown in Figure 3.

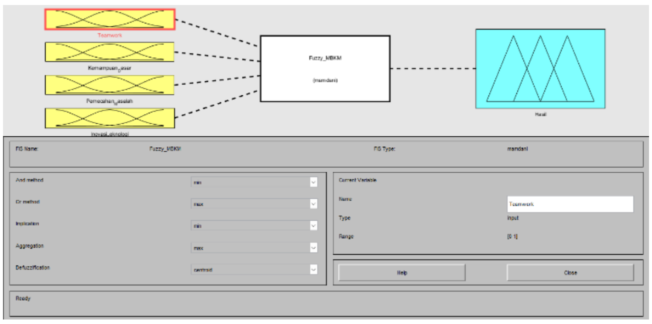

Fig.3. Fuzzy Settings View in MATLAB Application

In the case study in this research, there are four elements in the assessment components that are used as input variables, namely aspects of teamwork, basic skills, problem-solving skills, and innovation in technology. Each input variable has five fuzzy sets arranged based on the range of values at each level, as listed in Table 1. namely level 1 to level 5. After the process of setting the range of values of the set is carried out using MATLAB, the display of the fuzzy set graph for each variable can be seen in Figure 4.

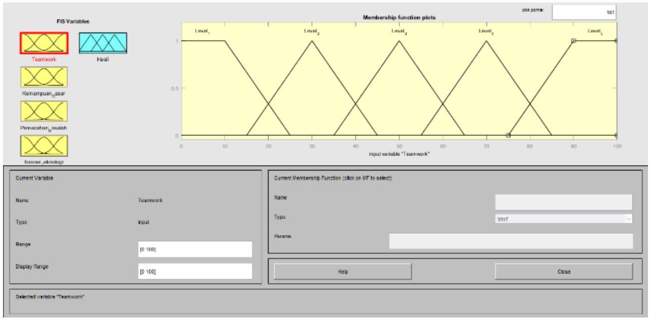

Fig.4. Fuzzy Set View of Input Variables

Based on the fuzzy set of input variables shown in Figure 4, it can be seen that the types of membership functions used include linear up, linear down, and triangular forms. Therefore, the mathematical equation used to calculate the fuzzy membership value on the level 1 set is shown in equation (4) below.

$$\mu(x)_{level1} = \begin{cases} 1; x \leq 10 \\ \dfrac{25-x}{25-10}; 10 \leq x \leq 25 \\ 0; x > 25 \end{cases} \quad (4)$$

The mathematical equation used to determine the fuzzy membership value in the level 2 set can be seen in equation (5) below.

$$\mu(x)_{level2} = \begin{cases} 0; x < 15 \\ \dfrac{x-15}{30-15}; 15 \leq x \leq 30 \\ \dfrac{45-x}{45-30}; 30 \leq x \leq 45 \\ 0; x > 45 \end{cases} \quad (5)$$

The mathematical equation used to determine the fuzzy membership value in the level 3 set can be seen in equation (6) below.

$$\mu(x)_{level3} = \begin{cases} 0; x < 35 \\ \dfrac{x-35}{50-35}; 35 \leq x \leq 50 \\ \dfrac{65-x}{65-50}; 50 \leq x \leq 65 \\ 0; x > 65 \end{cases} \quad (6)$$

The mathematical equation used to determine the fuzzy membership value in the level 4 set can be seen in equation (7) below.

$$\mu(x)_{level4} = \begin{cases} 0; x < 55 \\ \dfrac{x-55}{70-55}; 55 \leq x \leq 70 \\ \dfrac{85-x}{85-70}; 70 \leq x \leq 85 \\ 0; x > 85 \end{cases} \quad (7)$$

The mathematical equation used to determine the fuzzy membership value in the level 5 set can be seen in equation (8) below.

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$$\mu(x)_{level5} = \begin{cases} 0; x < 75 \\ \dfrac{x-75}{90-75}; 75 \le x \le 90 \\ 1; x \ge 90 \end{cases} \quad (8)$$

After the determination of input and output variables along with their membership functions is done, the next stage is to design a set of rules (rule base) in the fuzzy logic system. The preparation of these rules is based on various combinations of assessment levels from four main aspects, namely teamwork, basic skills, problem solving, and technological innovation. This process is implemented through the Fuzzy Inference System feature in MATLAB software, as shown in Figure 5 below.

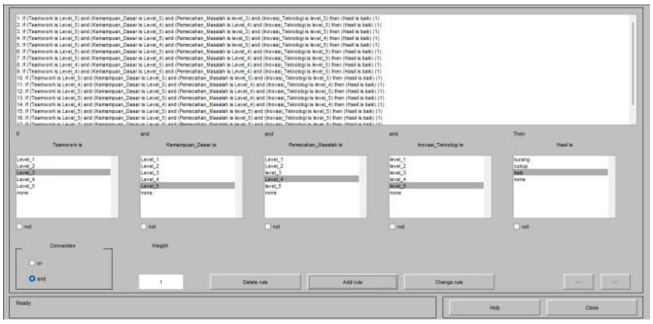

Fig.5. MBKKM Questionnaire Data Input

Meanwhile, the output variable used in this study is the final value of the implementation of MBKM activities, with a value range between 0 and 100. The final value is classified into three fuzzy sets, namely less, enough, and good. Visualization of this output variable can be seen in Figure 6. through the display generated in MATLAB.

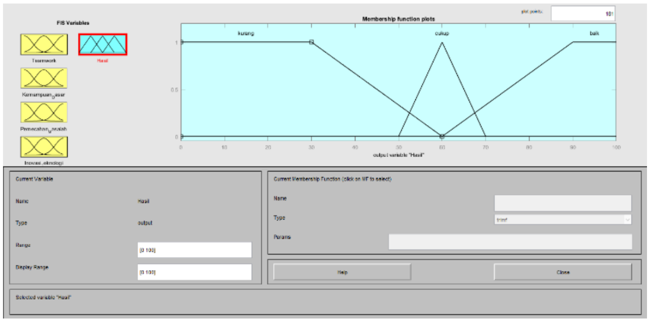

Fig.6. Fuzzy Set View of Input Variables

Based on the fuzzy set for the output variables shown in Figure 6 above, the mathematical equation used to calculate the fuzzy membership value in the lesser set is shown in equation (9) below.

$$\mu(x)_{not} = \begin{cases} 1; x \le 60 \\ \dfrac{60-x}{60-30}; 30 \le x \le 60 \\ 0; x > 60 \end{cases} \quad (9)$$

The following is the mathematical equation used to determine the fuzzy membership value in a sufficient set, which is shown in equation (10).

$$\mu(x)_{good} = \begin{cases} 0; x < 50 \\ \dfrac{x-60}{50-60}; 50 \le x \le 60 \\ \dfrac{70-x}{70-60}; 60 \le x \le 70 \\ 0; x > 70 \end{cases} \quad (10)$$

The following is a mathematical equation used to determine the fuzzy membership value in a good set, which is shown in equation (11).

$$\mu(x)_{enough} = \begin{cases} 0; x < 60 \\ \dfrac{90-x}{90-60}; 60 \le x \le 90 \\ 1; x \le 90 \end{cases} \quad (11)$$

After the input and output variables along with the fuzzy set are determined, the next stage is to formulate rules that will be the basis for determining the assessment output. One of the advantages of the fuzzy system is that its modeling does not only rely on empirical data, but also utilizes the knowledge of experts in their fields. In this study, the experts in question are the assessment team. Thus, the assessment output is also determined based on the rules made by the team. At this stage, the assessment team compiles a number of rules related to the passing grades of students' MBKM activities. In general, there are five main rules: if at least three components have a level 1 value, then the final grade is categorized as ‘less’; if at least three components receive a level 2 score, the grade is still classified as ‘less’; if at least three components reach level 5, the grade is classified as ‘good’. Meanwhile, if the dominant scores are at level 3 or 4, and none meet the thresholds for ‘less’ or ‘good’, the result is categorized as ‘enough’. Based on these five rules, a breakdown of all possible combinations of sets between input variables is carried out when entering the rules into the MATLAB application. The result is a total of 81 rules for determining fuzzy membership values.

The advantage of using fuzzy logic lies in the flexibility in determining rules that can be adjusted to the final assessment policy of MBKM activities. Furthermore, the results of the students' final grades can be seen in Figure 7. Below.

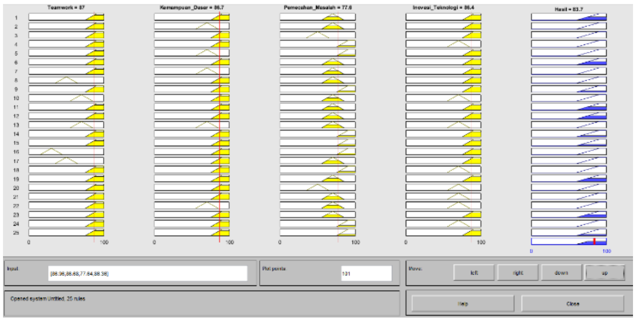

Fig.7. Results of MBKM Mathematics Students Class of 2021

Based on Figure 7, it is obtained that the input values from the four aspects of the MBKM activity assessment of the 2021 Mathematics Study Program students are: Teamwork of 87, Basic Ability of 86.7, Problem Solving of 77.6, and Technological Innovation of 86.4. These values are at levels 4 and 5, which reflects that students have high abilities in all

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aspects assessed.

The fuzzy graph visualization of each input variable shows a yellow area that represents the level of membership in the appropriate fuzzy set, with high intensity at the top level. Meanwhile, the output column on the right side displays the final result of the Mamdani fuzzy system in the form of a defuzzification value of 83.7, which is depicted through a blue graph.

Based on the previously established fuzzy rules, if three or more of the four assessment aspects have values at level 4 or 5, then the assessment results are included in the "Good" category. Not only that, the final output with a value of 83.7 is also in the "Good" category based on the previous equation. Therefore, students with these scores are declared to have successfully carried out MBKM activities optimally, demonstrating strong competencies in teamwork, basic skills, problem solving, and technological innovation development. These results reflect the success of the application of fuzzy logic in providing flexible and objective assessments of MBKM achievements.

IV. Conclusion

This study successfully demonstrated the implementation of Mamdani fuzzy logic as a decision support system in the assessment of the Merdeka Belajar Kampus Merdeka (MBKM) activities for Mathematics Study Program students of Bangka Belitung University, batch 2021. By using four main input variables, namely teamwork, basic skills, problem solving, and technological innovation, the fuzzy system is able to process linguistic data into numeric values that represent student learning outcomes objectively. The final results of the system show that students who have scores at level 4 or 5 in at least three aspects get the "good" category, as shown in the defuzzification results of 83.7. These findings indicate that Mamdani fuzzy logic is a flexible and accurate approach in evaluating the effectiveness of student participation in MBKM activities, as well as making a real contribution to the development of an artificial intelligence-based assessment system in higher education environments.

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