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Application of Fuzzy Logic to Find Out the Level of Student Satisfaction Towards Lecturers Performance

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***Abstract*: There are several benchmarks that determine the quality of a nation, one of which is the quality of education. In higher education, a lecturer plays a very large role in shaping the quality of education for students. There are students who are so smart but are not serious in attending classes. One of the reasons is because of the way the lecturer conveys material that is less attractive to students. Therefore, a measurement method is needed to determine the level of student satisfaction towards the performance of their lecturers. In this study, we distributed questionnaires to students at the end of each semester. Each student will fill out the questionnaire for each course that he/she attends. As a measurement tool, we use Mamdani fuzzy logic method. As input, we provide data of 3,000 questionnaires every semester for 4 semesters. The results show that students are very satisfied with the performance of lecturers at Universitas Pelita Harapan Surabaya Campus. This can be used as an evaluation material so that the lecturer's performance can be improved more in the next semester.**

***Keywords*: Fuzzy logic, Lecturer Performance, Satisfaction.**

1. Introduction

Education is one of the determining factors for the development progress of a nation. The higher level of education of the people, the more developed the country will be. In the implementation of higher education, lecturers play a very important role. One of them is by transferring knowledge to students.

Universitas Pelita Harapan (UPH) also sees the important role of lecturers in shaping every graduate. Therefore, towards the end of each semester, an activity is held where students will give an assessment of each course they are taking. If the course is taught by more than one lecturer, the assessment will be carried out repeatedly according to the number of lecturers who teach it. This activity is known as the Student Feedback Questionnaire (SFQ).

The questionnaire used for this SFQ activity has 11 statements. Each statement is asked with a linear scale model between 1 and 6. So far, SFQ activities have only been assessed based on the average score for each statement. Furthermore, the results of this assessment will be submitted to the Head of the Study Program which can be used as consideration for the progress of the teaching and learning process.

In this study, the results of the questionnaire are calculated using the fuzzy logic method where each statement will be an input attribute. Fuzzy logic is used in order to provide more objective results because fuzzy logic uses the concept of ambiguity of a value. This imitates the way humans think in giving judgments.

For example, when a student is given the statement "I understand the material given", then the student thinks that he/she is more than "understand enough" but not enough to said as "understand", or in other words, he/she "does not fully understand", then he/she will give an assessment between those two points.

Thinking about conventional logic with a definite truth value that is right or true and wrong or false in real life is very inappropriate. Fuzzy logic is a logic that can represent conditions that exist in the real world [1]. Fuzzy logic is a logic that has a value of ambiguity between true and false [2].

In contrast to conventional logic which only recognizes two values, namely zero and one, fuzzy logic uses values in the interval [0,1]. Fuzzy logic is a development of conventional logic, or in other words, conventional logic is a special occurrence of fuzzy logic [3].

The theory of fuzzy logic sets was first introduced by Prof. Lofti Zadeh circa 1965 in a paper entitled "Fuzzy Sets". He argues that the logic of right and wrong from conventional (boolean) logic cannot solve problems that exist in the real world. Unlike boolean logic, fuzzy logic has a continuous value. Obscurity is expressed in degrees of membership and degrees of truth. Therefore, something can be said to be “right” and “partially wrong” at the same time. Individual set theory can have membership degrees with continuous values, not just 0 and 1 [4].

One of the reasons why this study uses the fuzzy logic method is because this method is considered very good for assessments that have non-absolute values and the assessment process has clear rules [5]. Another reason is that the fuzzy expert system logic has been used to determine a person's level of satisfaction with his job based on an assessment of several existing job factors [6].

In addition, based on research [7] it is stated that factors

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related to the environment in which academic work, including university atmosphere, morale, sense of community, and relationship with colleagues, are the greatest predictors of job satisfaction. Therefore, in this study, we tried to use parameters similar to that, but adjusted for students to find the level of satisfaction with their learning process.

Researches show that soft computing techniques are more powerful and better suited in providing feasible solutions to the problems that deal with uncertainties and vagueness [8]. According to this fact, we use one of the soft computing techniques, which is fuzzy logic, to find out the satisfaction level of the student in university.

Some points that can be drawn from the results of this questionnaire are:

1. How clearly does the lecturer explain the lecture material?
2. How is the relationship between lecturers and students in the classroom?
3. How is the role of lecturers in the progress of their students?
4. To what extent have students mastered the presented material?

2. The Global Scheme

In this study, we designed a system consisting of three sub-processes, those are collecting data from students through questionnaires, process data from questionnaires using a fuzzy inference system, and create reports to be submitted to each head of the study program. Fig. 1 shows a schematic of the system being built.

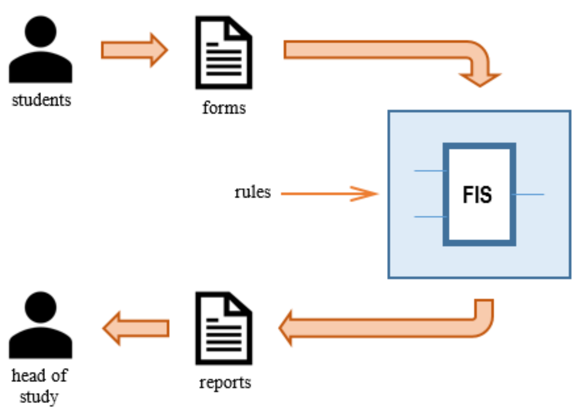

Fig. 1. The design of the Fuzzy Inference System

In this system there is a procedure that is carried out as follows:

- All students were selected as respondents.
- An online form is provided to receive input from students.
- The results of this questionnaire will be used as an input from the Fuzzy Inference System (FIS).
- This FIS structure will produce several forms of reports as its output.
- These reports will then be used by the Head of the Study Program for consideration.

This questionnaire form is distributed to all students at the end of each semester. Students will rate eleven statements on a scale of 1 to 6 using a web-based application. Each point in this application has a leap of 0.1 points, so students can provide a more flexible assessment.

The results of this questionnaire will be used as input for the designed FIS. The 6-point questionnaire scale will be translated into 3 points in this FIS while maintaining the range from 1 to 6. It is designed in such a way that students do not need to change their understanding in giving assessments that have been going on manually so far.

After that, the designed FIS will perform calculations using the Mamdani method. A set of rules will be used in this calculation process. The fuzzy membership in the FIS structure is calculated using the triangle method because this method is considered the most suitable for the case at hand [5]. In the fuzzification phase, the maximin calculation (aggregation max) will be used, while in the defuzzification phase, the centroid calculation will be used.

As a final step, the output of the FIS will be compiled in several forms of reports, that is reports per statement per lecturer, reports per statement per course, and reports per course per lecturer. All these reports will be submitted to the Head of the Study Program for further consideration.

3. Fuzzy Inference System

As the first step of this research is the distribution of questionnaires to all students. In addition to personal questions, the questionnaire contains eleven statements that use a linear scale from 1 to 3 to describe the level of student satisfaction with the performance of their lecturers. The eleven statements are:

1. The lecturer explains the lesson clearly.
2. Lecturers help me apply lecture material in various situations. (i.e. practical cases, different situations, etc.)
3. Lecturers can provide useful feedback in discussion forums, face-to-face tutorials, and online tutorials.
4. Lecturers use the latest information in teaching materials. (i.e. current events, journal articles in the last 5 years, etc.) that match the course).
5. Lecturers teach according to the Syllabus.
6. Lecturers show their integrity: (i.e. honest, fair, ethical, disciplined, and punctual).
7. Lecturers use language that is easy to understand in facilitating the online learning process.
8. Lecturers provide guidance and are willing to answer student questions (i.e. via email, at work, learn.uph.edu, Microsoft Teams, or Zoom).
9. Lecturers provide input to students regarding the progress of their studies. (i.e. providing timely feedback on student assignments).
10. Lecturers provide clear assessment criteria (i.e. fair, honest, and transparent) for each assignment and exam.
11. I learned a lot in this class.

Input parameters in this study are labeled from A to K, where each of which is divided into 3 categories which are disagree, neutral, and agree. While the output variable is labeled O which will describe the level of student satisfaction with lecturers who teach a certain course. This output variable is divided into 3 categories, which are unsatisfied, quite satisfied, and very satisfied. In general, the system design can be seen in Fig. 2.

Here are the process steps that will be carried out on fuzzy logic:

1. Fuzzification: fuzzify all input values into fuzzy membership functions.
2. Rule: execute all applicable rules in the rulebase to compute the fuzzy output functions.
3. Defuzzification: de-fuzzify the fuzzy output functions to get "crisp" output values.

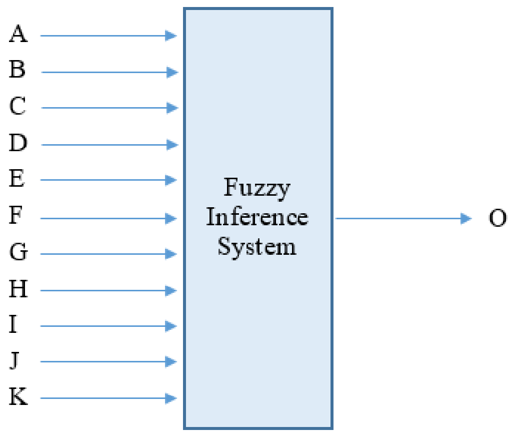

Fig. 2. The design of the Fuzzy Inference System

Since all input variables are divided into three categories and each category has the same range, it can be described as shown in Fig. 3, while the members of the fuzzy set can be seen in Table 1.

Table 1
Fuzzy set for input variable A to K

Universal Set	Fuzzy Sets	Domain
1 – 6	Disagree	1 – 3.5
	Neutral	2 – 5
	Agree	3.5 – 6

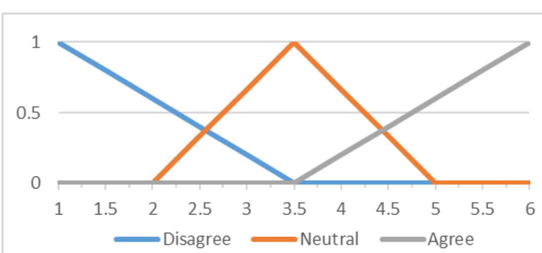

Fig. 3. Fuzzy set for each input variable

The representation of the members of the fuzzy logic set in Fig. 3 is obtained using the following formula:

$$\mu_{disagree} = \begin{cases} \frac{3.5-x}{3.5-1} & ; \quad 1 \le x \le 3.5 \\ 0 & ; \quad x \ge 3.5 \end{cases} \tag{1}$$

$$\mu_{neutral} = \begin{cases} 0 & ; \quad x \le 2 \\ \frac{x-2}{3.5-2} & ; \quad 2 \le x \le 3.5 \\ \frac{5-x}{5-3.5} & ; \quad 3.5 \le x \le 5 \\ 0 & ; \quad x \ge 5 \end{cases} \tag{2}$$

$$\mu_{agree} = \begin{cases} 0 & ; \quad x \le 3.5 \\ \frac{6-x}{6-3.5} & ; \quad 3.5 \le x \le 6 \end{cases} \tag{3}$$

Meanwhile, the fuzzy logic set for the output variables can be shown in Table 2 and illustrated in Fig. 4. The formulas used are (4), (5), and (6).

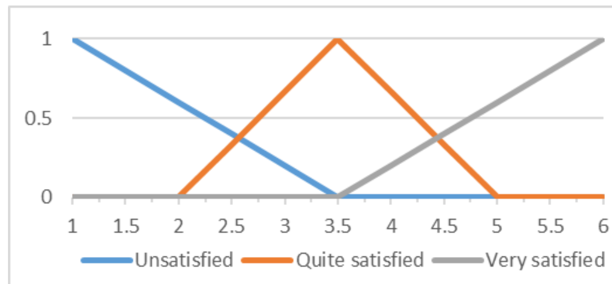

Fig. 4. Fuzzy set for each input variable

$$\mu_{unsatisfied} = \begin{cases} \frac{3.5-x}{3.5-1} & ; \quad 1 \le x \le 3.5 \\ 0 & ; \quad x \ge 3.5 \end{cases} \tag{4}$$

$$\mu_{quite\_satisfied} = \begin{cases} 0 & ; \quad x \le 2 \\ \frac{x-2}{3.5-2} & ; \quad 2 \le x \le 3.5 \\ \frac{5-x}{5-3.5} & ; \quad 3.5 \le x \le 5 \\ 0 & ; \quad x \ge 5 \end{cases} \tag{5}$$

$$\mu_{very\_satisfied} = \begin{cases} 0 & ; \quad x \le 3.5 \\ \frac{6-x}{6-3.5} & ; \quad 3.5 \le x \le 6 \end{cases} \tag{6}$$

The next step is to develop applicable rules to determine the level of student satisfaction to the lecturer performance using the IF-THEN method and the AND operator. We use the AND operator rather than OR operator because we want to find the minimum value from a set of maximum values, known as minimax. Here are some random examples of existing rules:

1. IF (A is Agree) AND (B is Agree) AND (C is Agree) AND (D is Agree) AND (E is Agree) AND (F is Agree) AND (G is Agree) AND (H is Agree) AND (I is Agree) AND (J is Agree) AND (K is Agree) THEN (O is Very Satisfied).
2. IF (A is Agree) AND (B is Agree) AND (C is Agree) AND (D is Neutral) AND (E is Disagree) AND (F is Agree) AND (G is Agree) AND (H is Agree) AND (I is Agree) AND (J is Agree) AND (K is Neutral) THEN (O is Very Satisfied).
3. IF (A is Agree) AND (B is Neutral) AND (C is Neutral) AND (D is Agree) AND (E is Agree) AND (F is Agree) AND (G is Neutral) AND (H is Disagree) AND (I is

Agree) AND (J is Neutral) AND (K is Agree) THEN (O is Very Satisfied).

4. IF (A is Neutral) AND (B is Agree) AND (C is Neutral) AND (D is Neutral) AND (E is Agree) AND (F is Agree) AND (G is Agree) AND (H is Disagree) AND (I is Disagree) AND (J is Neutral) AND (K is Agree) THEN (O is Quite Satisfied).
5. IF (A is Neutral) AND (B is Agree) AND (C is Neutral) AND (D is Agree) AND (E is Agree) AND (F is Agree) AND (G is Agree) AND (H is Agree) AND (I is Disagree) AND (J is Neutral) AND (K is Disagree) THEN (O is Quite Satisfied).
6. IF (A is Neutral) AND (B is Disagree) AND (C is Agree) AND (D is Agree) AND (E is Agree) AND (F is Disagree) AND (G is Agree) AND (H is Neutral) AND (I is Agree) AND (J is Disagree) AND (K is Disagree) THEN (O is Quite Satisfied).
7. IF (A is Agree) AND (B is Agree) AND (C is Disagree) AND (D is Agree) AND (E is Neutral) AND (F is Neutral) AND (G is Disagree) AND (H is Agree) AND (I is Agree) AND (J is Neutral) AND (K is Disagree) THEN (O is Quite Satisfied).
8. IF (A is Agree) AND (B is Neutral) AND (C is Disagree) AND (D is Neutral) AND (E is Disagree) AND (F is Neutral) AND (G is Neutral) AND (H is Disagree) AND (I is Disagree) AND (J is Neutral) AND (K is Disagree) THEN (O is Unsatisfied).
9. IF (A is Agree) AND (B is Neutral) AND (C is Disagree) AND (D is Disagree) AND (E is Disagree) AND (F is Neutral) AND (G is Neutral) AND (H is Neutral) AND (I is Neutral) AND (J is Disagree) AND (K is Disagree) THEN (O is Unsatisfied).
10. IF (A is Agree) AND (B is Disagree) AND (C is Agree) AND (D is Neutral) AND (E is Disagree) AND (F is Neutral) AND (G is Disagree) AND (H is Neutral) AND (I is Neutral) AND (J is Disagree) AND (K is Disagree) THEN (O is Unsatisfied).

In the fuzzy logic structure, the A, B, C, D, E, F, G, H, I, J, and K parameters are denoted as x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, and x_{11}, whereas O as the output is denoted by u. The rules of the relation are shown in Eq. 7.

$$
\begin{aligned}
R_{11} &= (x_{11}.u_{11}) \cup (x_{12}.u_{12}) \cup \ldots \cup (x_{1n}.u_{1n}) \qquad (7)\\
R_{12} &= (x_{11}.u_{21}) \cup (x_{12}.u_{22}) \cup \ldots \cup (x_{1n}.u_{2n})\\
&\vdots\\
R_{\mathrm{mn}} &= (x_{\mathrm{m1}}.u_{\mathrm{n1}}) \cup (x_{\mathrm{m2}}.u_{\mathrm{n2}}) \cup \ldots \cup (x_{\mathrm{mn}}.u_{n})
\end{aligned}
$$

Then the equation of the output from the fuzzy logic structure will be as shown in Eq. 8.

$$u^* = (x_1 \circ R_{11}) \cap (x_2 \circ R_{21}) \cap \ldots \cap (x_{11} \circ R_{111}) \qquad (8)$$

To determine the ownership of a degree of membership, the abscissa of the center of gravity of the area where the supporting elements are located must be sought. This abscissa point will be considered as the supporting element. If the curve of the membership function is an isosceles triangle, then the supporting elements do have the degree of membership as stated in the numerator. For each type of membership function curve, finding the center of gravity of the area can be done using the formula:

$$Z^* = \frac{\int \mu_x(x).x\,dx}{\int \mu_x(x)\,dx} \qquad (9)$$

4. Result

We took some data to be used in the testing phase. For example, we take data from the old type of questionnaire as follows: A = 4, B = 5, C = 5, D = 5, E = 4, F = 3, G = 4, H = 4, I = 5, J = 4, and K = 3. Where based on the average calculation, the result is 4.18.

To support this research, an application named SFQ that is a web-based application was created to receive input from students. In the SFQ application, students can give their opinion according to the eleven statements of SFQ using a slider range from 1 to 6. Fig. 4 showing the interface of the SFQ application.

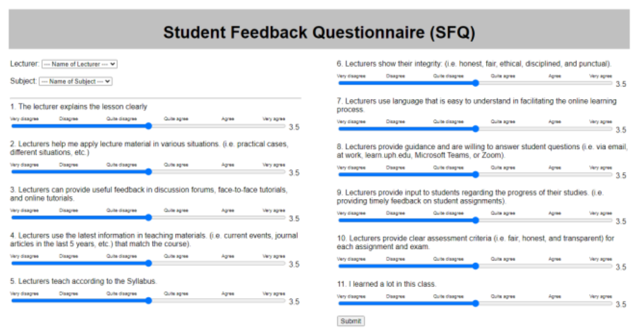

Fig. 5. User interface of the SFQ application

Using this application, students can give an assessment between two points. What they have to do is to slide the slider to the point that they desire. For example, through this application student can give a score of 4.5, or even 4.2 or 4.8, instead of just 4 or 5 on the submitted statements.

After designing the fuzzy logic system, the next step is to test the system using some sample data. For an example, data bellow is taken from one of the sample data where the student gives values of each statement as an input variable, which are A = 4.2, B = 4.7, C = 5.3, D = 5.5, E = 4.6, F = 3.2, G = 3.6, H = 4.1, I = 5.2, J = 4.2, and K = 2.6. The value of these input variables is then entered into the rules in the FIS. From the list of rules in the FIS, there are four appropriate rules. Fig. 6 shows the fuzzy inference process for the desired output, that is the level of student satisfaction with lecturer performance.

The first step is the fuzzification of the input variables. As we can see in Fig. 6, in the first rule, the degree of membership for the A is 0.28, B is 0.48, C is 0.72, D is 0.8, E is 0.27, F is 0.18, G is 0.93, H is 0.24, I is 0.68, J is 0.53, and K is 0.36. In the second rule, the degree of membership for the A is 0.53, B is 0.2, C is 0.72, D is 0.8, E is 0.44, F is 0.12, G is 0.04, H is 0.6, I is 0.68, J is 0.53, and K is 0.4. In the third rule, the degree of membership for the A is 0.53, B is 0.48, C is 0.72, D is 0.8, E is 0.44, F is 0.8, G is 0.93, H is 0.6, I is 0.68, J is 0.28, and K is 0.4. While in the fourth rule, the degree of membership for

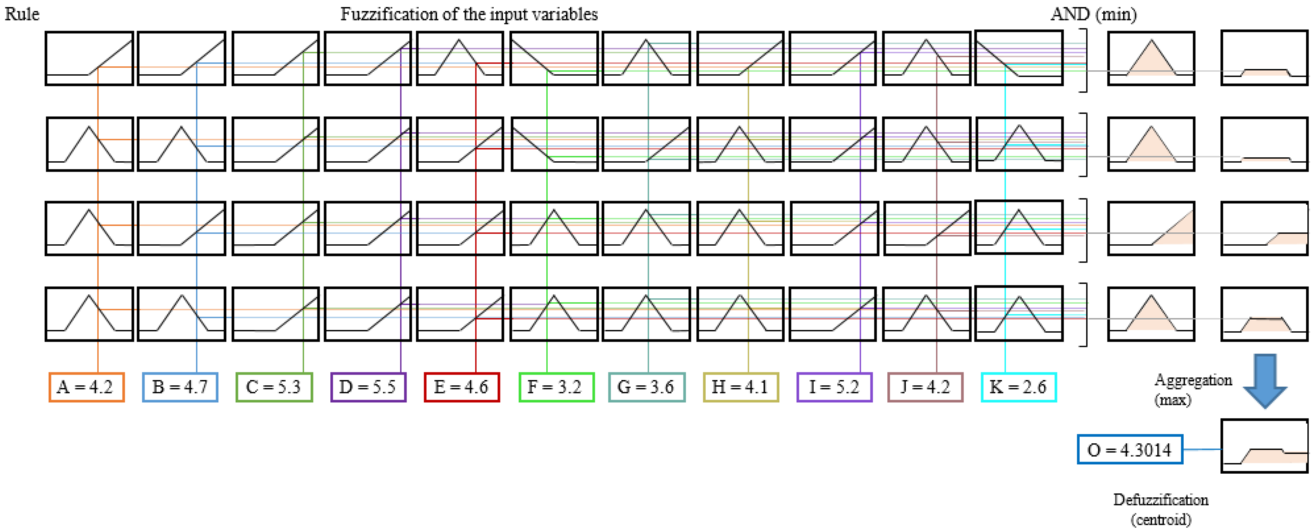

Fig. 6. Fuzzy inference system diagram

the A is 0.53, B is 0.42, C is 0.72, D is 0.8, E is 0.44, F is 0.8, G is 0.93, H is 0.6, I is 0.68, J is 0.53, and K is 0.4. Since all the rules use the AND operator where the conjunction uses the min operator, then the value for the first rule is 0.18, the second rule is 0.12, the third rule is 0.28 and the fourth is 0.4.

From the previous calculation, it is known that the value of the first rule is 0.18, so the fuzzy output O is 4.73. The second rule with a value of 0.12 will produce a fuzzy output O is 4.82. For the third rule with a value of 0.28, the fuzzy output O is 4.2. The fourth rule with a value of 0.4 will produce a fuzzy output is 4.4. From all the outputs, aggregation is performed using the max function, which means that all areas are combined. Then the last step is defuzzification using the centroid method as shown in Fig. 7. From the calculation, it can be seen that the centroid value of O is 4.3014.

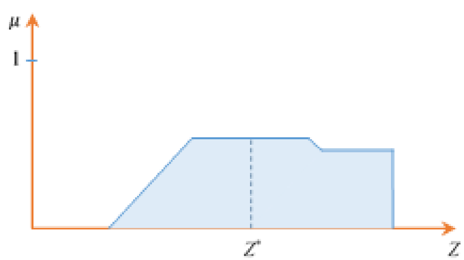

Fig. 7. The visualization of Eq. 9.

Next, we perform the same steps for 200 testing data. From the calculation results, it can be seen that calculations using the fuzzy method can provide a more specific picture. Table 3 shows the difference in the calculation results of the first 20 testing data from the two methods.

From the overall measurement of the testing data, it can be seen that there is a difference between the results of calculations using the old and new methods of 2.81%. This is not an error, but it happened because there is a difference in numbers that provided to the assessment of each statement in the questionnaire.

The calculation is continued by using the overall data from student questionnaires per semester. Furthermore, the results are processed statistically and conclusions can be seen as shown in Table 3, Table 4, Table 5, and Table 6.

Table 2
The difference in the calculation results of the two methods

No	Sample Data Used	Old Method	New Method
1.	Student 1, course 1	4.18	4.3014
2.	Student 1, course 2	5.36	5.1927
3.	Student 1, course 3	5.27	4.8413
4.	Student 1, course 4	4.91	5.0674
5.	Student 1, course 5	5.00	4.8297
6.	Student 2, course 1	5.00	5.0834
7.	Student 2, course 2	5.55	5.3872
8.	Student 2, course 3	5.18	5.2068
9.	Student 2, course 4	4.73	4.8217
10.	Student 2, course 5	4.73	4.9073
11.	Student 3, course 1	5.45	5.4921
12.	Student 3, course 2	5.73	5.5167
13.	Student 3, course 3	4.82	4.8736
14.	Student 3, course 4	4.55	4.7261
15.	Student 3, course 5	5.09	5.1057
16.	Student 4, course 1	5.36	5.3021
17.	Student 4, course 2	5.45	5.4376
18.	Student 4, course 3	5.64	5.2841
19.	Student 4, course 4	5.55	5.1648
20.	Student 4, course 5	5.27	5.2873

In Table 3 we can see the value of each statement given by all students. This assessment involves all courses in the semester. Table 4 shows the value of each lecturer. This assessment covers all courses taught by each of these lecturers. Table 5 and Table 6 show a more detailed report. Table 6 shows the value of each course taught by each lecturer. While Table 6 shows the value of each statement of each course per lecturer.

From these tables, several forms of reports are made which are then submitted to each Head of the Study Program. These reports are used as reference material in determining further policies.

Right now, there are several alternatives that can be taken by the Head of the Study Program, which are:

1. Conduct training on certain matters by looking at the results with low scores in Table 3.
2. Using the team teaching method for lecturers who have low scores in Table 4.

3. Reviewing the expertise of lecturers on certain subjects that have low scores in Table 5.
4. Improve the lecturer's weakness towards certain statements in certain classes by looking at the results in Table 6.

Table 3
The overall score of each statement of the questionnaire

No.	Component	Score
1.	Statement number 1	5.2634
2.	Statement number 2	4.8701
3.	Statement number 3	5.3840
4.	Statement number 4	5.6021
5.	Statement number 5	5.0643
6.	Statement number 6	5.3156
7.	Statement number 7	5.5027
8.	Statement number 8	5.4110
9.	Statement number 9	5.0267
10.	Statement number 10	5.3226
11.	Statement number 11	5.6814

Table 4
The overall score of each lecturer

No.	Component	Score
1.	Lecturer 1	5.0862
2.	Lecturer 2	5.4519
3.	Lecturer 3	5.4483
4.	Lecturer 4	5.5267
5.	Lecturer 5	5.5164
6.	Lecturer 6	5.4836
7.	Lecturer 7	5.4782
8.	Lecturer 8	5.3108
9.	Lecturer 9	5.4918
10.	Lecturer 10	5.6047
…	…	…

Table 5
The detailed score of each course per lecturer

No.	Component	Score
1.	Lecturer 1, course 1	5.5034
2.	Lecturer 1, course 2	5.0857
3.	Lecturer 1, course 3	5.5021
4.	Lecturer 2, course 1	5.5506
5.	Lecturer 2, course 2	4.6481
6.	Lecturer 3, course 1	5.5901
7.	Lecturer 3, course 2	5.7006
8.	Lecturer 3, course 3	5.4784
9.	Lecturer 3, course 4	5.6039
10.	Lecturer 4, course 1	5.4372
…	…	…

Table 6
The detailed score of each statement per course per lecturer

No.	Component	Score
1.	Lecturer 1, course 1, statement number 1	5.0361
2.	Lecturer 1, course 1, statement number 2	4.2830
3.	Lecturer 1, course 1, statement number 3	4.7394
4.	Lecturer 1, course 1, statement number 4	5.1346
5.	Lecturer 1, course 1, statement number 5	5.5041
6.	Lecturer 1, course 1, statement number 6	4.8307
7.	Lecturer 1, course 1, statement number 7	4.9672
8.	Lecturer 1, course 1, statement number 8	5.3218
9.	Lecturer 1, course 1, statement number 9	5.4931
10.	Lecturer 1, course 1, statement number 10	5.5002
11.	Lecturer 1, course 1, statement number 11	5.3027
…	…	…

5. Conclusion and Future Work

Based on several forms of reports generated from the system, it can be seen that the calculated values in this application are not much different from those done manually. By using this application, students can provide a more detailed assessment because the values given are not exact numbers and the results are felt to better describe students' feelings towards each statement on the questionnaire.

It can be concluded that the application of this system is acceptable. The resulting output can also be used as a reference for the Head of the Study Program in making further decisions.

For further research, this research can be developed using machine learning methods such as Naive Bayes and text mining to classify student satisfaction through their comments given on the questionnaire form.

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