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Measuring the quality of the learning process in basic courses using the multivariate statistical process control method

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Abstract: The quality of learning is the key to being able to compete in the world of education. This research aims to measure the quality of the learning process in basic courses at the University of Logistics and International Business. The method used is Multivariate Statistical Control Process with subgroups whose size is not constant. In this method, multivariate control of the target process is carried out using the T2 Hotelling control diagram. Meanwhile, control of multivariate process variability is carried out using a generalized variance control chart. The sample data used in this research was taken from grades in English courses and introductory logistics courses from 20 classes with a total of 498 students. Data collection was carried out randomly from 2019-2022. The results obtained were that in the Multivariate Process Target (MPT) calculation using the T2 Hotelling control diagram it was found that class 1 was out of control. Meanwhile, in calculating Multivariate Process Variability (MPV) using a Generalized Variance (GV) based control diagram, it was found that classes 5 and 20 were out of control. Investigating the cause of the class being out of control is a part that must be explored by study program and university leaders in an effort to improve the teaching and learning process.

Keywords: Control diagram, multivariate process variability, multivariate statistical process control, multivariate target process, quality of learning process

Pengukuran kualitas proses belajar pada mata kuliah dasar menggunakan metode multivariate statistical proses control

Abstrak: Kualitas pembelajaran adalah kunci untuk dapat bersaing dalam dunia Pendidikan. Penelitian ini bertujuan untuk mengukur kualitas proses belajar pada matakuliah dasar di Universitas Logistik dan Bisnis Internasional. Metode yang digunakan adalah Multivariate Statistical Control Process dengan subgrup yang ukurannya tidak konstan. Didalam metode ini pengendalian multivariat terhadap proses target dilakukan dengan menggunakan diagram kendali T2 Hotelling. Sedangkan pengendalian variabilitas proses multivariat dilakukan dengan menggunakan diagram kendali generalized variance. Data sampel yang digunakan pada penelitian ini diambil dari nilai mata kuliah Bahasa inggris dan mata kuliah pengantar logistic yang berasal dari 20 kelas dengan total terdapat 498 mahasiswa. Pengumpulan data dilakukan secara acak dari tahun 2019-2022. Hasil yang diperoleh bahwa pada perhitungan Multivariate Proses Target (MPT) menggunakan diagram kontrol T^2 *Hotelling* ditemukan bahwa kelas ke 1 berada dalam keadaan diluar kontrol. Sedangkan pada perhitungan Multivariate Proses Variability (MPV) menggunakan diagram kontrol berbasis *Generalized Variance* (GV) ditemukan bahwa kelas ke 5 dan ke 20 berada dalam keadaan diluar kontrol. Penelusuran penyebab kelas berada dalam out of control merupakan bagian yang harus digali oleh pimpinan program studi dan universitas dalam upaya meningkatkan proses belajar mengajar.

Kata Kunci: Diagram kontrol, multivariat proses variability, multivariate statistical proses control, multivariat proses target, kualitas proses belajar

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INTRODUCTION

In the context of developing higher education, the Government through the Republic of Indonesia's PERMENDIKBUD states that the targets for developing higher education include improving the quality of learning and improving the quality of lecturers (Wahyuningrum, 2022; Yurida et al., 2021). Achieving this quality of learning certainly needs to be done through quality assurance activities so that it can legitimize the institution to develop the academic programs offered, apart from that, it also provides information for the Institution's stakeholders regarding the fulfillment of the expected quality standards (Gessa et al., 2022).

According to Besterfield, quality is defined as the ability of a product or service to meet or exceed the user's expectations (Handes et al., 2013). Meanwhile, processes are defined as activities carried out to convert input into output (Irihm, 2018). Maintaining the quality of teaching can be done by providing academic supervision by seeing how the learning process runs well (Wahyudi et al., 2022). Analysis of getting good quality results in education is very important to do, therefore an effort is needed beforehand to measure the learning process being carried out. This analysis will give us information, which classes are running according to expectations and which classes which is outside of control, this can be seen from the calculation results which are visualized in a control diagram. A control chart is a graph that provides an overview of the behavior of a process (van Delsen & Talakua, 2016).

Measuring and analyzing the quality of learning is very important because it can provide information about the extent to which educational goals are achieved and how effective the learning process is, we can also find out the weaknesses and strengths of existing educational programs, and determine corrective actions that need to be taken to improve the quality of education. By measuring the quality of the teaching and learning process, we can control the effectiveness of learning and become the basis for creating appropriate programs and policies. Apart from that, measuring the quality of teaching and learning in higher education is very important for assessing learning effectiveness, student satisfaction, improving the reputation of higher education, and increasing the ability of graduates to compete in the world. Quality measurement plays an important role in various fields, one of the goals of which is to be able to carry out continuous improvements so as to exceed customer expectations (Shehata et al., 2018).

The Association to Advance Collegiate School of Business (AACSB) as an international accreditation organization for business colleges, in one of its conferences on the application of quality management practices in business, provided recommendations to universities to apply statistical methods to detect the presence or absence of "out of control" conditions. in the educational system that is run (Hanna & Raichura, 2012). Many studies carry out quality measurements using statistical process control (SPC), but these measurements are mostly carried out in the industrial sector, such as research conducted by Pratiwi and Aksioma (2019) who used a multivariate statistical process to measure quality in the cigarette production process. Another research conducted by Dicky Hands which discussed controlling the quality of a product using Statistical Process Control gave results in the form of products that were out of control and resulted in production defects (Handes et al., 2013).

The application of statistical process control is also often found in research in the service sector such as education, including research from Belinda which applies Statistical

Process Control to measure the quality of the lecture process seen from the GPA attributes and length of study of graduates. This research provides findings where the lecture process is the mathematics department is not under control (Yuneidi et al., 2012). In the research conducted by Antoro et al. (2023), it was also found that Statistical Process Control was applied as a learning evaluation tool, but this research used control charts and sub-group divisions, which were different.

Quality measurements in the service sector, especially in the education sector, are still very rarely carried out. Therefore, it is hoped that the research conducted by the author can contribute to enriching the case study of measuring educational quality using a Multivariate Statistical Control Process which uses basic course grades as attributes used in the calculation process. This research aims to measure the quality of the learning process using the multivariate statistical process control (MSPC) technique with the data used being grade data from two basic courses at the University of Logistics and International Business (ULBI), namely the English and introduction to logistics courses, the language course English reflects language skills as a campus with an international vision and the Introduction to logistics course is a typical ULBI subject.

METHOD

Research population and sample

The population in this study were students from the 2019-2022 class. Meanwhile, the sample was students who took basic courses such as English language and Introduction to Logistics from 10 study programs at the University of Logistics and International Business. Data collection was carried out randomly from 20 classes with the number of students sampled being 498 students..

Multivariate Process Target (MPT) and Multivariate Process Variability (MPV) parameter control must be adjusted to the sampling scenario. The sampling scenario used in this research uses a non-constant based subgroup sampling scenario because this scenario is used to control the quality of processes in service industries such as services at BIG (Business, Industry & Government) agencies including educational services such as teaching and learning processes (Djauhari & Herwindiati, 2022). The meaning of Multivariate Process Target (MPT) is controlling the population mean vector and Multivariate process variability (MPV) refers to measuring and analyzing multiple variables simultaneously to monitor and understand variation (Djauhari et al., 2008).

Research steps

To achieve the research objectives that have been set can be seen in Figure 1. The first step in this research is to determine the problem formulation, which is related to process quality control. This is followed by determining more specific research objectives. Data collection was carried out in coordination with the Student Administration and Academic Affairs Section at the University of Logistics and International Business.

Next, the researcher carries out exploratory data analytics (EDA), which is the process of extracting and understanding data from what is available, which also includes a data cleaning process if there is still dirty data such as empty data, unbalanced data or duplicate data.

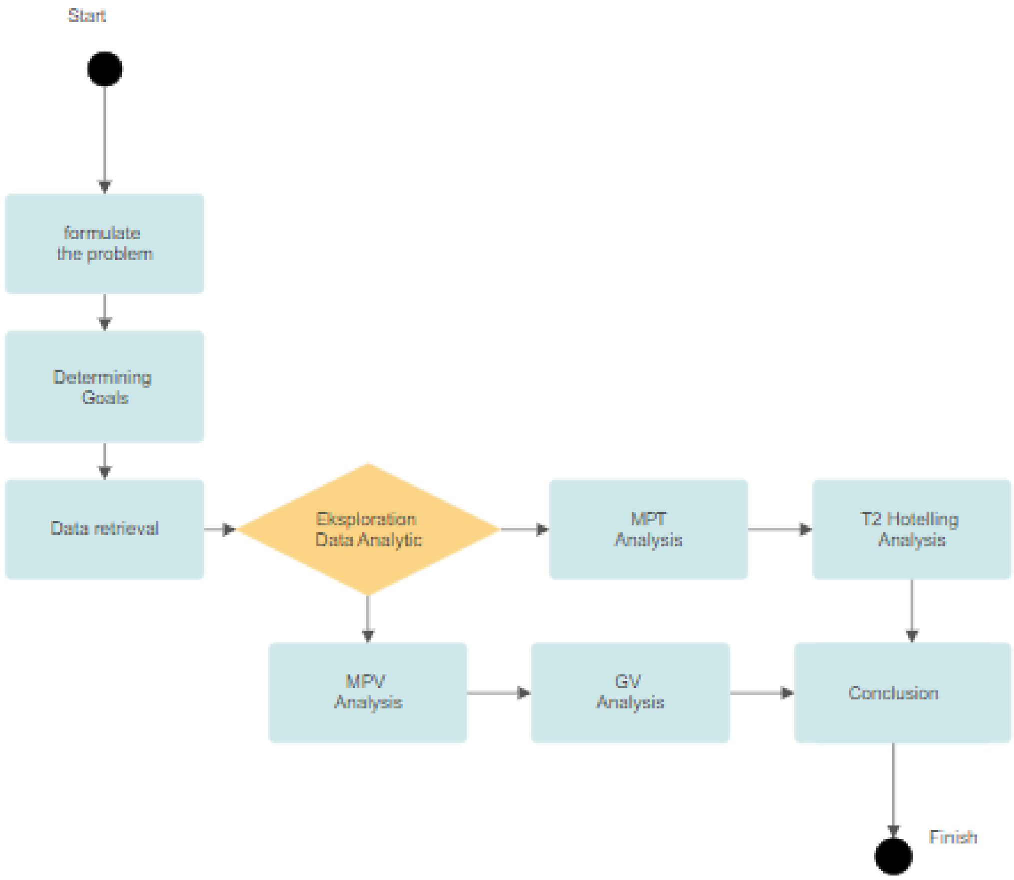

Fig. 1. Research flow diagram

After carrying out analytical data exploration, the research process is then divided into two stages, namely 1) The first stage of MPT control is carried out using a control chart based on T2-Hotelling statistics. 2) The second stage of MPV control is carried out using a Generalized Variance (GV) based control diagram.

The T2-Hotelling Control Diagram itself is a technique for using a graph to evaluate whether a process is under statistical quality control or not so that it can produce quality improvements (Imro'ah et al., 2017). If there are two or more variables that must be controlled simultaneously, then the control chart used is a multivariate control chart. One control diagram that can be used to control the mean vector of these variables is T2-Hotelling (Fitriyawan et al., 2019; Yuneidi et al., 2012). The T2-Hotelling control diagram is a diagram used to control the mean vector in a multivariate process. The control chart with the number of subgroups m=1 uses the T2-Hotelling Individual control chart. Meanwhile, if subgroup m > 1 then use the T2-Hotelling control chart with subgroups. The T2-Hotelling control diagram is used to control the process target parameters (MPT). The T2-Hotelling control chart is used to monitor process means which consist of more than quality characteristics. T2Hotelling is used to test the vector average of several variables that have multivariate properties and test whether there is a difference in the average of two vectors of several variables. The T2 Hotelling method is a technique used to monitor the average change of a process in the case of multivariate variables based on individual observations in quality control analysis (Maulana, 2023).

In simple terms, the first stage above begins with calculating the average of each characteristic, such as the average course grade, the average of all courses (grandmean) and then continues to calculate the variance covariance matrix of the two basic courses. The next step is to calculate the T2-Hotelling statistical value and also calculate the Upper Control Limit (UCL) and describe it.

The control procedures for the multivariate process target (MPT) are as follows (Djauhari & Herwindiati, 2022):

1. Take m independent subgroups.
2. Calculate the mean vector of each subgroup.
3. Calculate the total mean vector of all m subgroups (grand mean vector).
4. Centers the dub-group mean vector with respect to the total mean vector.
5. Calculate the covariance matrix for each subgroup.
6. Calculates the weighted average matrix of all sample covariance matrices.
7. Calculates the inverse matrix of the weighted average matrix.
8. Calculating T_k^2.
9. Calculate UCL for each subgroup.
10. Create a T^2 control chart.

In the second stage, the research developed control by controlling MPV using the Generalized Variance (GV) diagram. The GV diagram is a tool used to measure process variability where the data is multivariate (Prasetia & Sunendiari, 2019).

The GV Control Diagram is a tool used to measure process variability where the observation data is multivariate (Prasetia & Sunendiari, 2019). The GV diagram helps us to determine whether the process variability is operating in a controlled state or not. According to Montgomery, the GV control diagram is used to monitor control of variance. Process variance is written into the covariance matrix (Prasetia & Sunendiari, 2019).

The control procedures for multivariate process variability (MPV) are as follows:

1. Take m independent subgroups.
2. Calculate the mean vector in each subgroup.
3. Calculate the covariance matrix for each subgroup.
4. Calculates the weighted average matrix.
5. Calculates the determinant of the weighted average matrix.
6. Calculating $b_{1,k}$
7. Calculating $b_{2,k}$
8. Calculating b_7
9. Calculating b_8
10. Calculating UCLk
11. Create an IGV control diagram

RESULTS

In this research, the data used was 498 student grades or scores from two basic courses, namely English and Introduction to Logistics, spread across 20 classes (sub-groups). This research aims to see the quality of the learning process of the 20 sample classes using the T2-Hotelling control diagram and the Generalized Variance control diagram. Before testing, we must first carry out several activities such as descriptive analysis, normality test and correlation test for the two basic subjects that will become variables.

Descriptive analysis of data

In this descriptive analysis the author will describe the characteristics of the 20 classes that will be used as research samples. The number of subgroups (classes) m = 20 and the number of students (n) in each subgroup are presented in table 1. From this table we get N (total number of students) = 498 students

Table 1. Sub-group size data (class)

Class Number	n	Class Number	n
1	24	11	24
2	27	12	26
3	28	13	20
4	29	14	24
5	18	15	24
6	29	16	27
7	26	17	24
8	24	18	28
9	25	19	24
10	24	20	23

Based on the data in table 1, the distribution of students can be seen that the largest class is 29 students in class 4 and 6. And the class with the least number is 20 students in class 13. Next, let's look at the overall distribution of grades for the basic English course as shown in Figure 2, and the overall distribution of grades for the Basic Introduction to Logistics course in Figure 3.

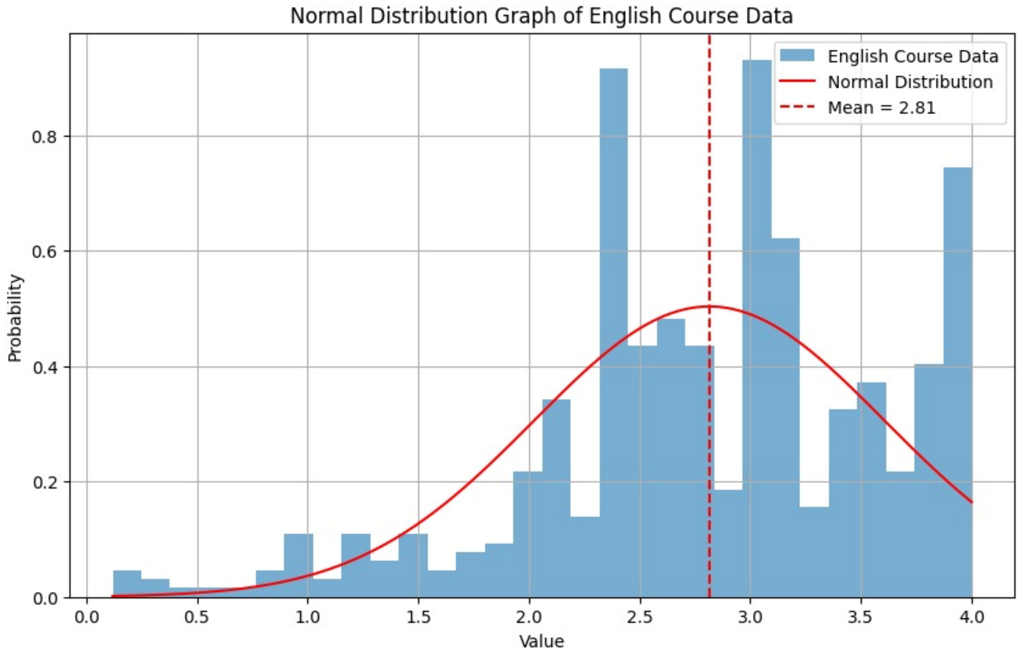

Fig. 2. Distribution graph for English course grades

In Figure 2, it can be seen that the English course grade graph tends to have negative skewness or the slope of the data distribution skews to the left, which means the average grade is less than the mode and median. It can be seen that the average value is 2.814920 while the mode is 4.0 and the median is 2.91. The skewness value of the graph in Figure 2 above is -0.668781994689723.

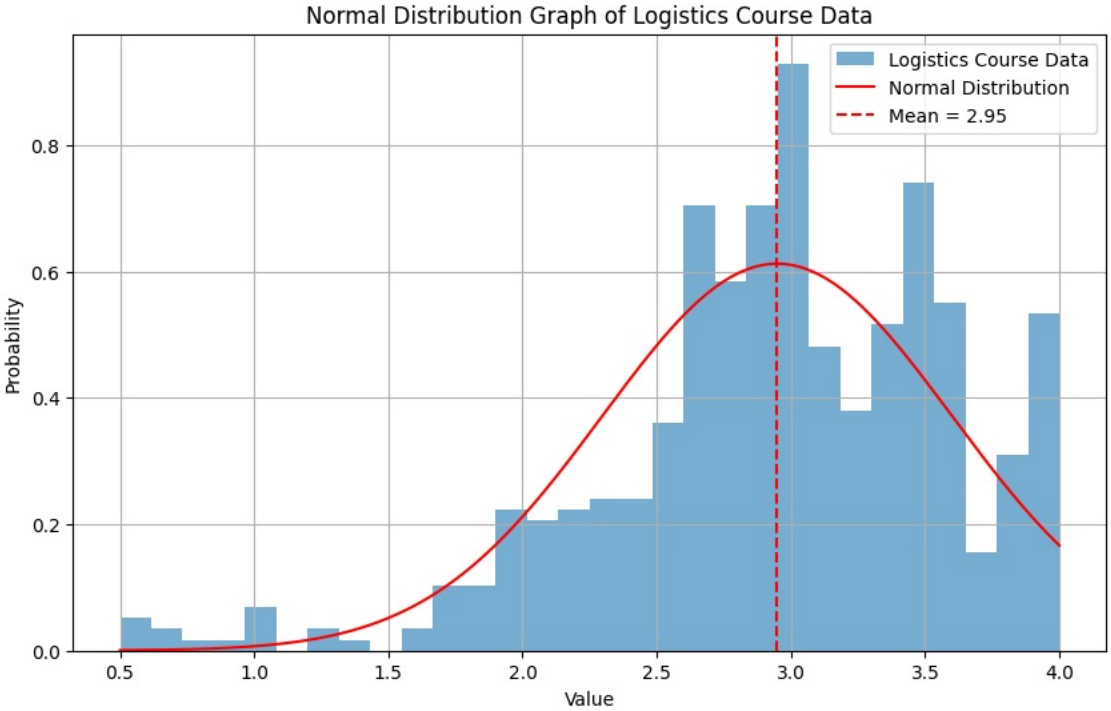

Fig. 3. Distribution chart for introductory logistics course grades

In Figure 3, it can be seen that the grades for the introduction to logistics course have a negative skewness too, the average value is 2.948815 while the mode is 4.0 and the median is 3.0. The skewness value of the graph in Figure 3 is -0.8543181592557508. In general, the behavior of data from 20 classes can be seen in Table 2.

Based on Table 2, for English scores it can be seen that the largest mean is 3.19 which comes from the 2nd class. Meanwhile, the smallest mean is 2.23 which comes from the 13th class. For the standard deviation value, the largest value is 1.04 which comes from the 20th class. Meanwhile, the smallest standard deviation is 0.48 which comes from the 7th class. The mean value shows the statistical measure used to represent the center of distribution, while the standard deviation is a statistical measure that measures the distribution of data. The higher the standard deviation value, the greater the data distribution. And conversely, the lower the standard deviation value, the smaller the spread or diversity of the data. For the introductory logistics score, it can be seen that the largest mean is 3.34 which comes from the 19th class, while the smallest mean value is 2.59 which comes from the 6th class. For the standard deviation value, the largest value is 0.78 which comes from the 3rd class. Meanwhile, the smallest standard deviation is 0.38 which comes from the 14th class.

Table 2. Data centering from 20 classes

Class	English Language						
	Mean	Max-min	SD	Median	Modus	Variansi	Skewnes
1	2.95	2.53	0.65	3.2	3.20	0.42	-0.78
2	3.19	3.14	0.72	3.3	3.07	0.52	-1.27
3	3.07	3.65	0.81	3.1	4.00	0.66	-1.32
4	3.12	3.00	0.73	3.1	3.93	0.54	-0.78
5	2.69	3.00	0.85	2.9	3.00	0.73	-0.16
6	2.66	3.19	0.57	2.8	2.38	0.33	-2.07
7	2.57	2.24	0.48	2.6	2.38	0.23	-0.45
8	2.46	1.88	0.50	2.4	2.38	0.25	-0.80
9	2.33	2.88	0.59	2.4	1.25	0.35	-0.09
10	2.80	2.95	0.71	3.0	3.07	0.51	-1.29
11	2.35	2.88	0.60	2.4	1.25	0.36	-0.14
12	2.93	2.88	0.65	3.0	3.07	0.43	-0.70
13	2.23	3.31	0.64	2.2	2.07	0.41	0.35
14	2.64	3.12	0.90	2.8	2.60	0.80	-0.78
15	3.01	3.87	0.89	3.3	3.63	0.79	-1.35
16	2.81	2.60	0.65	2.7	3.93	0.42	-0.15
17	3.06	3.49	0.80	3.1	3.00	0.64	-1.25
18	3.11	3.51	0.88	3.4	4.00	0.78	-1.16
19	3.10	3.88	0.88	3.4	4.00	0.78	-1.71
20	2.96	3.79	1.04	3.2	3.87	0.42	-1.05
	Introduction to Logistic						
Class	Mean	Max-min	SD	Median	Modus	Variansi	Skewnes
1	2.66	2.05	0.55	2.7	3.05	0.30	-0.34
2	3.06	2.04	0.57	3.2	3.00	0.32	-0.84
3	3.07	3.33	0.78	3.3	3.32	0.61	-1.80
4	3.04	2.84	0.59	3.1	3.58	0.35	-1.93
5	2.79	3.00	0.77	2.9	2.85	0.59	-0.73
6	2.59	3.28	0.60	2.7	2.71	0.36	-0.59
7	2.61	2.33	0.50	2.8	2.86	0.25	0.23
8	2.63	2.55	0.48	2.7	2.86	0.23	-3.52
9	2.75	2.37	0.51	2.7	2.86	0.26	0.87
10	3.02	2.00	0.52	3.1	2.00	0.27	-0.46
11	2.78	2.37	0.52	2.8	2.86	0.27	0.71
12	3.02	2.22	0.53	3.1	3.53	0.28	-0.67
13	2.72	3.07	0.62	2.9	3.05	0.38	-0.84
14	3.09	1.94	0.38	3.0	2.95	0.15	-0.06
15	3.19	3.46	0.76	3.4	3.96	0.58	-1.78
16	2.93	2.26	0.51	3.1	3.16	0.26	-0.44
17	3.28	3.00	0.71	3.5	3.79	0.51	-1.71
18	3.25	2.33	0.62	3.5	3.96	0.39	-1.21
19	3.34	2.00	0.54	3.5	4.00	0.29	-0.88
20	3.06	3.50	0.93	3.3	3.33	0.87	-1.33

Normality and correlation test

Before proceeding to the testing stage using the T2-Hotelling control diagram and GV control diagram, the sample data needs to be tested for Kolmogorov-Smirnov normality. The hypothesis used is as follows:

H_o = Normally distributed data

H_1 = Data is not normally distributed

Significant level: $\alpha = 0.05$

Table 3. Data centering from 20 classes

Subject	KS Count	P *Value*	α	Decision
Englih Language	0.8742354777909159	0.00	0.05	Reject H_o
Introduction to Logistik	0.921658486248563	0.00	0.05	Reject H_o

Because the calculated value above has a conclusion of rejecting H_o, the data does not follow a normal distribution, the correlation test produces a Pearson correlation coefficient of 0.610038172254252, with P Value: 4.3252896481369556e-52, it is concluded that there is a significant correlation between the English language value and the Introduction to Logistics value.

Process target control using T2-hotelling control chart

In this section, the results will be described based on the steps in the T2-Hotelling procedure. This control is carried out in 2 stages. In Stage 1, a T2 control diagram is produced as in Figure 4.

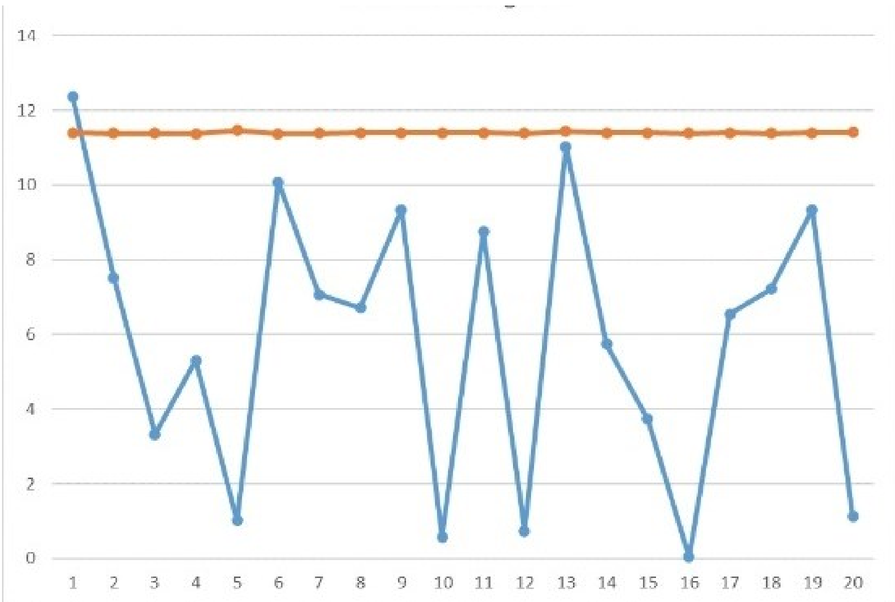

Fig. 4. T2 Control diagram

In stage 2, a process capability analysis is produced on the T2 control chart. It can be seen that there is one observation that is out of control in the 1st observation, so that 95% of observations are within control limits. From the explanation above, it can be seen that in the T2 control chart there is 1 class that is outside the control limits. The following is an explanation of the characteristics of the grades for English and Introduction to Logistics courses from students in class 1.

Table 4. Score data for all 1st class subjects

Student	English Language	Introduction to logistics	Student	English Language	Introduction to logistics
1	3.20	3.05	13	3.20	3.42
2	3.53	3.37	14	2.57	1.42
3	3.53	3.42	15	3.93	3.47
4	3.10	3.05	16	3.60	3.11
5	3.10	2.74	17	1.40	1.96
6	3.33	3.16	18	1.69	1.86
7	3.50	2.58	19	1.94	2.30
8	3.29	2.69	20	3.57	2.58
9	2.80	2.65	21	2.60	2.38
10	2.27	2.04	22	2.50	2.00
11	3.27	3.00	23	3.60	2.95
12	2.27	2.26	24	3.00	2.46

Based on Table 4, it can be seen that the mean scores for English and Introduction to Logistics in Class 1 are 2.95 and 2.66. So it can be concluded that there is a low average score for both courses in Class 1 which causes out of control.

Controlling process variability using generalized variance (GV) control charts

In this section, the results will be described based on the steps in the GV procedure. This control is carried out in 2 stages. In Stage 1, a data plot of GV and UCL values is produced on the same diagram as in Figure 5.

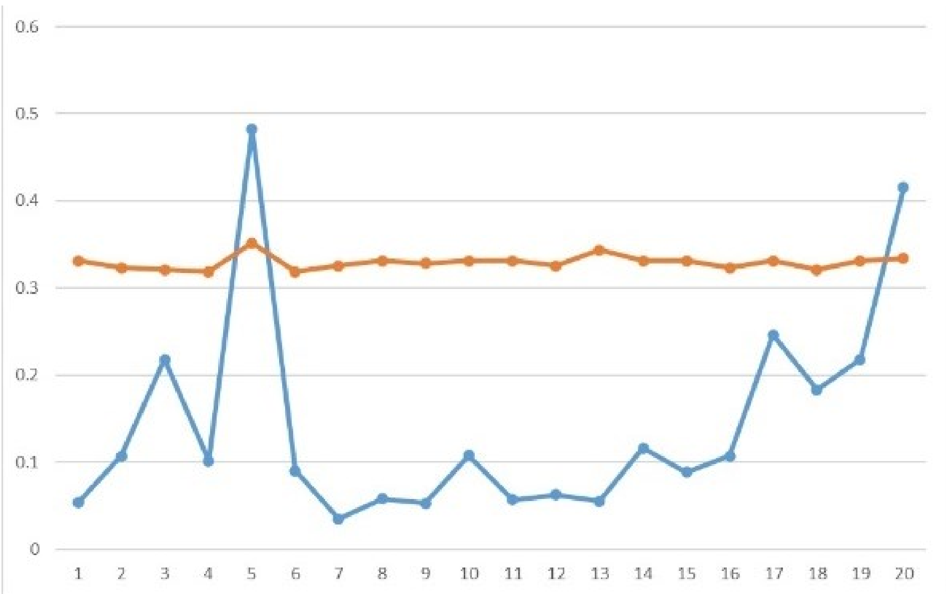

Fig. 5. IGV control diagram

In stage 4, a process capability analysis is produced on the IGV control chart. It can be seen that there are two observations that are out of control in the 5th and 20th observations, so that 90% of observations are within control limits. From the explanation above, it can be seen that in the course IGV control chart there are 2 classes that are outside the control limits. The following is an explanation of the characteristics of the grades for English and Introduction to Logistics courses from students in class 5 and class 20.

Table 5. Score data for all 5th class subjects

Student	English Language	Introduction to logistics	Student	English Language	Introduction to logistics
1	3.00	2.85	10	3.00	3.60
2	1.00	1.00	11	3.75	1.30
3	1.47	2.68	12	4.00	2.92
4	3.10	2.63	13	4.00	2.25
5	3.53	3.11	14	1.94	2.14
6	1.83	4.00	15	2.05	3.55
7	2.47	2.91	16	2.05	2.72
8	3.07	2.26	17	2.10	3.39
9	3.35	3.33	18	2.73	3.64

Table 6. Score data for all 20th class subjects

Student	English Language	Introduction to logistics	Student	English Language	Introduction to logistics
1	3.87	3.38	13	3.37	3.95
2	3.82	3.50	14	3.58	3.85
3	3.71	3.96	15	2.33	2.00
4	3.95	3.33	16	1.04	2.17
5	3.95	3.29	17	3.00	3.33
6	2.67	4.00	18	0.21	1.00
7	3.87	3.63	19	3.18	3.62
8	1.29	2.15	20	2.00	2.15
9	4.00	3.04	21	3.82	3.83
10	2.63	3.23	22	2.08	0.50
11	3.00	3.42	23	4.00	3.79
12	2.82	3.21			

Based on Table 5 and Table 6, it can be seen that the variance in grades for English and Introduction to Logistics courses in Class 5 is 0.73 and 0.59 and in Class 20 is 1.08 and 0.87. So it can be concluded that there is high variance for the two courses in both classes which causes out of control.

DISCUSSION

The quality of learning has an important role in producing quality education, so measuring and analyzing the quality of learning is very important because it can provide information about the extent to which educational goals are achieved and how effective the learning process is, we can also find out the weaknesses and strengths of existing educational programs, and determine corrective actions that need to be taken to improve the quality of education. By measuring the quality of the teaching and learning process, we can control the effectiveness of learning and become the basis for creating appropriate programs and policies. This quality measurement process should become a routine agenda in universities, the results obtained can be very valuable input so that it can improve the quality of learning, both for students, lecturers and the learning methodology used. Of course there needs to be structured efforts to improve the quality of the learning process (Imro'ah et al., 2017).

As mentioned in the previous article, the aim of this research is to measure the quality of the learning process that has taken place, the results of this research can help institutions in making decisions and following up on classes that are classified as out of control classes. In this study, there were 20 classes sampled with a total of 498 students, because each class has a different number of students, the sampling scenario used was a non-constant subgroup-based sampling scenario. This type of sampling scenario is a new type of scenario (Djauhari & Herwindiati, 2022). Measuring process quality in the service sector such as education is a measurement that is rarely carried out considering the number of samples can change at any time, in contrast to control in the industrial sector which tends to have more stable output. So in this research the most obvious contribution is the effort to enrich the application of process quality measurements using multivariate statistical process control in subgroups whose sizes are not constant.

The findings obtained from this research are that of the 20 classes sampled, there is 1 class that is out of control based on Multivariate Process Target (MPT) calculations using the T2 Hotelling control diagram, namely class 1. Measurement of the vector mean of this population indicates that there is significant differences from class 1 to other classes. Some possibilities that we can discuss are changes in process characteristics or behavior which will have an impact on quality. If not treated early, this anomaly can result in unstable fluctuations beyond the desired control limits. Miliana Erpianti in her research stated that the T2 Hotelling results also indicated that the learning process had not been carried out as expected and needed to be improved (Erpianti et al., 2020).

In Multivariate Process Variability (MPV) calculations using a Generalized Variance (GV) based control chart. The findings obtained from this research were that of the 20 classes sampled, there were 2 classes that were outside of control, namely class 5 and class 20. The results of this measurement indicated that there were significant changes or variations in several of the variables observed. The next step after detecting an "out of control" condition usually involves further investigation to identify the cause of the change or variation. Further analysis, including examination of possible contributing factors, may assist in determining necessary corrective or remedial action. Further research can be carried out by also analyzing the process capability index used to see whether the learning process is capable or not (Lestari, 2021).

CONCLUSION

The conclusion that can be given is that in descriptive analysis it was found that the dominant sample data had negative skewness, which means the average value was smaller than the average value. mode and median. In the Multivariate Process Target (MPT) calculation using the T2 Hotelling control diagram, it was found that class 1 was out of control. Meanwhile, in calculating Multivariate Process Variability (MPV) using a Generalized Variance (GV) based control diagram, it was found that classes 5 and 20 were out of control. Tracing the root causes of out of control is a part that must be explored by study program and university leaders in an effort to improve the teaching and learning process.

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