A STUDY ON DIFFERENT CONTROL CHARTS TO MONITOR STUDENTS' ACADEMIC PERFORMANCE

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A project report submitted in partial fulfilment of the requirements for the award of Master of Mathematics

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"A STUDY ON DIFFERENT CONTROL CHARTS TO MONITOR STUDENTS' ACADEMIC PERFORMANCE"** was prepared by **ONG JING YING** has met the required standard for submission in partial fulfilment of the requirements for the award of Master of Mathematics at Universiti Tunku Abdul Rahman.

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ABSTRACT

In recent years, control charts are increasingly adopted in educational field as a statistical control approach in monitoring students' academic performance due to simplicity and reliability. This paper presents $\bar{X}$ and s charts as useful statistical tools to monitor students' academic performance based upon the assessment practices. The points fall beyond the upper control limits signify extraordinary performance by students whereas the points falling below lower control limit signal the poor performance by students where both scenarios are regarded as out-of-control. The purpose of this paper is to identify which students' performance appeared to be out of control so that appropriate measure can be provided to students for quality improvement in learning outcomes. This study enables academicians to set up a feasible benchmark limit in attaining the state of statistical control and identify when there is significant change on students' academic performance. Thus, academicians are able to provide suitable teaching approaches as well as strategies and adapt it to the identified learning preference and characteristics of students to enhance the educational process.

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LIST OF SYMBOLS / ABBREVIATIONS

$\bar{X}$	average of measurements
$\bar{\bar{X}}$	average of averages
n	number of subgroups
σ_0	population standard deviation
A_3	factor used to calculate control limits for $\bar{X}$ chart
B_3, B_4	factors used to calculate control limits for s chart (no standard given)
B_5, B_6	factors used to calculate control limits for s chart (standard given)
UCL	upper control limit
LCL	lower control limit
CL	center line

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

1.1.1 Academic Performance

In today's world, academic performance is a vital key to a successful life. Having a good academic performance will achieve better employment opportunities with higher earnings in the workplace. On the contrary, without academic excellence, one will encounter the difficulties in searching for jobs in the competitive world at work and this leads to a rise in the unemployment rate. Therefore, it is imperative that students' academic performance should be consistently monitored in order to produce well-qualified graduates that make a valuable contribution in dynamic labour market. Concisely, academic performance is a good indicator of success in life as it provides for quality conformance and quality assurance. Mok, K.H. (2011) stated that quality assurance is meant by systematic management, assessment practices and review procedures adopted by universities to safeguard quality or standards in education institutions.

Academic performance is evaluated through assessments that are comprised of test, assignments and final examination. The marks allocation for each assessment will be constituted to the final mark which is then allocated accordingly to its respective grades and grade point average (GPA) using standardized grading system. As a matter of fact, the academic performance of students are varied from semester to semester, thus it establishes a need for statistical process control to monitor the students' academic performance.

1.1.2 Brief History of Quality Control

Control chart is recognised as one of the commonly used statistical process control (SPC) tools to monitor the variation of students' academic performance and to attain the state of statistical control. Control chart was a graphical tool originally introduced by physicist Shewhart (1920) that created the basic concept of statistical quality control in the manufacturing industry in order to ensure the quality of manufactured products by reducing variations that exist in the process design. However, both the statistical quality control and the statistical control chart have received little attention due to lack of understanding in conducting successful implementation of SPC into manufacturing field.

The idea of statistical quality control has been further developed by Deming (1986) by introducing PDCA (Plan-Do-Check-Act) Cycle and total quality management (TQM). PDCA cycle, commonly also known as Deming cycle is a continuous improvement cycle which enables management in stabilizing and improving processes, products or services. The implementation of quality culture and quality principles into process management has been summarized into 14 key points of TQM by Deming (1986). Since then, the application of statistical quality control and control charts has been widely adopted in the industry and lately become quite pervasive among educational institutions.

1.1.3 Statistical Process Control (SPC)

1.1.3.1 Definition of SPC

According to Montgomery (2009), statistical process control is defined as "a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability". From the point view of the education, SPC is enacted for the purpose of monitoring educational process such as retention-progression-graduation as it is used to make sense of any process or outcome measured over time to guarantee process stabilization and performance improvement by prevention of non-conformance rather than ex post detection (Montgomery, 2000).

1.1.3.2 Common Causes and Assignable Causes

In fact, variation always exists in the production process regardless of how well of the design or maintenance of the manufactured product. The variation in the outcome of a process can be either due to common (chance) causes or assignable (special) causes. A process is said to be in statistical control when it only consists of common causes of variation that influence the quality of output (Lewis and Smith, 1994). A process is described as being out of control whenever the output quality is affected by assignable causes (Montgomery, 2009). From the perspective of education, common causes of variation in the students' academic performance is greatly contributed by students' knowledge, for instance, students' learning attitude, level of comprehension, level of preparation for exams and so on. Meanwhile, assignable causes of variation can be attributed to a sudden change in the required prerequisites for subject taken, teaching method and management' objectivity.

1.1.3.3 Interpretation of Out of Control

In general, there is a significant difference in the interpretation of control charts between manufacturing industry and the educational sector. For the manufacturing industry, if there are one or more points plotted outside the control limits, the process is described as being out of control which is an unacceptable scenario that requires a remedial action to be put in place to reduce the process variation. The meaning of out of control concept varies when it applies to the educational sector. For educational sector, an observation that exceeds upper control limit indicates that the extraordinary performance by the student while an observation below the lower control limit implies that the poor performance by the student. In this case, management should investigate the assignable cause for the low academic performance and come up with corrective action to improve the students' performance.

1.1.4 Summary

In essence, students' academic performance should be monitored constantly and consistently in every educational institution using control chart so that shifts in the process average can be detected and the appropriate remedial action will be carried out such that the student will be given a constant supervision of academic advisor. As a result, the student is more capable to overcome the academic obstacles, enhance academic performance and achieve success in life.

1.2 Importance of the Study

It is apparent to all that students represent the most valuable product in every educational institution as they will become the backbone of the nation in future. Therefore, keeping an eye towards students' academic performance at all times plays a vital role to ensure a qualified output being produced through the educational system. In this manner, control charts are recognized as one of the most useful monitoring mechanism in relation to the students' academic performance. The application of control charts will be able to set up meaningful benchmarks for academic performance and identify students who are at risk to perform poorly on a programme of study in the early stage due to the assignable causes. Academicians are able to come up with more effective teaching approaches and guidance system that well suit the students. For instances, provide constant supervision, change teaching style that adapts the students' learning, give more assessment practices, etc. This helps to improve students' academic performance while attempting to decrease failure rate to a significant level and allows qualified graduates with great achievement in academic success being generated through implementation of regular monitoring of students' academic performance by control charts.

1.3 Problem Statement

Malaysia Education Blueprint 2015–2025 (Higher Education) was established by the Ministry of Education in year 2013 with the objective to upgrade the Malaysian education standard to international level. The improvement in quality, equity and assess in education is achieved through an efficient education system which will then equip graduates with necessary skills to compete in the modern 21st century. Thus, the quality of education has become one of the challenges encountered by every education institution in which they are forced to maintain the ability to produce high quality education to occupy a space in an increasingly competitive education world. The quality of education can be assessed through students' academic performance by examining whether students' performance are in statistical control. This establishes a need to develop a statistical tool in monitoring students' academic performance for quality assurance. This study will focus on the application of control charts as a measuring tool for academic performance.

1.4 Aims and Objectives

The aim of this research is to investigate the use of different control charts as statistical control device in monitoring students' academic performance. To accomplish the goal of this research, two objectives are established as follows:

i. To determine out-of-control academic performance by identifying any observation exceeding control limits due to assignable causes.

ii. To enhance the quality of academic performance and ensure the quality of education.

1.5 Contribution of the Study

In particular, this research demonstrates the value of control chart as a useful monitoring device in assessing students' academic performance in educational sector. Education institution will be aware of out-of-control academic performance due to special causes and corrective actions could be taken to reduce the non-completion rates. This ensures the efficiency in the academic progress that is caused by enhancement of retention-progression-graduation. The developed performance monitoring control chart has a lot of advantages towards education sector as it helps to provide convenience to academic staffs by reducing time and efforts in monitoring students' academic performance. Education institutions are able to reap benefits by cutting down material resources and money such as the costs associated to assessments. In essence, the quality control of the academic performance is maintained through proper monitoring which in turns improves the quality of education. A quality education provides for smooth flow of qualified graduates into industrial workforce and also prepares them to sustain in the intense competitive world. An efficient and qualified workforce drives productivity and participation in the labour force which resulting to increased economic growth and national development.

CHAPTER 2

LITERATURE REVIEW

2.1 Statistical Process Control (SPC) Tools

SPC aims to produce superior quality manufactured goods in the most economic and useful way and continually improves the entire production lifecycle. A number of SPC tools have been developed to assess students' learning outcomes and allow high quality graduates to be generated. In general, there are seven basic quality control tools namely "Magnificent Seven", for example: histogram, pareto chart, check sheet, control chart, Ishikawa diagram, process flow chart and scatter diagram (Ishikawa, 1985). Among SPC tools, control charts are the most commonly used tool to detect any positive or negative shift of the process parameters value from its in-control value which signal the outperformance or poor performance by students respectively. This is due to its simple graphical illustration of the process behavior which allows the interpretation becomes easier. Evans and Lindsay (1999) found that the control chart is a very useful process monitoring technique to indicate the presence of unusual variations when the sample points are plotted outside the control limits.

2.2 Control Charts

Typically, a control chart consists of a center line, an upper control limit (UCL), and a lower control limit (LCL). Any point that exceeds the UCL and below the LCL implies that an out-of-control process caused by unusual variations within a system. It is customary practice to set the UCL and LCL of the control chart as 3 times of process standard variation (sigmas) away from the baseline which was first suggested by Walter A. Shewhart which has been applicable in industry field for many years.

The most common of control charts are Shewhart charts in which they are named after Walter A. Shewhart due to its simple interpretation and implementation based on the two assumptions (Savić, 2006). Firstly, data are assumed to be independent and identical distributed (process where the data being obtained is stable). Secondly, data is assumed to follow a normal distribution. Shewhart control charts can be classified into control charts for variables and attributes respectively. Control charts for variables are used to monitor characteristics that is measurable such as length, weight and diameter which belong to continuous data whereas control charts for attributes are used to monitor characteristics that is countable such as number of nonconforming or defective unit and nonconformities which belong to discrete data (Marilyn and Robert, 2007). The examples of control charts for variables are $\bar{X}$, *R*, and *s* while control charts for attributes are *p*, *np*, *u* and *c*. For each chart, three criteria must be taken into consideration before plotting the graph: the size of the sample, frequency of the sample being drawn, the computation of the center line and the control limits. Montgomery (1985) pointed out that the chance to detect any variation in the process increases with the size of the sample.

Basically, Shewhart charts are useful in detecting large shifts in the process mean and variance reasonably quick due to their small out-of-control average run length (ARL). However, they are less effective in detecting small shifts such that large number of false alarms are being generated resulting in less accuracy of the results. In this case, Cumulative Sum (CUSUM) and Exponentially Weighted Moving Average (EWMA) charts might be a preferable choice to detect small shifts. CUSUM charts were originally invented by Page (1954) while EWMA charts were introduced by Roberts (1959) in which both of them claimed that their charts have higher sensitivity in determining small shifts in the process average as compared to the standard Shewhart charts. The detailed descriptions about the construction and application of CUSUM and EWMA charts were provided by Woodall (2006).

Additionally, Shewhart control charts are suitable to use for normally distributed data but not for non normal and correlated data due to presence of massive false alarms. (Wardell, et al., 1992; Montgomery, 1996; Zhang, 1998; Borror, et al., 1999). Also, in the study of Maul et al. (1996), he noted too many false alarms were being generated by implementing Shewhart control charts in welding process. They have figured out that the screening process and sampling rate should be revised to reduce the false alarm rate without considering data characteristics and assumptions of control charts. Inappropriate use of the Shewhart charts tend to cause misplacement of unmeaning control limits which lead to a defective charting scheme that greatly affects the efficiency of monitoring process. It turns out that CUSUM and EWMA charts are able to overcome this situation due to their robustness of non-normally distributed data with correlation (Montgomery and Mastrangelo, 1991; Wardell, et al., 1992; Montgomery, 1996; Zhang, 1998; Borror, et al., 1999). The other control charts such as residuals and ARIMA models (Box, et al., 1994), multivariate $(TC)^2$ chart (Nijhuis, et al.,1999) are also recommended for these situations.

Generally speaking, control charts can be categorized into two groups, i.e. univariate and multivariate charts. Shewhart, CUSUM and EWMA charts are part of the univariate control charts in which they are ideal in detecting which variable signalled the out of control situation (Montgomery, 1996). On the other hand, multivariate control charts are applicable when there are at least two characteristics of the inspection item are being monitored (Pillet, et al., 2013). The examples of the multivariate control charts are chi-square (χ^2), Hotelling T^2, multivariate CUSUM and multivariate EWMA charts (Montgomery, 1996). Montgomery (1996) suggested that univariate control charts should be used along with the multivariate control charts in conducting root cause analysis to find out whether the variation in process is caused by special causes.

2.3 Application of Control Charts

For many decades, the application of control charts is widely used in manufacturing industry since it was first introduced by Walter A. Shewhart to assess and assure the quality of manufactured goods (Shewhart, 1931). A variety of new approaches and applications of control charts have been developed for process control and improvement purpose since then. Nowadays, SPC has gained worldwide attention and been adopted in many manufacturing or a production facility around the world in order to deliver high quality products and services to the customers (Montgomery, 2009). De Vries and Reneau (2010) gave an overview of the control chart methods to detect changes in animal production systems. Moreover, Stewart et al. (2011) showed how feasible the non-traditional control limits in quality control of feed management on dairy farms and how it facilitated in management decision making. The use of control charts was demonstrated in monitoring the machining process of the inside diameter of a steel cylinder to ensure the conformance of products to design specifications (Maia, et al., 2011). Annalakshmi (2013) applied the control chart into process monitoring of manufacturing industry to maintain the quality of products and services.

However, the utility of statistical quality control chart has not deeply penetrated in services industry due to lack of awareness and understanding on conceptualization of service quality monitoring which was discussed in a study by

Sulek (2004). She also has discussed the use of a system framework such as multivariate control charts for assessing service quality standards as well as the respective potential misapplication. Indeed, a large body of literature concerning statistical control chart techniques for quality monitoring purpose in services areas has been described by MacCarthy and Wasusri (2002).

In the recent years, there is an upward trend in the application of control chart in the service industry especially in education. In fact, numerous empirical studies on implementation of control charts in monitoring students' academic performance have been conducted. Marcucci (1985) introduced the use of a control statistic similar to a chi-squared statistic which was subsequently used by Edwards, Govindaraju and Lai (2007) in evaluating students' grade to detect any existence of assignable cause variations. Bakir and McNeal (2010) demonstrated the use of nonparametric control chart based on signed-ranks which was first advocated by Bakir (2004) to monitor students' GPAs with the condition that the distribution of GPAs should be symmetrical. A research had conducted by Mirko Savić (2006) to investigate the use of p chart in grading process control of high educational system. Ding and Verma (2006) illustrated the statistical process control-based methods by comparing three control charts for monitoring teaching performance as measured by student evaluation scores and revealed that modified p chart is the best approach due to its simplicity and appropriate distribution for categorical data. In addition, Shewhart control charts were implemented as the means of quality control monitoring in a large-scale educational assessment program (Schafer, et al., 2011). Research by Hanna, Raichura and Bernardes (2012) discovered that the establishment of statistical control helps detecting the special causes of variability to the educational process, identifying the workable instructional issues, consequently improving academic progression on retention, progression and graduation. Akinrefon and Balogun (2014) have presented the use of Shewhart control chart procedure as process monitoring tool in students' academic performance. Furthermore, the application of p-chart was studied to monitor students' failure rate in tertiary educational system for the statistical control of teaching/ learning process (Braimah and Abdulsalam, 2015). Okwonu and Ogini (2017) presented $\bar{X}$ and s control charts approach to assess the academic performance through examining the causes that lead to the fluctuation of students' performance.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This study was conducted in Universiti Tunku Abdul Rahman (UTAR) located at Malaysia while the respondents of the study were selected from the Department of Mathematical and Actuarial Sciences (DMAS) students during May intake of 2018. The dataset which consists of total 129 observations were obtained from the records of students' test scores in the Probability and Statistics I subject. Internal assessments which include class test marks, assignments and final exam are used as quantitative attributes to monitor the students' performance by observing the pattern of test scores using control charts.

This section presents the procedures undertaken to create the statistical quality control limits of different control chart in monitoring students' performance over time. In this research, the variable of interest will be test scores of students. The measurement data of samples are employed when a quantitative process variable is studied and it then forms a subgroup. The simple illustration of a control chart is shown in Figure 3.1.

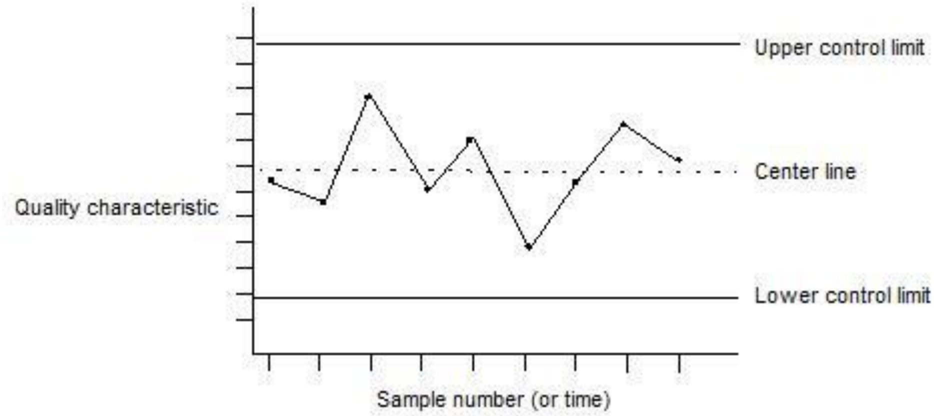

Figure 3.1: Quality Control Chart Example

Typically, a control chart is constructed by plotting quality characteristics of the subgroups (scores) against time. A control chart is comprised of a center line which represents process average performance or process mean and two control limits, i.e. upper control limit (UCL) and lower control limit (LCL) which represent the maximum and minimum allowable range at which the process is in a state of control in correspondence to common cause variations only. Any point that is plotted outside the control limits indicates that the process is out of control and hence assignable causes of variation should be examined and eliminated, followed by a remedial action. In this manner, the observations falls below the LCL signal a decline in students' performance while the observations falls above the UCL indicate an improvement in performance.

In this section, we will look into the application of different control charts in establishing meaningful benchmarks for academic performance and identify when a significant change in students' performance has occurred by looking into the extent of performance in either positive or negative directions. This application of $\bar{X}$ and s charts will be discussed in terms of the accuracy and consistency of academic performance with the goal of improving the quality of academic performance.

In practice, the control limits are set at plus or minus three standard deviations from the center line (overall mean) which are also known as three-sigma limits. Shewhart proposed that three-sigma limits should be applied in the statistical quality control with the justifications that they remain effectiveness when being implemented into real world statistics while reducing economic loss to the least. The selection of control limits should be based on the standard given since the study consists of entire population which are represented by a total of 129 students.

3.2 $\bar{X}$ and s Charts

$\bar{X}$ and s charts are widely recognized as Shewhart variables control charts in control over both the mean and variation of a process when measuring subgroups at regular intervals from a process. A study by Montgomery (2013) revealed that $\bar{X}$ and s control charts are a better choice for sample size of subgroup that is greater than 10, or when the sample size n is represented as a variable instead of $\bar{X}$ and R control charts. The plotting and analysis of $\bar{X}$ and s control charts are viewed as pairs as $\bar{X}$ chart are utilized to monitor process mean while s chart are utilized to monitor the process variability (standard deviation). Both $\bar{X}$ and s control charts have employed the control limits to determine the shift of the process in either positive or negative directions.

Let X_{ij} represents observations in the j^{th} sample of the i^{th} subgroup, i = 1, 2, . . . , and j = 1, . . . , n; where n is the size of the subgroups. The Shewhart $\bar{X}$ control chart illustrates a time sequence plot of the averages $\overline{X_\iota}$ rational subgroups which consists of a center line (CL) and two control limits denoted by upper control limit (UCL) and lower control limit (LCL). When the standard deviation is known, the general formulas for the control limits of Shewhart control chart are given by:

$$\text{UCL} = \bar{\bar{X}} + z\frac{\sigma_o}{\sqrt{n}} \tag{3.1}$$

$$\text{CL} = \bar{\bar{X}} \tag{3.2}$$

$$\text{LCL} = \bar{\bar{X}} \; - z\frac{\sigma_o}{\sqrt{n}} \tag{3.3}$$

where

$\bar{\bar{X}}$ = the average of the sample means

z = standard normal variable (2 for confidence interval of 95.44% , 3 for confidence interval of 99.74%)

$\frac{\sigma_o}{\sqrt{n}}$ = standard deviation of the distribution of sample means

The above variables can be computed as follows for easy understanding.

$$\bar{\bar{X}} = \frac{\sum_i^n \overline{X_\iota}}{n} \tag{3.4}$$

$$\sigma_o = \sqrt{\frac{\sum_i^n (X_i - \mu)^2}{n}} \tag{3.5}$$

Suppose that $\overline{X_\iota}$ is normally distributed with mean μ and variance $\frac{\sigma^2}{n}$,

$$\bar{X}_i \sim N(\mu\,, \frac{\sigma^2}{n})$$

the established 3-sigma control limits for the $\bar{X}$ chart are computed using the formulas:

$$\text{UCL} = \bar{\bar{X}} + 3\frac{\sigma_o}{\sqrt{n}} \tag{3.6}$$

$$\text{CL} = \bar{\bar{X}} \tag{3.7}$$

$$\text{LCL} = \bar{\bar{X}} - 3\frac{\sigma_o}{\sqrt{n}} \tag{3.8}$$

For an unknown standard deviation, an unbiased estimate of σ_o is represented by $\frac{\bar{s}}{c_4}$ given that $A_3 = 3\frac{c_4}{\sqrt{n}}$, therefore 3-sigma limits for $\bar{X}$ chart can be computed as follows:

$$\text{UCL} = \bar{\bar{X}} + 3\frac{\sigma_o}{\sqrt{n}} = \bar{\bar{X}} + 3\frac{\bar{s}}{c_4\sqrt{n}} = \bar{\bar{X}} + A_3\bar{s} \tag{3.9}$$

$$\text{CL} = \bar{\bar{X}} \tag{3.10}$$

$$\text{LCL} = \bar{\bar{X}} - 3\frac{\sigma_o}{\sqrt{n}} = \bar{\bar{X}} - 3\frac{\bar{s}}{c_4\sqrt{n}} = \bar{\bar{X}} - A_3\bar{s} \tag{3.11}$$

On the other hand, the 3-σ control limits of s chart given the standard deviation can be calculated as follows:

$$\text{UCL} = c_4\sigma_o + 3\sigma_o\sqrt{1 - c_4{}^2} = \left(c_4 + 3\sqrt{1 - c_4{}^2}\right)\sigma_o = B_6\sigma_o \tag{3.12}$$

$$\text{CL} = c_4\sigma_o \tag{3.13}$$

$$\text{LCL} = c_4\sigma_o - 3\sigma_o\sqrt{1 - c_4{}^2} = \left(c_4 - 3\sqrt{1 - c_4{}^2}\right)\sigma_o = B_5\sigma_o \tag{3.14}$$

Let s_i represents standard deviation of i^{th} sample where m preliminary samples are selected with each of size n. The average of m standard deviations can be denoted as:

$$\bar{s} = \frac{\sum_i^m s_i}{m} \tag{3.15}$$

For a normal distribution, suppose an unbiased estimate of σ is represented by $\frac{\bar{s}}{c_4}$ which is indicated by $E\ (\sigma_{\bar{X}}) = E(\frac{\bar{s}}{c_4}) = \frac{1}{c_4}\ E(\bar{s}) = \sigma$. Therefore, the standard deviation s is derived as $\sigma\sqrt{1 - c_4{}^2} = \frac{\bar{s}}{c_4}\sqrt{1 - c_4{}^2}$ for s chart given that $B_4 = 1 + \frac{3}{c_4}\sqrt{1 - c_4{}^2}$ and $B_3 = 1 - \frac{3}{c_4}\sqrt{1 - c_4{}^2}$, the established control limits for the s chart are derived as follows:

$$\text{UCL} = \bar{s} + 3\frac{\bar{s}}{c_4}\sqrt{1 - c_4{}^2} = \bar{s} + 3\frac{\bar{s}}{c_4}\sqrt{1 - c_4{}^2} = (1 + \frac{s}{c_4}\sqrt{1 - c_4{}^2})\bar{s} = B_4\bar{s} \tag{3.16}$$

$$\text{CL} = \bar{s} \tag{3.17}$$

$$\text{LCL} = \bar{s} - 3\frac{\bar{s}}{c_4}\sqrt{1 - c_4{}^2} = \bar{s} - 3\frac{\bar{s}}{c_4}\sqrt{1 - c_4{}^2} = (1 - \frac{s}{c_4}\sqrt{1 - c_4{}^2})\bar{s} = B_3\bar{s} \tag{3.18}$$

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Application of $\bar{X}$ and s Charts (using 3σ limits)

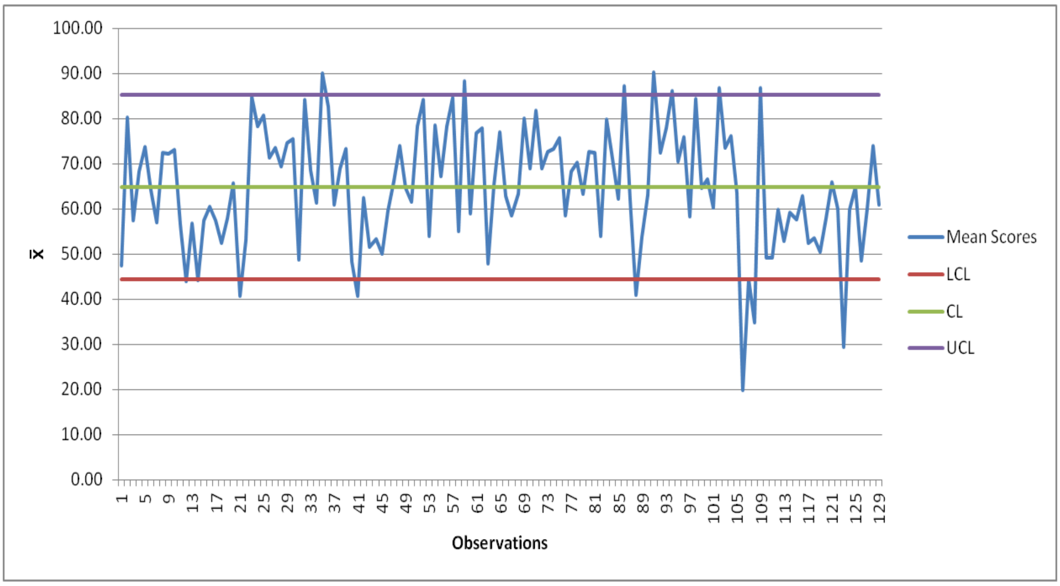

Figure 4.1: $\bar{X}$ Control Chart for Assessment Marks

Figure 4.1 demonstrates the $\bar{X}$ chart for average marks based on test 1, test 2, assignment and final exam where center line (CL) = 64.87, upper control limit (UCL) = 85.28 and lower control limit (LCL) = 44.47. Here, the control limits are calculated using equations [3.6], [3.7] and [3.8]. Due to unequal weightage allocated in test 1, test 2, assignment and final exam, we first convert each of the assessment mark to 100% and then calculate the average of these four assessment marks for each student.

It can be observed that 35th, 59th, 86th, 91st, 94th, 102nd, 109th points are plotted above the UCL. This reveals that 7 out of total 129 students' average assessment mark are outstanding. Meanwhile, there are nine points falling below the lower control limit which indicate that nine students are not well performed in their assessment. This implies that there is existence of unusual process variations and lack of control on students' academic performance.

Overall, we can conclude that approximately 5 % of the students are well performed while 7 % of the students are performing poorly in the assessment. Hence, further analysis on the assessment marks breakdown need to be carried to identify the assignable causes.

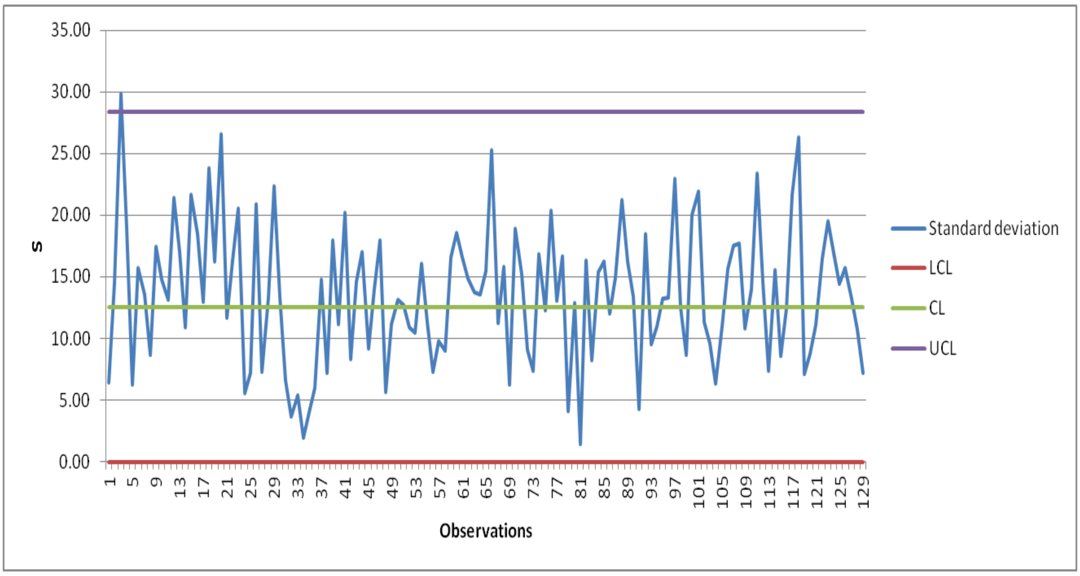

Figure 4.2: *s* Control Chart for Assessment Marks

Besides $\bar{X}$ chart, *s* chart for the average assessment marks is also constructed and illustrated in Figure 4.2. The UCL and LCL for this chart are 28.41 and 0.00, respectively while the center line is 12.53. These control limits are calculated using the equations [3.12] , [3.13] and [3.14].

From Figure 4.2, it is obviously seen that the variation of each student's performance is fluctuating around the center line but still within the control limits except for the 3rd student, which is greater than the upper control limit. This implies that the volatility in the academic performance of 3rd student is relatively high. However, the performance of this 3rd student is considered permissible due to the average assessment marks are still within the control limits as showed in Figure 4.1.

Also, it is vividly seen that the 91st student has the highest average assessment marks at 90.17 while the 106th student has the lowest average assessment marks at 19.75 with their in-control performance variation according to Figure 4.1. By referring to the Figure 4.2, it can be deduced that 91st student have performed well consistently in all assessment marks due to the low standard deviation of test scores (4.23). The academic performance of the 106th student appears to be more volatile than 91st student since the standard deviation of his test scores is relatively high (15.62). Due to the standard deviation of test scores for 106th student lies within the control limits, this implies that such student maintained poor performance in every assessment taken.

To obtain a more in-depth insight towards the behavior of students' performance, $\bar{X}$ control chart for assessment marks is then further analyzed based on different aspects of the assessments by constructing the relative individual X control chart. Thus, we will be able to determine which part of the assessments exerts major influence on the out-of-control performance of students in either $\bar{X}$ or s control chart for assessment marks by looking into all the 17 out-of-control points i.e., an outlier in s chart and another 16 outliers in $\bar{X}$ chart corresponding with individual X chart.

Individual X Control Chart

As the sample size of individual X Control Chart equals 1, it is not feasible to use traditional Shewhart three sigma control limits for students' test scores monitoring. Therefore, a modified control scheme is being generated by selecting control limits based on the percentages. In this study, the choice of limit is set as ± 15 percent away from the center line as it establishes meaningful control limits on monitoring student's academic performance.

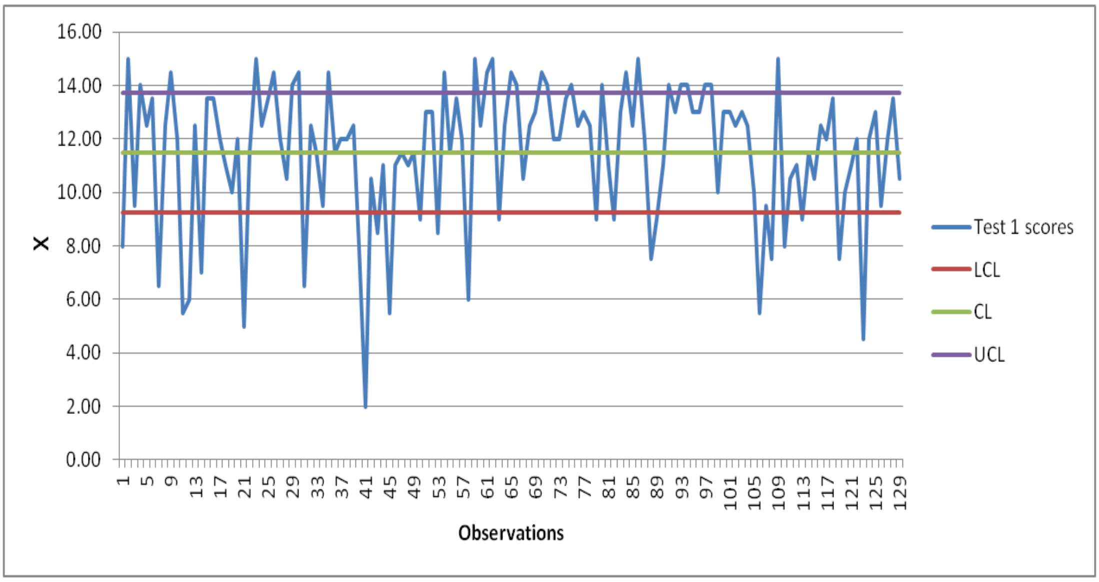

Figure 4.3: Individual X Control Chart of Test 1

Figure 4.3 shows the individual test 1 mark in Probability and Statistics I with the average 11.48. About 60% of students (78) have performed satisfactorily in the test 1 as their scores fall within the control limits; of the rest 26 students are scored above upper control limit and 25 students scored below the lower control limit. Despite there are 51 students rate out of control limits, but the further analysis will be focus on those 17 students numbered 3, 12, 14, 21, 35, 41, 59, 86, 88, 91,94, 102, 106,107,108, 109, 123 as stated in the previous section since the other students' overall performance are fall within the control limits (please refer to Figure 4.1). Figure 4.3 reveals the excellent results obtained by the 35th, 59th, 86th, 91st, 94th, and 109th students in test 1 as their individual score is higher than the upper control limit, conversely, the students corresponding to 12th, 14th, 21st, 41st, 88th, 106th, 108th and 123rd do underperform due to their individual marks fall below the lower control limit while the remaining are resulted in moderate outcome.

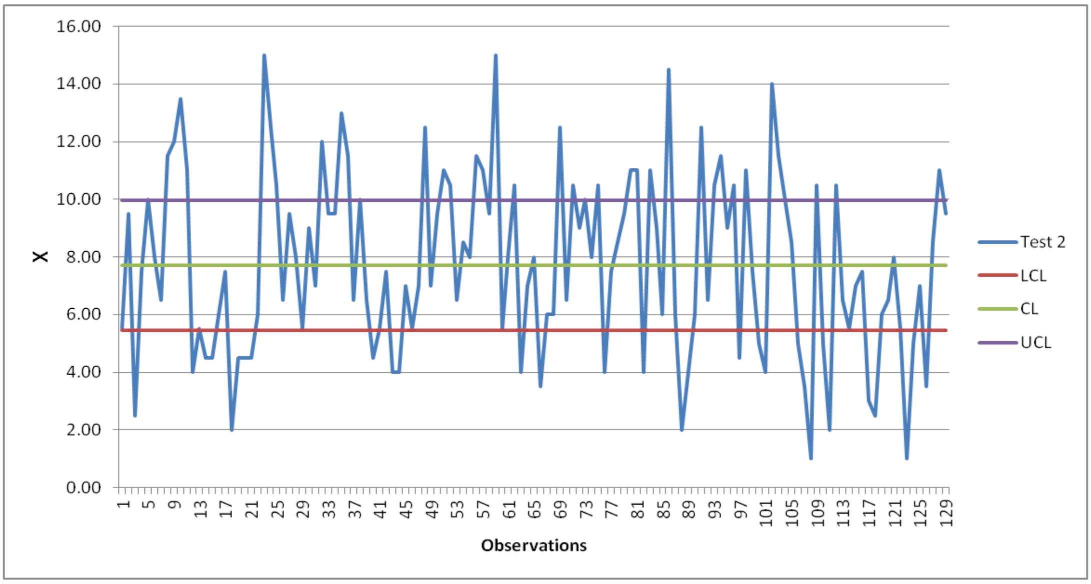

Figure 4.4: Individual X Control Chart of Test 2

From Figure 4.4, there is a noticeable decrease in the performance of students in test 2 as compared to test 1. Overall, it can be seen that the average mark of test 2 (7.72) is comparatively lower than the average mark in test 1 (11.48). As a result, the number of students who exhibit out-of-control manner accounted for about half of all the population such that 30 students' result are below the lower control limit while 38 students' result are above the upper control limit. Among those 17 students highlighted in the previous paragraph, the 3rd, 14th, 21st, 88th, 106th, 107th, 108th and 123rd fail to meet the satisfactory level except for the 12th and 41st due to their test scores are lesser than the lower control limit. In the meanwhile, students numbered 35, 59, 86, 91, 94, 102, 109 have outperformed the others with their scores are beyond upper control limit.

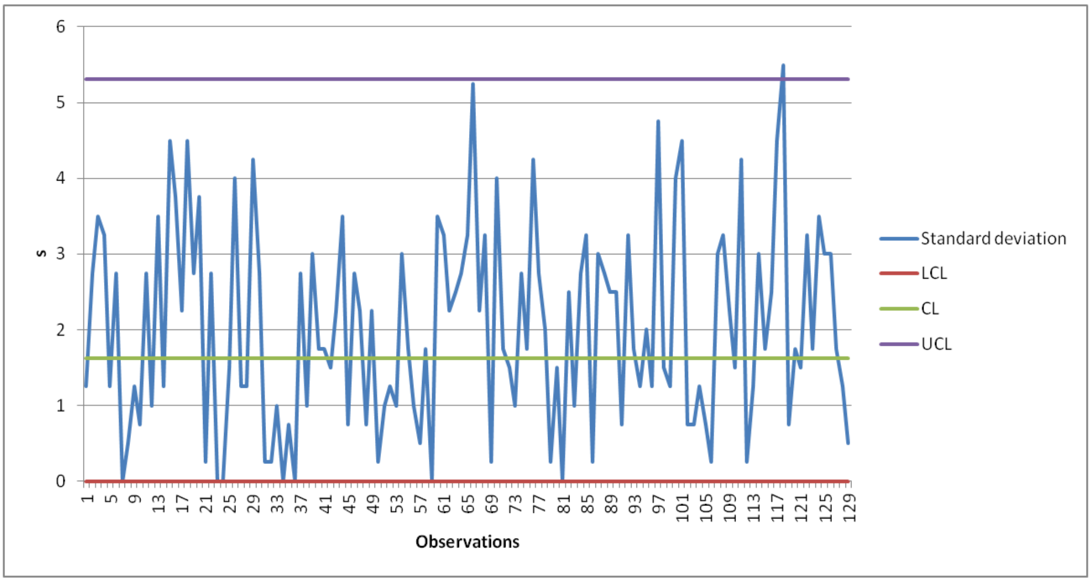

Figure 4.5: *s* Control Chart for Test 1 and Test 2

As presented in Figure 4.5, the established LCL, CL and UCL for *s* chart are 0.00, 1.63 and 5.31, respectively. It is evident from the graph that the performance variability of each student except 118th is within the control limits. The consistency of the variation in performance implies that there is no much differences in the test scores between test 1 and test 2 obtained by students. Regardless of the out-of-control status illustrated by 121st student, it is still remained as an acceptable scenario due to student's eventual average performance is being secured within control limits as shown in Figure 4.1.

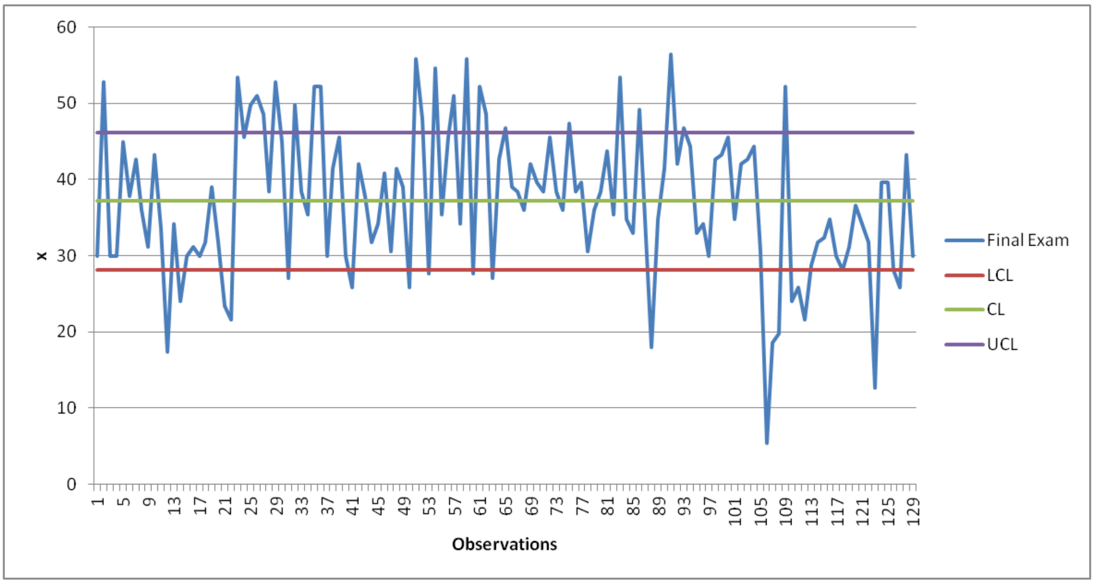

Figure 4.6: Individual *X* Control Chart of Final Exam

Figure 4.6 shows that majority of the students' final examination marks are within the control limits, while minority group of students, i.e. about 15% were rated below the lower control limit. It can also be observed that 18% were rated above the upper control limit. Out of the 17 targeted students in this study, 12th, 14th, 21st, 41st, 88th, 106th, 107th, 108th and 123rd students except for the 3rd student tend to perform unsatisfactorily in the final examination. Meanwhile, the final examination marks for students numbered 35, 59, 86, 91, 94 and 109 are outperform as compared to the others since the points are plotted above the upper control limit.

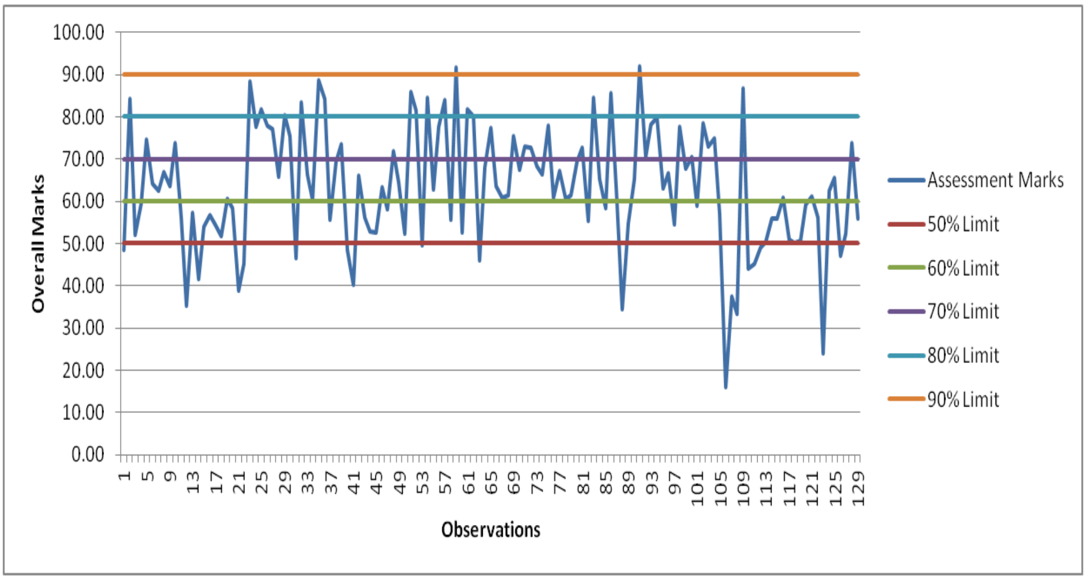

Figure 4.7: Benchmark Limits of Overall Results

Based on the grading system practice implemented by Universiti Tunku Abdul Rahman (UTAR), an overall mark of 50% is set as the benchmark for students to pass the subject. Students who scored below the passing mark will be viewed as failure in the subject taken. As illustrated in the graph, there are 19 students who have failed the subject. Consequently, necessary intervention should be provided to such students by examining assignable factors that are indicator of course performance in order to reduce the failure rate significantly.

Apart from that, the developed control charts' statistics by using benchmark limits based on passing mark (50%) enables academician to find out whether student' overall academic performance is in-control. With regard to the Appendix-3, if 60, 70, 80 and 90 are set as benchmark limits, there will be 34, 34, 24 and 16 students fall into category I, II, III and IV, respectively. The combination of benchmark limit of 60% and 70 % as in-control limit is not desirable since it only cover about half of the students with in-control academic performance. As a result, an appropriate benchmark limit can be proposed by combining 60%, 70 % and 80% and 90% limits since this limit covers more than three quarters of the students (84%) who have their performance are in control associated with the least out-of-control observations.

4.2 Summary of Results

This research presents the application of control charts in early identification of both excellent and poor students in a class. In the study, student numbered 35, 59, 86, 91, 94, 102 and 109 are outstanding as showed in Figure 4.1. This can be further proven by their excellent academic results in each assessment as shown in Figure 4.3, 4.4 and 4.6. Also, such students' academic performance exhibit in-control standard deviations which imply that their overall academic performance is consistently above the average in the assessment.

In the contrary, students numbered 12, 14, 21, 41, 88, 106,107,108, 123 are viewed as low-proficiency students due to their poor results in tests and final exam which is indicated by an in-control standard deviation in Figure 4.2. Generally, uniform test scores either high or low may be attained when standard deviation of academic performance is maintained under controlled situation. No matter how well or how bad of the students' performance, it signals the existence of unusual process variations that lead to an out-of-control scenario and worthy of investigation. The results in Figure 4.2 have witnessed 3rd student's result with extremely large standard deviation value which is beyond the center line and this indicates that such student's performance is unstable and inconsistent. Yet, his performance still desirable as his average performance is maintained within control limits as illustrated in Figure 4.1.

Apart from that, the established control chart using benchmark limit allows us to achieve desired proportion of students to pass a subject. More than three-quarters of students managed to obtain passing results by setting the threshold range between 60% and 90% limit. Indeed, the quality of students' learning progress over time can be evaluated through the developed benchmark limit control chart. In other words, it presents as a good indicator to tell academicians whether there is an improvement or a decline in the students' academic performance had occurred as compared to previous batch of students. Academicians will be able to maintain the learning progress and thus level up the educational quality by using control chart as a tool in monitoring the overall students' academic performance.

CHAPTER 5

CONCLUSIONS

In conclusion, control charts have been proven effective in the quality control of academic performance throughout the study as they are able to give a comprehensive view of the state of the students' performance periodically. Control charts allow academic administrators to find out which students are likely to perform extraordinarily in their study and pinpoint which students are failing to meet minimum criteria in the early stage of the programme of study.

Additionally, by using the control charts, academicians will be able to identify the assignable causes that lead to the variation of students' academic performance which is indicated by the shifts in the students' average marks. A positive variation will improve the overall academic achievement of students whereas a negative value indicates the opposite. The remedial action plans should be taken to resolve the issue of poor academic performance indicated by negative variation and implement factors that contributed to academic excellence implied by positive variation.

In other words, academicians should set up teaching approaches as well as strategies by taking into consideration of the unusual factors that resulted into extraordinary performance while eliminating the assignable causes that lead to poor performance. Therefore, they can come up with effective teaching plans which best suit the students by adapting it to the identified learning preference and characteristics of students. In this manner, it ensures a high standard of assessments and also a high-efficiency of monitoring learning progress which can further improve the quality of the educational process. Concisely, the appropriate use of control chart in educational sector will provide the accuracy and precision of monitoring process stability by removing the erroneous results due to unusual factors and applying the corresponding rectification.

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APPENDICES

Appendix-1: Assessment Marks for Probability and Test I

Obs	Test 1 (15%)	Test 2 (15%)	Assignment (10%)	Final Exam (60%)
1	8.00	5.50	5.00	30.00
2	15.00	9.50	7.00	52.80
3	9.50	2.50	10.00	30.00
4	14.00	7.50	8.00	30.00
5	12.50	10.00	7.00	45.00
6	13.50	8.00	5.00	37.80
7	6.50	6.50	7.00	42.60
8	12.50	11.50	7.00	36.00
9	14.50	12.00	6.00	31.20
10	12.00	13.50	5.00	43.20
11	5.50	11.00	6.00	33.60
12	6.00	4.00	8.00	17.40
13	12.50	5.50	5.00	34.20
14	7.00	4.50	6.00	24.00
15	13.50	4.50	6.00	30.00
16	13.50	6.00	6.00	31.20
17	12.00	7.50	5.00	30.00
18	11.00	2.00	7.00	31.80
19	10.00	4.50	7.00	39.00
20	12.00	4.50	10.00	31.80
21	5.00	4.50	6.00	23.40
22	11.50	6.00	6.00	21.60
23	15.00	15.00	5.00	53.40
24	12.50	12.50	7.00	45.60
25	13.50	10.50	8.00	49.80
26	14.50	6.50	6.00	51.00
27	12.00	9.50	7.00	48.60
28	10.50	8.00	9.00	38.40
29	14.00	5.50	8.00	52.80
30	14.50	9.00	7.00	45.00
31	6.50	7.00	6.00	27.00
32	12.50	12.00	9.00	49.80
33	11.50	9.50	7.00	38.40
34	9.50	9.50	6.00	35.40
35	14.50	13.00	9.00	52.20
36	11.50	11.50	9.00	52.20
37	12.00	6.50	7.00	30.00
38	12.00	10.00	6.00	41.40
39	12.50	6.50	9.00	45.60
40	8.00	4.50	6.00	30.00
41	2.00	5.50	7.00	25.80
42	10.50	7.50	6.00	42.00

Obs	Test 1 (15%)	Test 2 (15%)	Assignment (10%)	Final Exam (60%)
43	8.50	4.00	6.00	37.80
44	11.00	4.00	6.00	31.80
45	5.50	7.00	6.00	34.20
46	11.00	5.50	6.00	40.80
47	11.50	7.00	9.00	30.60
48	11.00	12.50	7.00	41.40
49	11.50	7.00	7.00	39.00
50	9.00	9.50	8.00	25.80
51	13.00	11.00	6.00	55.80
52	13.00	10.50	10.00	48.00
53	8.50	6.50	7.00	27.60
54	14.50	8.50	7.00	54.60
55	11.50	8.00	8.00	35.40
56	13.50	11.50	7.00	45.60
57	12.00	11.00	10.00	51.00
58	6.00	9.50	6.00	34.20
59	15.00	15.00	6.00	55.80
60	12.50	5.50	7.00	27.60
61	14.50	8.00	7.00	52.20
62	15.00	10.50	6.00	48.60
63	9.00	4.00	6.00	27.00
64	12.50	7.00	6.00	42.60
65	14.50	8.00	8.00	46.80
66	14.00	3.50	7.00	39.00
67	10.50	6.00	6.00	38.40
68	12.50	6.00	7.00	36.00
69	13.00	12.50	8.00	42.00
70	14.50	6.50	7.00	39.60
71	14.00	10.50	10.00	38.40
72	12.00	9.00	6.00	45.60
73	12.00	10.00	8.00	38.40
74	13.50	8.00	9.00	36.00
75	14.00	10.50	6.00	47.40
76	12.50	4.00	6.00	38.40
77	13.00	7.50	7.00	39.60
78	12.50	8.50	9.00	30.60
79	9.00	9.50	7.00	36.00
80	14.00	11.00	6.00	38.40
81	11.00	11.00	7.00	43.80
82	9.00	4.00	7.00	35.40
83	13.00	11.00	7.00	53.40
84	14.50	9.00	7.00	34.80
85	12.50	6.00	7.00	33.00
86	15.00	14.50	7.00	49.20

Obs	Test 1 (15%)	Test 2 (15%)	Assignment (10%)	Final Exam (60%)
87	12.00	6.00	7.00	34.80
88	7.50	2.00	7.00	18.00
89	9.00	4.00	7.00	34.80
90	11.00	6.00	7.00	41.40
91	14.00	12.50	9.00	56.40
92	13.00	6.50	9.00	42.00
93	14.00	10.50	7.00	46.80
94	14.00	11.50	10.00	44.40
95	13.00	9.00	8.00	33.00
96	13.00	10.50	9.00	34.20
97	14.00	4.50	6.00	30.00
98	14.00	11.00	10.00	42.60
99	10.00	7.50	7.00	43.20
100	13.00	5.00	7.00	45.60
101	13.00	4.00	7.00	34.80
102	12.50	14.00	10.00	42.00
103	13.00	11.50	6.00	42.60
104	12.50	10.00	8.00	44.40
105	10.00	8.50	8.00	30.60
106	5.50	5.00	0.00	5.40
107	9.50	3.50	6.00	18.60
108	7.50	1.00	5.00	19.80
109	15.00	10.50	9.00	52.20
110	8.00	5.00	7.00	24.00
111	10.50	2.00	7.00	25.80
112	11.00	10.50	6.00	21.60
113	9.00	6.50	6.00	28.80
114	11.50	5.50	7.00	31.80
115	10.50	7.00	6.00	32.40
116	12.50	7.50	6.00	34.80
117	12.00	3.00	6.00	30.00
118	13.50	2.50	6.00	28.20
119	7.50	6.00	6.00	31.20
120	10.00	6.50	6.00	36.60
121	11.00	8.00	8.00	34.20
122	12.00	5.50	7.00	31.80
123	4.50	1.00	6.00	12.60
124	12.00	5.00	6.00	39.60
125	13.00	7.00	6.00	39.60
126	9.50	3.50	6.00	28.20
127	12.00	8.50	6.00	25.80
128	13.50	11.00	6.00	43.20
129	10.50	9.50	6.00	30.00

Appendix-2: Factors for Constructing Variable Control Charts

	Factors for Control Limits of $\overline{X}$ Chart		Factors for Control Limits of *s* Chart			
Sample Size = m	**A_2**	**A_3**	**B_3**	**B_4**	**B_5**	**B_6**
2	1.880	2.659	0	3.267	0	2.606
3	1.023	1.954	0	2.568	0	2.276
4	0.729	1.628	0	2.266	0	2.088
5	0.577	1.427	0	2.089	0	1.964
6	0.483	1.287	0.030	1.970	0.029	1.874
7	0.419	1.182	0.118	1.882	0.113	1.806
8	0.373	1.099	0.185	1.815	0.179	1.751
9	0.337	1.032	0.239	1.761	0.232	1.707
10	0.308	0.975	0.284	1.716	0.276	1.669
11	0.285	0.927	0.321	1.679	0.313	1.637
12	0.266	0.886	0.354	1.646	0.346	1.610
13	0.249	0.850	0.382	1.618	0.374	1.585
14	0.235	0.817	0.406	1.594	0.399	1.563
15	0.223	0.789	0.428	1.572	0.421	1.544
16	0.212	0.763	0.448	1.552	0.440	1.526
17	0.203	0.739	0.466	1.534	0.458	1.511
18	0.194	0.718	0.482	1.518	0.475	1.496
19	0.187	0.698	0.497	1.503	0.490	1.483
20	0.180	0.680	0.510	1.490	0.504	1.470
21	0.173	0.663	0.523	1.477	0.516	1.459
22	0.167	0.647	0.534	1.466	0.528	1.448
23	0.162	0.633	0.545	1.455	0.539	1.438
24	0.157	0.619	0.555	1.445	0.549	1.429
25	0.153	0.606	0.565	1.435	0.559	1.420

Appendix-3: Marks Allocation for Benchmark Limits of Overall Results

Benchmark Limit (%)	Marks	Category
60	50% - < 60%	I
70	60% - < 70%	II
80	70% - < 80%	III
90	80% - < 90%	IV