

Evaluating students' performance in mathematics and other subjects using fixed and individual control chart grading methods

Emmanuel Deogratias ^{1*} , Gadde S. Rao ² , Filbert Alphonse ^{2**} 

¹Sokoine University of Agriculture, TANZANIA

²The University of Dodoma, TANZANIA

*Corresponding Author: deograti@ualberta.ca

**Corresponding Author: mfilbertsukums@gmail.com

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ABSTRACT

This paper focuses on evaluating students' performance in mathematics and other subjects using fixed and individual control chart grading methods. This quantitative study involved 240 students and conducted in ordinary secondary schools in the Mbulu district. Minitab statistical software was used to analyze collected students' performance by comparing fixed grading method with individual control charts grade. The findings revealed that a large number of students performed well using individual control chart than the fixed grading method. The findings imply that individual control chart grade was higher and practical method in evaluating students' performance because of lowering the cut-off point of the performance for the individual student. Therefore, school teachers can use individual control chart grading method for improving individual student performance in each subject.

Keywords: individual control chart, students' performance evaluation, fixed grading method, quantitative study and secondary schools

INTRODUCTION

Tanzania is one of the countries facing challenges in their respective educational system, including poor students' performance in ordinary secondary schools. Focusing on Tanzania's education system, education has been acknowledged as a critical component for social and economic development of the nation (Paulo & Tilya, 2014). A successive country has people termed as human resources who are well equipped with knowledge, skills, competence, and attitudes for the success of the national economy acquired through investing in education, in particular school education (Fallis, 2013).

The individual students' performance is evaluated using examinations in schools while focusing on successes in such examinations (Kambuga & Dadi, 2015). To ensure high quality of evaluating individual students' performance, the examination is monitored closely (Akessa & Dhufera, 2015; Akinrefon & Balogun, 2014; David, 2014; Fallis, 2013; Gay, 2018; Kotz & Johnson, 2011; Moser, 2019; Motanya, 2011; Ndyali, 2016; Patena & Dinglasan, 2013; Saqib & Rehman, 2018; Stebbins, 2017; Woodall, 2017). In doing so, scientific ways for evaluating students' performance to meet educational objectives should be developed (Ali et al., 2009; Dzana, 2012; Gay, 2018; Stebbins, 2017; Stufflebeam & Coryn, 2014). This study proposes using fixed grading and individual control chart grading methods to evaluate students' performance in Tanzanian secondary schools.

Beshah (2012) conducted a study in Ethiopia on how to evaluate students' performance in higher education using statistical quality control (SQC) method. It was found that using SQC-based technique was motivating students in learning the subject.

Zacharia (2018) conducted a study in Tanzania to evaluate students' performance in secondary schools by using quality control approaches. It was found that students' performance was not statistically controlled. As a result, sources of variations in performance still need to be identified and addressed. Similar results have been found by other scholars (e.g., Beshah, 2012; Zacharia, 2018). Also, Filbert et al. (2022) conducted the study on evaluation of students' performance schools in Tanzania using fixed grading and mean and dispersion charts grading methods. In the reviewed research, no study that has been conducted on the comparison of fixed grading with individual control charts grading method.

Individual Control Chart

Individual control charts can be defined as a type of variable control charts that can be used with data that is subject to change. The individual control chart looks at how individual sample results have changed over time. The average on the individual chart is our population average estimate if the procedure is statistically controlled. The population variance would be calculated using the average range (Biswas et al., 2015).

Table 1. Fixed grading system in Tanzanian ordinary secondary education

Early grading system		New grading system	
Score	Grade	Score	Grade
81-100	A	75-100	A
61-80	B	65-74	B
41-60	C	45-64	C
21-40	D	30-44	D
0-20	F	0-29	F

Source: NECTA (2012)

According to Biswas and colleagues (2015) when only one observation is needed to illustrate a scenario at a specific moment, individuals control charts should be applied. A point on the individual control chart could be used to represent each sample obtained. This enables an individual to determine if or not the process is statistically controlled for each sample. In individual control charts, one would be given individual measurement data, such as x_i ; $i = 1, 2, \dots, m$.

The mean for individual measurement data were given by:

$$\bar{x} = \frac{1}{m} \sum_{i=1}^m x_i \quad (1)$$

Montgomery (2020) stated that in many separate control chart applications, we use the range of movement of two consecutive observations as the basis of estimating the process variability; hence, moving range MR_i is given by:

$$MR_i = |x_i - x_{i-1}| \quad (2)$$

The average moving range can be used to construct center line of the control chart.

Individual control chart in education

Individual control charts have been used in education for assessment of student's performance in schools, colleges and universities. For example, Shewhart control charts have been used to assess student's performance in higher education for improvement of students' learning and achievement (Nandedkar & Bhati, 2021).

Scores on examinations, tests and assignments in any education level can be evaluated using control charts method for continuously improvement of education (Inglis, 2008; Nandedkar & Bhati, 2021). For example, control charts method can be used to identify causes for low quality in education because the method is potential in assessing students' performance (Peterson, 2015). The assessment is done based on the benchmark established by an educational institution such as a school, college and university depending on the educational process (Kaur & Batra, 2019; Nandedkar & Bhati, 2021). In doing so, the method helps to identify reasons for sustaining quality education in an institution during teaching and learning process (Hrynkevych, 2017).

If proper assessment tools and strategies have not been used to assess students' performance, students may lack motivation to pursue the subjects (Nandedkar & Bhati, 2021). For instance, control charts method has been used in higher education to evaluate students' performance; students performed better in theoretical subjects than numerical based subjects (Nandedkar & Bhati, 2021). Therefore, effective monitoring is required during assessing students' performance to maintain quality education. In doing so, statistical control charts method is critical for the assessment of students' performance.

Fixed Grading Method

Guskey and Pollio (2012) state that assessment is a set of signs, words, or figures representing different degrees of success or competence. In Tanzania, grades are presented by letters A, B, C, D, and F; symbols or numbers by 1, 2, 3, or 4, ..., and descriptive terms by Below satisfactory, Satisfactory, Good, Very good or Excellent. These grades were created by the method of grading system. Guskey and Pollio (2012) declare that grading to save purposes, including selecting talents, placement, and professionalism. For a long time, all examinations at the Tanzanian ordinary secondary level of education use five grades as shown in the **Table 1**.

METHODOLOGY

This quantitative study employed the cross-sectional research design (Kumar, 2018; Sieber, 2014; Tavakoli, 2012). The quantitative approach was important for presenting numerical data.

Secondary data were collected from Mbulu district focusing on six subjects taught in ordinary secondary schools, including mathematics and science subjects. 240 students volunteered to participate in this study from six different schools. The individual control chart grade and fixed grading methods were used in data analysis with the help of Minitab statistical software as described in sub section below.

Using Fixed Grading and Control Chart Grading Methods to Evaluate the performance of the Students

The data about students' performance was gathered and the normality assumptions were checked for individual subject. The individual control chart was used to analyze individual subject by developing an \bar{X} - chart as indicated below using Equations (1) and (2). The lower control limit (LCL), upper control limit (UCL) and central line (CL) is given as follows:

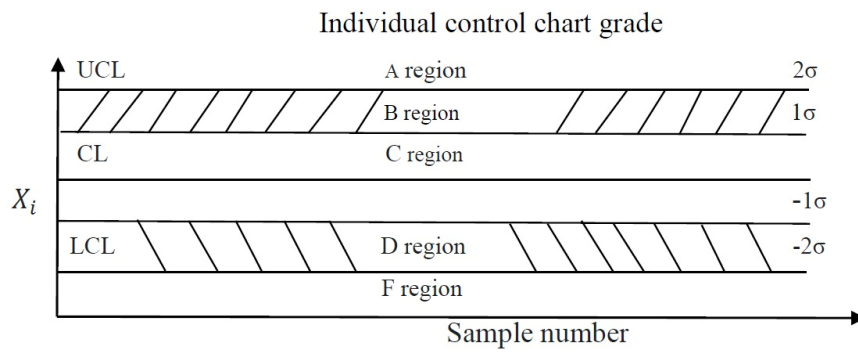


Figure 1. Grading of a subject using individual control chart (Source: Authors' own elaboration)

Table 2. Fixed grading method for individual subject

Score	75-100	65-74	45-64	30-44	0-29
Grade	A	B	C	D	F

$$LCL = \bar{x} - 3 \frac{\overline{MR}}{d_2} = \bar{X} - 2.66\overline{MR} \quad (3)$$

Since, $\frac{3}{d_2} = \frac{3}{1.128} = 2.659574 \approx 2.66$, the value of factor d_2 is obtained from the statistical table when $n = 2$ which gives $d_2 = 1.128$.

$$\begin{aligned} CL &= \bar{X} \\ UCL &= \bar{X} + 2.66\overline{MR} \end{aligned} \quad (4)$$

Mean moving range \overline{MR} is given by:

$$\overline{MR} = \frac{1}{m-1} \sum_{m=2}^m MR_i \quad (5)$$

The control limits for moving range chart are given as follows:

$$LCL = D_3\overline{MR} \quad (6)$$

$$\begin{aligned} CL &= \overline{MR} \\ UCL &= D_4\overline{MR} \end{aligned} \quad (7)$$

where $D_3 = 0$ and $D_4 = 3.267$ when $n = 2$.

In the fixed grading method, excel was utilized in data analysis whereby the special formula were used to assign fixed grade to the individual subject performance of students as specified it in **Table 2**.

RESULTS AND DISCUSSIONS

According to Montgomery (2020), individual control chart demonstrates individual observations. Individual control charts reveal their respective moving range chart when graphing individual observations. In this study, a single subject was treated as an individual measurement and the analysis was performed out with the use of Minitab statistical software and individual control chart grade. The individual control chart of each secondary school was described as shown in **Figure 2**: Interpretation of individual control charts grade of S_1 secondary school.

In **Figure 2** it is depicted that individual control grade for a Kiswahili subject with center line at the total sample mean of $\bar{X}=37.27$, $UCL=71.10$, and $LCL=3.45$ which show that grade A is above $UCL=71.10$, B between 71.10 and 54.19, C between 54.19 and 20.36, D between 20.36 and 3.45 and F below $LCL=3.45$.

In education, below LCL indicates there is poor performance and above UCL good performance. According to the chart, no student scored grade A, 5 students scored grade B, most of the students got grade C, 3 students got grade D and no student got grade F. In fixed grading system analysis, from Kiswahili subject, it is observed that no student scored grade A and B, 12 students obtained grade C, 16 got grade D and 12 attained grade F. Therefore, individual control chart grade is more appropriate to raise the performance of the students than using fixed grading method.

In **Figure 3**, it is presented that individual control chart grade for a Geography subject with center line at the total sample mean of $\bar{X}=42.15$, $UCL=72.56$ and $LCL=11.74$ which indicate that grade A is above $UCL=72.56$, B is between 72.56 and 57.36, C is between 57.36 and 26.94, D is between 26.94 and 11.74 and F is below $LCL=11.74$. The chart shows that one sample observation was plotted above UCL that implies one student scored highest marks. In education, the observations found under LCL indicate poor performances of students and points above UCL imply good performance of the students. Still the performance of the student in Geography is better using individual control chart grade than fixed grading.

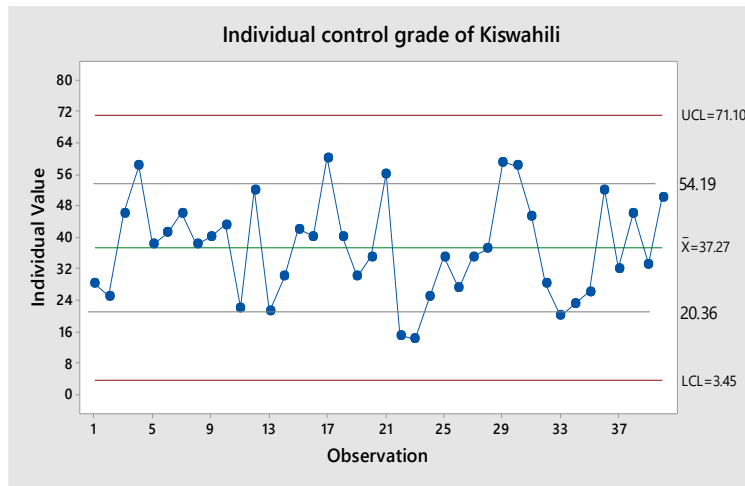


Figure 2. Chart for individual control grade of Kiswahili (Source: Authors' own elaboration)

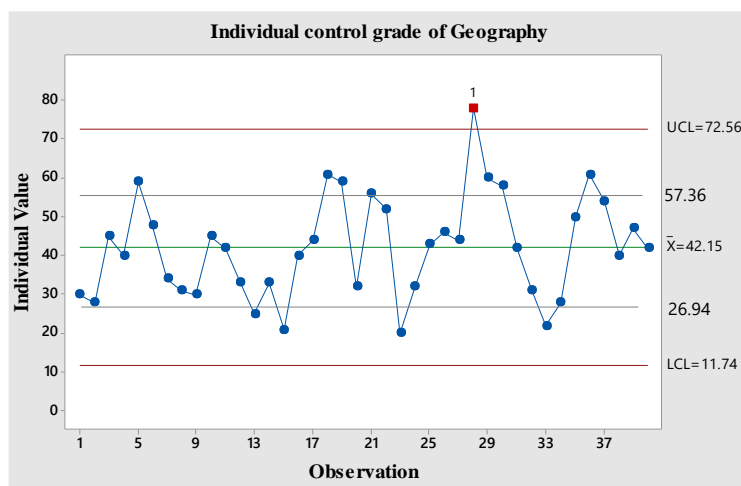


Figure 3. Chart for individual control grade of Geography (Source: Authors' own elaboration)

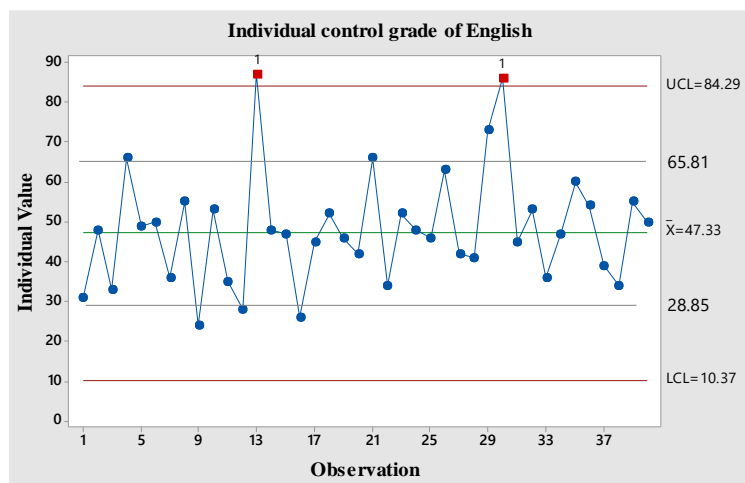


Figure 4. Chart for individual control grade of English (Source: Authors' own elaboration)

Figure 4 show individual control chart for the English subject with the centerline, which is presented at the entire sample mean $\bar{X}=47.33$, $UCL=84.29$, and $LCL=10.37$, implying that grade A is above $UCL=84.29$, B is between 84.29 and 65.81, C is between 65.81 and 28.85, D is between 28.85 and 10.37, and F is below $LCL=10.37$. The chart shows that large number of the students scored average marks where by two students scored above UCL that means they scored high marks, but no student scored marks below LCL, which implies low marks. In education, the observations found under LCL indicate poor performance of students where points above UCL implies good performance of the students. Using individual control chart grade raise the performance of the student in English than when using fixed grading method.

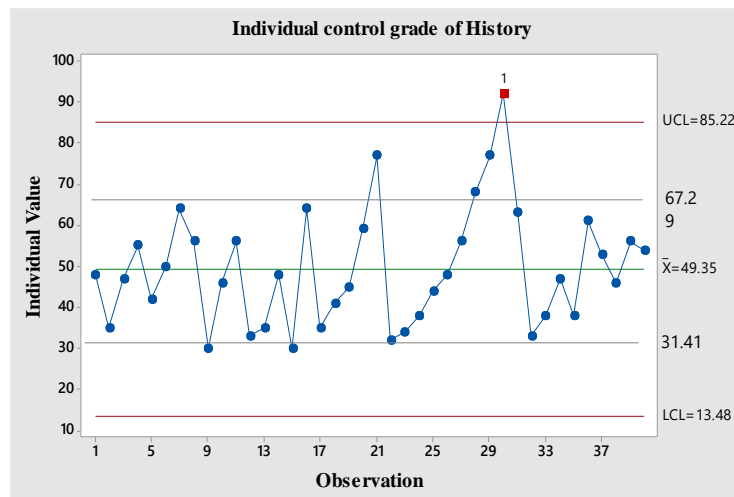


Figure 5. Chart for individual control grade of History (Source: Authors' own elaboration)

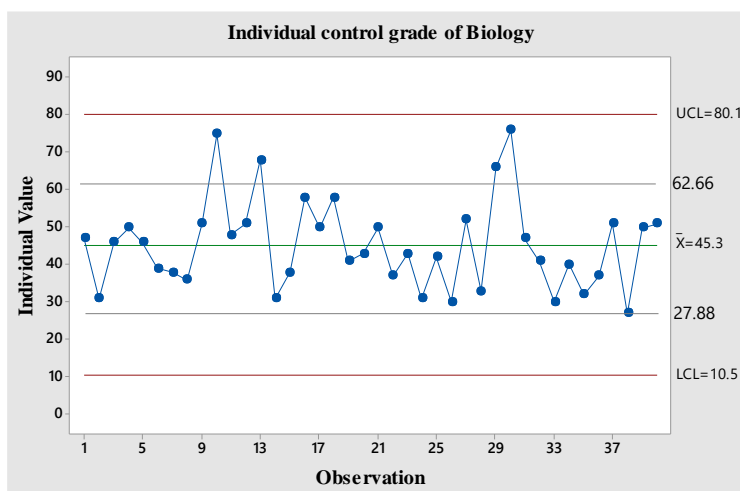


Figure 6. Chart for individual control grade of Biology (Source: Authors' own elaboration)

Figure 5 describes individual control chart of History subject for the CL that is displayed at the entire sample mean $\bar{X}=49.35$, $UCL=85.22$ and $LCL=13.48$ which shows that grade A is above $UCL=85.22$, B is between 85.22 and 67.29 , C is between 67.29 and 31.41 , D is between 31.41 and 13.48 and F is below $LCL=13.48$. At the same line, it is observed that, more observation was found at the centerline whereby one points is found to fall above UCL indicating that one student scored grade A since the region above UCL represent grade A whereas the region below the LCL represent grade F region. In education, the observations found under LCL denote poor performances of students are observations over UCL infer excellent performance of the students. Still fixed grading method lowers the performance of the students in History than using individual control chart grade method.

Figure 6 presents the individual control chart for Biology subject for the CL that is displayed at the entire sample mean of $\bar{X}=45.30$, $UCL=80.10$ and $LCL=10.50$ which indicate that grade A is above $UCL=80.10$, B is between 80.10 and 62.66 , C is between 62.66 and 27.88 , D is between 27.88 and 10.50 and F is below $LCL=10.50$.

In education, the observations below LCL represent poor of performance where the observations above UCL indicate excellent performance of the candidate. From the chart, it is shown that individual control chart grade method raises the performance of the students in Biology subject than using fixed grading technique.

Figure 7 demonstrates the individual control chart for Mathematics for the CL, which is displayed at the entire sample mean $\bar{X}=33.83$, $UCL=62.67$, and $LCL=7.31$, indicating that grade A is above $UCL=62.67$, B is between 62.67 and 48.25 , C is between 48.25 and 19.41 , D is between 19.41 and 7.31 , and F is below $LCL=7.31$. In education, the observations found under LCL signify poor performances of students are observations over UCL imply excellent performance of the students. According to the chart, it is confirmed that, individual control chart grade method raises the performance of the students in Mathematics subject than when using fixed grading method.

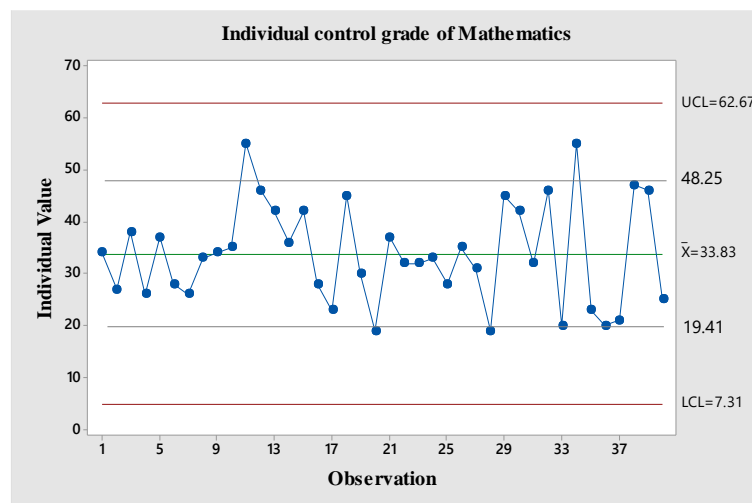


Figure 7. Chart for individual control grade of Mathematics (Source: Authors' own elaboration)

CONCLUSIONS

This article presents fixed grading and individual control chart grading methods in the evaluation of the performance of students in Tanzanian ordinary secondary education systems. The study involved six secondary schools which has been conducted in Mbulu district in Manyara region in Tanzania. It was found that students scored good marks when their scores are evaluated using individual control chart grade rather than using fixed grading method. The result has implications in secondary schools including teachers can use individual control chart grading method to raise the performance of the students for any subject taught in secondary schools including mathematics. Furthermore, this method can be used in evaluation of the performance of the students in subjects taught in pre-primary, primary, advanced, and university levels.

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Ethical statement: The authors stated that this study is own original research work of the authors. It was conducted in a truthful and complete manner and not currently considered to be published elsewhere. The authors further stated that the study was approved by the University of Dodoma on 16 September 2021 (Approval code: MA.84/261/02/'A'). Written informed consents were obtained from the participants.

Declaration of interest: The authors declare that there is no conflict of interest.

Data sharing statement: The data is available and can be accessed from the corresponding author when requested.

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