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The Performance of Students in Differential Equation Course with a New Assessment System

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In the engineering education syllabus, mathematics is an important course student should dominate especially Differential Equation (DE). This study explores students' performance in DE among engineering students. The study is carried out on student's results data, which consisted of 336 engineering students from different departments namely Department of Civil and Structural Engineering (JKAS), Department of Mechanical and Materials Engineering (JKMB), Department of Chemical and Process Engineering (JKKP) and Department of Electrical, Electronic and Systems Engineering (JKEES) in Faculty of Engineering and Built Environment (FKAB) at Universiti Kebangsaan Malaysia (UKM). The results are verified using Pearson product-moment correlation coefficient, analysis of variance (ANOVA) and Tukey test. Results show positive linear relationships between new final exam scores with quiz scores and mid-semester exams. ANOVA and Tukey test also show that there are significant differences on the new final exam result among engineering departments. JKKP and JKMB show huge difference in performance of new final exam score among students from two departments, followed by JKEES and JKMB. There is a slight difference on performance between two departments, JKKP and JKEES. The result also shows that JKKP students perform way better compared with JKAS, JKEES and JKMB. New assessment system is an efficient tool which helps students to continuously perform on DE course.

Key words: *Engineering Students' performance, Differential Equation, Pearson product-moment correlation, ANOVA, Tukey test.*

Introduction

Mathematics is an expression of the human mind which reflects the active will, the contemplative reason and the desire for aesthetic perfection which the basic elements are logic and intuition, analysis and construction, generality and individuality (Courant & Robbins, 1996). According to Fennema & Sherman (1977), Mathematics is used and studied in courses other than mathematics such as computing, chemistry and physics. Mathematical courses are widely used in almost all educational institutions. Students' performance can be evaluated through final exam results consist of students' assignment, quizzes, e-learning tutorial and mid-semester exam.

Previous studies reported that most university students face difficulty in mathematics subjects (Jourdan, Cretchley & Passmore, 2007). It is important to maintain the quality of the students' admitted into any higher institutions as it will gives impact on the level of research and training of that particular institution (Oladokun, Adebanjo & Charles-Owaba, 2008). There are several factors which contribute to negative performance in engineering mathematics subject as reported by previous research (Soo et al., 2015). These factors include lack of basic understanding in mathematics subjects, most students usually perform by memorizing steps to solve mathematics problem, poor confidence to confront non- routine questions and careless mistakes during problem solving.

Other than that, the engineering students should able to perform in the engineering mathematics subjects because it will eventually help in other related engineering courses (Aziz et al., 2013). Previous studies implement multivariate analysis and shows significant relationship between performance on mathematics courses and engineering courses (Naccache & Hleiss, 2016; Bischof & Zwölfer, 2015). Engineering Mathematics is a fundamental course for all engineering courses at tertiary level typically consisting of Vector Calculus, Linear Algebra and Differential Equations. Students in Faculty of Engineering and Built Environment (FKAB), Universiti Kebangsaan Malaysia (UKM) are required to take Differential Equations (DE) course for third semester. In engineering syllabus, mathematics particularly DE is one of the important courses that should be dominated (Hamzah et al. 2015). However, students often fail to excel in this course. Hence, they cannot perform well in most of the engineering courses that emphasize on quantitative methods.

The Engineering Education Council has recently implemented a new assessment system in which students need to pass both midterm and final examinations. Failure in one of the two examinations will result in failure in the whole course. However, the old system was flexible where failure in the examination did not really affect the course. Since it is important to explore the effect of the new system on the student's performance, two objectives are stated here. The first objective is to explore the relationship between the assessment elements in DE course. Secondly is to investigate if there is a significant difference on the new final exam scores between the departments.

Methodology

This section explains the three main sub-sections, namely demographic, procedure and data analysis which are used in this study. A quantitative method was used to demonstrate all the output.

Demographic

A total number of 336 students' final exam results for DE semester 2 year 2016/2017 are used for the data in this study from four different departments which are Department of Civil and Structural Engineering (JKAS), Department of Mechanical and Materials Engineering (JKMB), Department of Chemical and Process Engineering (JKKP) and Department of Electrical, Electronic and Systems Engineering (JKEES) in Faculty of Engineering and Built Environment (FKAB) at Universiti Kebangsaan Malaysia(UKM).

Procedure

Other than DE final exam marks, there are other five types of marks are considered such as groups' assignment (Cooperative Learning- CL), Problem Based Learning (PBL), quizzes, e-learning tutorial (EL), mid-semester exam. Therefore, all these types of marks were considered as a tool for this study. The data are collected from database at Fundamental Engineering Studies Programme, FKAB.

Before making any further analysis, the collected data was prepared. The dataset was checked for missing data and outliers using boxplot. All values outside the calculated range were considered outliers.

Data Analysis

Assessing a complex data structure requires a suitable statistical technique. In particular, statistical techniques via quantitative and qualitative approaches are essential. The collected data was analysed using SPSS. The descriptive analyses such as mean score, frequency and the percentage will be used to describe the demographic background of the students. Accordingly, an inferential analysis such as Pearson product-moment correlation coefficient tests was conducted to analyse the correlation between two assessment components of this study. The one-way Analysis of Variance (ANOVA) is also used to compare the new final exam score between the four engineering departments. Then, Tukey test is used to further analyse which of these departments shows significant difference in the new final exam scores.

Pearson product-moment correlation coefficient

Pearson product-moment correlation coefficient (Pearson correlation) test is used to measure the existence and strength of a linear relationship between two variables. In order to apply this test, assumption of homoscedasticity must not be violated. Homoscedasticity implies that the variances along the line of best fit remain similar along the line. This terms indicates that error at each level of independent variable is constant [10]. There are three types of linear relationship that may exist between these two variables namely positive linear correlation, negative linear correlation and no correlation. This can be tested by using these two hypotheses:

H_0: There is no linear relationship between two assessment components
H_1: There is a linear relationship between two assessment components

When p-value $< \alpha = 0.05$ (95% level of confidence), then H_0 is rejected and show that there is a significant linear relationship between two assessment components. The strength of these variables can be seen by the value of the correlation coefficient. This is a measure of the strength and direction of the linear relationship between the two variables. This is the correlation coefficient of the pair of variables indicated. The correlation coefficient can range from -1 to +1, with -1 indicating a perfect negative correlation, +1 indicating a perfect positive correlation and 0 indicating no correlation at all. A variable correlated with it will always have a correlation coefficient of 1.

Analysis of Variance

According to Bu et al. (2010) and Mendiguchi'A et al. (2007), the One - Way ANOVA is used to determine the differences in the mean of a factor at different leves since it allows a comparison of more than two levels of factor while t-test only compares means of two levels of factoR (Park, 2005). The F statistic which represents the ratio of the variance between departments and variance within departments for new final exam scores. Two hypotheses are determined, and they are tested as follows:

H_0: There are no significant differences in means of the New Final Exam Scores between Departments
H_1: There are significant differences in means of the New Final Exam Scores between Departments

If p-value $< \alpha = 0.05$, H_0 is rejected and it shows that there are significant differences in means of the final scores between departments. ANOVA is used based on a few assumptions. The first assumption is the samples are taken from a normal distribution and the data should have homogeneity of variances (Demšar, 2006). The second assumptions imply that the variance within each of the population is equal. Other than that, the samples must also be drawn independently of each other (Kucuk et al., 2016; Alice, 2017).

Post-Hoc Test

ANOVA cannot provide detailed information on the difference among multiple study groups, hence, it is important to conduct test of the difference between the experimental and control groups. The t- test between the study groups is not suitable to be implemented due to two factors. Firstly, repeated statistical test will result in alpha inflation which is known as type 1 error. The second factor is the t-test result will be hard to interpret because the individual t-test can only examine two pair of groups at one time.

Multivariate statistics that can be used to replace the t-test function is the post hoc test. There are many type of post hoc test available such as Tukey, Neuman-Keuls, Scheffee, Bonferroni and Dunnett. Each post hoc test or known as multiple comparison analysis has their own advantages and disadvantages. Each test has its own function. Bonferroni test has the simplest procedure.

ANOVA compare all set of means of the new final exam scores across departments at once. The significant result in ANOVA indicates at least two groups differ from one another but it does not identify which group that differ. Hence it is important to conduct a test which will identify the particular difference between the departments. The approach is called pairwise comparison and one of the examples is Tukey test (Driscoll, 1996; Abdi & Williams, 2010) . The advantage of using Tukey test is to keep the Type 1 error equal to the chosen alpha level. It is mostly used to test simple comparisons as it is not designed to test the complex pairs.

Mathematically, the Tukey Honest Significant Difference (HSD) can be calculated by using the formula as shown below:

$$HSD = \frac{M_i - M_j}{\sqrt{\frac{MS_w}{n_h}}} \qquad (1)$$

where it represents the difference between the pair of means such that and is the mean square within and is the number in the group. There are a few assumptions that must be satisfied in order to conduct the Tukey test. Firstly, the observations are independent within and among groups. In this study, the first assumption implies that there is different participant in each group. The second assumption is the group for each mean in the test are normally distributed. Lastly, there is equal within-group variance across the groups associated with each mean in the test.

Result and Discussion

Figure 1 below shows the percentage of students for each department JKAS, JKMB, JKKP and JKEES. JKEES shows the highest representation of the overall number of student by 27% followed by JKAS, 26%, JKMB, by 24% and the least number of students is from JKKP which only represent 23% from the total number of students in engineering department.

Figure 1. Percentage of students' in engineering departments

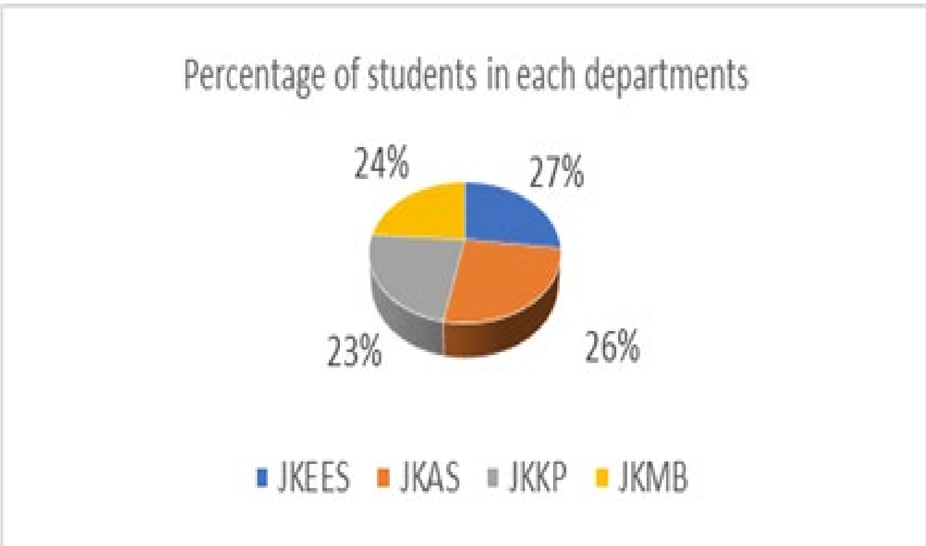
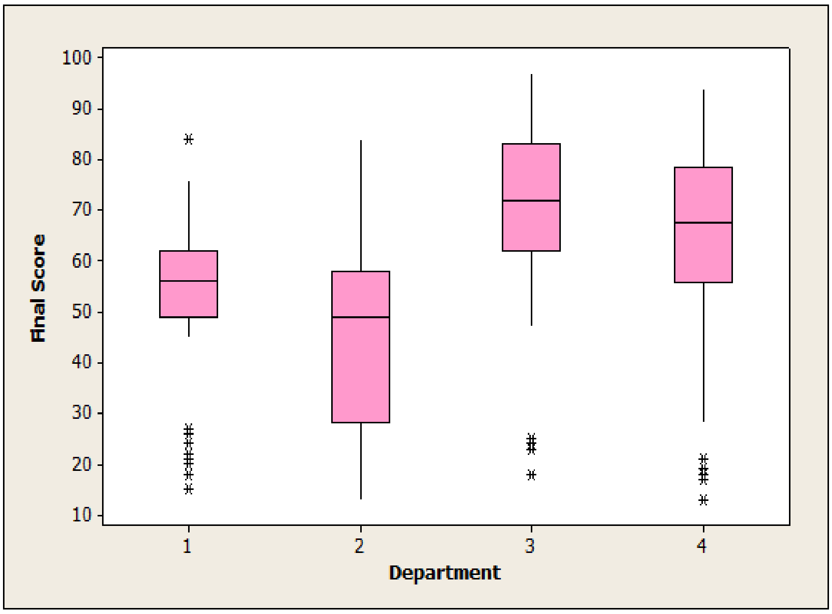


Figure 2below represents Box-and-Whisker plot from the overall performance of students in DE courses. The plot is a visual display of data spread around the median. From the plot, one can determine the high value, low value, first quartile, median and fourth quartile (Brase & Brase, 2015). The departments are listed as JKAS, JKMB, JKKP and JKEES accordingly. Based on the boxplot, the median value is the middle line inside the box. This line shows that 50% of the data is greater than this value. Based on Figure 2, the median value for each department is different. Median value for JKMB is the lowest, below 50 points compared to JKKP, the median value is above 70 points. In comparison among the entire engineering program, JKKP has shown highest median score followed by JKEES, JKAS and lastly JKMB. 50% of the students from JKKP score greater than the median value. Based on the plot, we can also deduce that many students from JKMB scores below the median value.

The maximum value can be seen through the top "whisker". The highest maximum score is coming from JKKP department with score greater than 90 points. The lower part of the whisker represents the minimum value obtained by the students in every department ranging from 10 to 20 points. Data set sometimes contain values so high or so low that they seem to stand apart from the rest of the data. This data are known as outliers. It usually represents data collection error or sometimes it was simply valid but outstand the other data from the data set. For this study, the unusual data is valid since it represents the final score of the students in engineering departments. Some of the students excel in the DE course and some of them lie below average. The outliers can be seen in asterisk (*) in the box and whisker plot below. For JKAS, quite number of students score below average.

Figure 2. Final scores by departments listed as (1) JKAS, (2) JKMB, (3) JKKP and (4) JKEES



A Pearson correlation was computed to assess the relationship between two assessment components. The correlation values of less than 0.50 interpret the relationship between the two variables as very low, the values between 0.51 and 0.79 interpret the relationship as low, 0.8 to 0.89 as moderate relationship and the correlation values with value greater than 0.9 represent very strong relationship between the two variables.

Table 1 below indicates the results for Pearson correlation of the assessment components. There was a positive correlation between the two variables namely, mid-semester exam and new final exam score with Pearson. Overall, there was a strong, positive correlation between mid-semester exam and new final exam score. Increases in mid-semester exam score were correlated with increases in new final exam score. This is because the new grading system of DE course is based on both, the mid-term and final exam score, rather than final exam score alone. Other than that, quiz scores also impact on the new final exam score with Pearson. This implies increase in quiz scores will also impact on the increase in new final exam scores (Priego-Quesada et al., 2019).

Table 1: Pearson product-moment correlation coefficient

		Quiz	PBL	CL	EL	Mid Sem.	Final Exam	New Final Exam
Quiz	*Pearson Correlation* *Sig. (2-tailed)* *N*	1 336	-.039 .472 336	-.435** .000 336	.271** .000 336	.357** .000 336	.612** .000 336	.631** .000 336
PBL	*Pearson Correlation* *Sig. (2-tailed)* *N*	-.039 .472 336	1 336	.102 .063 336	.186** .001 336	.042 .441 336	.026 .640 336	.057 .298 336
CL	*Pearson Correlation* *Sig. (2-tailed)* *N*	.435** .000 336	.102 .063 336	1 336	.474** .000 336	.232** .000 336	.295** .000 336	.325** .000 336
EL	*Pearson Correlation* *Sig. (2-tailed)* *N*	.271** .000 336	.186** .001 336	.474** .000 336	1 336	.373** .000 336	.310** .000 336	.388** .000 336

Mid Sem Exam	*Pearson Correlation Sig. (2-tailed) N*	.357** .000 336	.042 .441 336	.232** .000 336	.373** .000 336	1 336	.655** .000 336	.759** .000 336
Final Exam Score	*Pearson Correlation Sig. (2-tailed) N*	.612** .000 336	.026 .640 336	.295** .000 336	.310** .000 336	.655** .000 336	1 336	.954** .000 336
New Final Exam Score	*Pearson Correlation Sig. (2-tailed) N*	.631** .000 336	.1057 .298 336	.325** .000 336	.388** .000 336	.759** .000 336	.954** .000 336	1 336

**. Correlation is significant at the 0.05 level (2-tailed)

In ANOVA table, degree of freedom represents the total or corrected total and can be calculated using formula [13]. The most important value in ANOVA table is the sig. column. If the number under this column is less that α value set earlier (usually α is 0.05), then this result in significant effect. Otherwise, if the value under the sig. column is greater than α value, it will result in no significant effect. By comparing ratio of difference between means of the group and variability within groups, the F value can be calculated. Mathematically, it can be written as follow:

$$F = \frac{\text{between group variance}}{\text{within group variance}} \qquad (2)$$

Basically, large values of F means that the between group variance (the effect variance) exceeds the within group variance (the error variance) by a significant amount [19]. The bigger F-value also indicates the higher effects of factors on that response [20]. A one-way between subject ANOVA was conducted to compare the new final exam scores between different engineering departments. Since , the hypotheses of is rejected, thus, there was a significant difference in the new final exam scores at among the four departments with as shown in Table 2.

Table 2: ANOVA of new final exam score between departments

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29331.464	3	9777.155	34.358	.000
Within Groups	94476.346	332	284.567		
Total	123807.810	335			

Post-hoc Tukey test was conducted to determine which groups exactly shows the significant difference as mentioned in the ANOVA report. Based on Table 3, JKKP and JKMB shows larger mean difference in new final exam scores by . This implies that there is huge difference in new final exam scores between these two departments. Other than that, JKEES and JKMB has the second highest different of new final exam score with mean difference of . The groups that shows no significant difference in new final exam scores is between JKKP and JKEES which only report slight mean difference of - The negative sign shows in the mean difference for new final exam scores for JKEES is higher than JKKP.

Table 2: Post-Hoc Tukey test of new final exam score

(I) Program	(J) Program	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	*Upper Bound*
1	2	6.745*	2.608	.049	.01	13.48
	3	-17.316*	2.616	.000	-24.07	-10.56
	4	-12.094*	2.522	.000	-18.61	-5.58
2	1	-6.745*	2.608	.049	-13.48	-.01
	3	-24.061	2.693	.000	-31.01	-17.11
	4	-18.839*	2.601	.000	-25.55	-12.12
3	1	17.316*	2.616	.000	10.56	24.07
	2	24.061*	2.693	.000	17.11	31.01
4	1	12.094*	2.522	.000	5.58	18.61
	2	18.893*	2.601	.000	12.12	25.55
	3	-5.222	2.610	.190	-11.96	1.52

Conclusion

An analysis on DE courses performance by engineering students from four departments, namely, JKAS, JKMB, JKKP and JKEES was analyzed to determine which department perform better in that course. Based on the study conducted using ANOVA and Tukey test, students' from JKKP have a very good performance in DE course based on the new final exam score while JKMB perform the very least compared to JKAS and JKEES. Other than that, this study also determines the connection between assessment factor like quizzes, e- learning, mid semester exam and final exam result. By conducting the study using Pearson correlation, the result shows there is a linear relationship between the new final exam score with quizzes score and mid semester exam score respectively.

Thus, it is important for the students to have a positive continuous assessment throughout the semester in DE course particularly in quizzes. Students should also master their study skills in order to excel in study since the study skill comprise of regular study, attending lectures and taking notes, efficient written explanation, active participant in classroom, completing assignments, preparing and attending exams [21]. The new grading system for final exam score can be considered as efficient since it ensures that the students perform in both the mid-term and final exam. Continuous assessment will surely help the students to perform in other engineering subject related to the courses as well.

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