STUDENTS’ PERFORMANCE IN ENGINEERING MATHEMATICS COURSES: VECTOR CALCULUS VERSUS DIFFERENTIAL EQUATIONS

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Abstract

Students’ performance can be evaluated through final exam results consist of students’ assignment, quizzes, e-learning tutorial and mid-semester exam. In engineering, mathematics is one of the important course students should dominated especially in Differential Equation (DE) course. However, students should have deep understanding of some important topics covered in Vector Calculus (VC) at early stage such as Integration, Differentiation and Series before they taken the DE course. This article attempts to explore students’ performance and correlation between two mathematics courses, VC and DE among engineering students. A study is carried out on student’s results data which consisted of 205 engineering students from four different departments; 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). The results, which are verified by using paired t-test and Pearson product-moment correlation coefficient, indicated that VC and DE courses are related and have positive linear relationship.

Keywords: Students’ performance, Grades, Vector calculus, Differential equations.

1. Introduction

Mathematics is an expression of the human mind 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 [1]. According to Fennema and Sherman [2], 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.

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 Vector Calculus (VC) course at first semester and Differential Equations (DE) course for third semester. In engineering, mathematics is one of the important course students should dominated especially in DE course. However, students should have deep understanding of some important topics covered in Vector Calculus (VC) at early stage such as Integration, Differentiation and Series before they taken the DE course. The purposes of this paper are to explore students' performance and correlation between two mathematics courses among engineering students.

2. Methodology
A total number of 205 students’ final exam results for two courses VC and DE 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). Final exam results data consist of students’ assignment, quizzes, e-learning tutorial and mid-semester exam. The data was analysed using Microsoft Office Excel and SPSS (version 18). Analyses included descriptive statistics. A paired t-test and Pearson product-moment correlation coefficient tests was conducted to analyse the results of VC and DE. The score interval for each grade is shown in Table 1.

<table>
<thead>
<tr>
<th>Grades</th>
<th>Score Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>75-100</td>
</tr>
<tr>
<td>B</td>
<td>60-74.9</td>
</tr>
<tr>
<td>C</td>
<td>45-59.9</td>
</tr>
<tr>
<td>D</td>
<td>35-44.9</td>
</tr>
<tr>
<td>E</td>
<td>0-34.9</td>
</tr>
</tbody>
</table>

2.1. Paired t-test
Typically researchers analyse paired data using the paired t-test, which essentially is a one-sample Student t-test performed on difference scores [3]. It is the most basic statistical test that measures group differences which is appropriately used when the researcher wishes to determine whether two groups, as defined by the independent variable, differ on the basis of a selected dependent variable [4, 5]. Andrew et al. [5] Also states that the t-test allows a researcher to compare a
categorical independent variable with two groups on the basis of an interval or ratio-scaled dependent variable specifically. The t-test for two dependent groups is used to compare the mean of the two data sets obtained from the same sample. Two hypotheses tested are as follows:

$H_0$ : There are no significant differences between VC and DE final exam results

$H_1$ : There are significant differences between VC and DE final exam results

If $p$-value < $\alpha = 0.05$, $H_0$ is rejected and shows that there are significant differences between the mean of VC and DE final exam results.

A paired t-test is used to calculate differences of group by examining the means of the groups [6]. The difference between the means of the groups is divided by the standard error of the difference. The variance is simply the square of the standard deviation. This calculation results in a t-value, which can be referred in table of significance to test for a significant difference between the groups. Fortunately, in this paper, we can use SPSS to automate this process. The formula for the test statistics for paired differences is

$$ t_o = \frac{\bar{d} - \mu_d}{s_d / \sqrt{n}} \tag{1} $$

where

$\mu_d$ = Mean of the paired differences

$\bar{d}$ = Difference in the means

$s_d$ = Standard deviation of the difference

$n$ = Number of sample size

2.2. Pearson product-moment correlation coefficient

Pearson product-moment correlation coefficient test is used to measure the existence of a linear relationship between two variables. 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 VC and DE

$H_1$ : There is a linear relationship between VC and DE

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 VC and DE. The strength of these variables can be seen by the value of the correlation coefficient. In addition, correlation coefficient for each department is also has been investigated.

This is a measure of the strength and direction of the linear relationship between the two variables [7]. 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.

3. Results and Discussion

Based on Fig. 1, the pie chart shows the percentage of students for each department JKAS, JKMB, JKKP and JKEES. JKKP and JKEES shows the highest number of students with the same percentage of 27.8, followed by JKAS with the percentage of 22.9 and the lowest percentage is 21.5 for JKMB.

![Pie Chart showing distribution of engineering students by department.](image)

**Fig. 1. Distribution of engineering students by department.**

Figure 2 shows the distribution of students for VC and DE according to each grade. The bar chart shows there is high number of difference which is almost half who get grade A, B, C and D for the two courses. In particular, the number of students who get grades A and B in DE are higher than VC and the numbers of students who get grades C and D in DE are smaller than VC. Obviously, none of the students fail in DE (grade E) course compare to VC.

![Bar Chart showing distribution of students for VC and DE courses by grade.](image)

**Fig. 2. Distribution of students for VC and DE courses by grade.**

Figure 3 shows the comparison of grades for VC and DE courses according to departments. The bar chart shows for all departments JKAS, JKMB, JKKP and JKEES produces same results as increasing number of students get grades A, and B and decreasing number of students get grades C and D for DE compare with VC course. It is also found that none of the students get grade D in DE for JKAS and JKKP compare to VC. Surprisingly, there are no students fails (grade E) in these two courses for all departments except for JKEES.
Table 2 indicates the results for paired samples t-test and Pearson product-moment correlation coefficient of the pair variables VC and DE. The t-test statistics is -22.077 and the corresponding two-tailed p-value is 0.000 which is less than level of significance ($\alpha$) 0.05. Therefore, we can conclude that there is significance difference in final exam marks between VC and DE course. The value of mean difference with -12.1560 suggested that mean marks for DE course
is greater than VC course. The value of the Pearson correlation of 0.714 and p-value is less than 0.05 imply there is significant strong positive linear relationship between VC and DE. The positive value of the correlation means that students who scored high on the VC course tend to score high on the DE course.

Table 2. Paired Samples t-Test and Pearson product-moment correlation coefficient.

<table>
<thead>
<tr>
<th>Courses</th>
<th>N</th>
<th>Mean difference</th>
<th>t-test</th>
<th>Pearson Correlation, r</th>
<th>Sig. (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC-DE</td>
<td>205</td>
<td>-12.1560</td>
<td>-22.077</td>
<td>0.714</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Pearson product-moment correlation coefficient of the pair variables VC and DE for each department is shown in Table 3. Generally, the Pearson correlation for each department more than 0.6 and p-value is less than 0.05 but the highest value of Pearson product-moment correlation coefficient of 0.745 which is JKAS whilst the lowest is JKMB imply there is significant strong positive linear relationship between VC and DE. The highest positive value of the correlation from JKEES means that students who scored high on the VC course tend to score high on the DE course compare than other department.

Table 3. Pearson product-moment correlation coefficient for each department.

<table>
<thead>
<tr>
<th>Department</th>
<th>Courses</th>
<th>N</th>
<th>Pearson Correlation, r</th>
<th>Sig. (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JKAS</td>
<td>VC-DE</td>
<td>47</td>
<td>0.745</td>
<td>0.000</td>
</tr>
<tr>
<td>JKMB</td>
<td>VC-DE</td>
<td>44</td>
<td>0.680</td>
<td>0.000</td>
</tr>
<tr>
<td>JKKP</td>
<td>VC-DE</td>
<td>57</td>
<td>0.732</td>
<td>0.000</td>
</tr>
<tr>
<td>JKEES</td>
<td>VC-DE</td>
<td>57</td>
<td>0.724</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Based on Table 4, we have found that the corresponding two-tailed p-value for all department is 0.000 which is less than level of significance (α) 0.05. Therefore, we can conclude that there is significance difference in final exam marks between VC and DE course for all departments. The value of mean difference with all the negative values suggested that mean marks for DE course is greater than VC course but the highest mean differences is from JKEES whilst the lowest is from JKAS.

Table 4. Paired Samples t-Test for each department.

<table>
<thead>
<tr>
<th>Department</th>
<th>Mean Difference</th>
<th>SD Difference</th>
<th>t-test</th>
<th>Sig (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JKAS</td>
<td>-9.63830</td>
<td>7.05083</td>
<td>-9.372</td>
<td>0.000</td>
</tr>
<tr>
<td>JKMB</td>
<td>-10.93182</td>
<td>8.40652</td>
<td>-8.626</td>
<td>0.000</td>
</tr>
<tr>
<td>JKKP</td>
<td>-13.42105</td>
<td>7.32156</td>
<td>-13.839</td>
<td>0.000</td>
</tr>
<tr>
<td>JKEES</td>
<td>-13.91228</td>
<td>8.15099</td>
<td>-12.886</td>
<td>0.000</td>
</tr>
</tbody>
</table>
4. Conclusion

An analysis on students’ performance based on their final exam results in two Engineering Mathematics courses: Vector Calculus (VC) and Differential Equations (DE) were conducted. Based on analysis and results, the t-test and Pearson correlation shows that VC and DE courses are related and have positive linear relationship. The main reason of the correlation of these two courses is topics covered in VC such as Integration and Differentiation are the basic knowledge students have to know in order to learn DE. This shows that students have to take VC course before they proceed to the DE course. As conclusion, VC is important as preparatory course for DE course.

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References