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IMPACT OF MATHEMATICS IN LEVEL 1 ON THE ACADEMIC PERFORMANCE OF ENGINEERING STUDENTS: A CASE STUDY

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ABSTRACT

In engineering sciences, mathematical knowledge is highly essential to improve the analytical thinking of engineering undergraduates. Therefore, a significant component of advanced mathematics has been included in the engineering degree programs. The objective of this study is to explore the impact of mathematics in Level 1 on the academic performance of undergraduate engineering students in Level 2. The study was conducted with engineering students at the University of Moratuwa, Sri Lanka. Findings revealed that the mathematics performance in Level 1 was significantly correlated with students' overall performance in all engineering disciplines. The impact of mathematics in Semester 2 was significantly higher than the impact of mathematics in Semester 1 on the students' performance in Level 2. Furthermore, the impact of mathematics was significantly different among various engineering disciplines. The study concluded that the performance in mathematics in Level 1 could indicate the trend towards the student academic performance in all engineering programs.

KEYWORDS: Engineering Mathematics, Multivariate Multiple Linear Regression, Students' Academic Performance

INTRODUCTION

Mathematics is more than a tool for solving problems and it can develop intellectual maturity and logical thinking of students. The skills in mathematics would certainly assist to enhance students' knowledge in other subjects such as engineering, physics, accounting, etc. (Imran, Nasor and Hayati 2011; Aina 2013; Alfan and Othman 2005). Especially, in engineering sciences, mathematical knowledge is crucial importance to improve the analytical thinking of engineering undergraduates. Pyle (2001) and Sazhin (1998) stated the importance of mathematical knowledge for engineering students. A study by Goold and Devitt (2012), with the focus on professional engineers in Ireland, discovered that mathematical knowledge gained prior and during engineering education is highly essential in engineering practice as they use a high level of curriculum mathematics and mathematical thinking in their work. It is clear that mathematics is more important foundation for the education of engineers.

In many countries, the pre-university requirement for engineering degrees is based mostly on mathematics for all higher education institutions. Similarly, in Sri Lanka, for engineering undergraduate degree programs, higher mean Z score of the individual Z scores of Mathematics, Physics and Chemistry subjects in General Certificate of Education Advanced Level; G.C.E. (A/L) examination is the pre-requisite.

Pre-university qualification and admission criteria for university entrance, have been widely studied in the literature and are commonly accepted to have a beneficial effect on students' subsequent performance in a variety of academic fields: Engineering (Ali and Ali 2010; Hermon and Cole 2012), Chemistry (Seery 2009), Medicine (Ali 2008; Hailikari, Katajavuori and Lindblom-Ylanne 2008; Mufti and Qayum 2013), Equine and animal studies (Huws and Taylor

2008), Accounting (Alfan and Othman 2005) and Psychology (Huws, Reddy and Talcott 2006; Thompson and Zamboanga 2004).

Numerous studies have been investigated on the predictive validity of pre-university mathematical knowledge on student performance in engineering degree programs and revealed that pre-university mathematical knowledge effect on the performance of engineering students (Barry and Chapman 2007; Hermon and Cole 2012; Ismail, et al. 2012; Lee et al. 2008; Othman et al. 2009). Conversely, Adamson and Clifford (2002) and Todd (2001) found that engineering student performance in university cannot be reliably predicted from pre-university qualification. A study by Nopiah, Fuaad, Rosli, Arzilah, and Othman (2013) in Malaysia, was focused on predicting the performance of students in subsequent engineering mathematics courses using pre-test. They found a weak correlation between the pre-test and performance in engineering mathematics courses.

A study conducted among undergraduates of three engineering programs by Imran et al. (2011) revealed students' overall performance in engineering programs were significantly correlated with the performance in the mathematics and physical science courses taken in their respective programs. This correlation was relatively stronger for the mathematics courses compared to the physical science courses. However, there is a lack of studies related to examining the impact of mathematics in undergraduate engineering degree programs on student' academic performance.

According to Sri Lankan education system, students entering university with diverse prior knowledge and background. However, there is a high probability that the students who admitted to the Faculty of Engineering, University of Moratuwa, Sri Lanka have obtained higher grades for mathematics in G.C.E. (A/L) examination. Nevertheless, mathematics performance of engineering students in their undergraduate degree programs varies significantly between and within different engineering disciplines. Hence, it is crucial to understand the impact of mathematical knowledge that students acquired from their undergraduate degree programs. This knowledge would be useful for educational stakeholders at different level of decision making. The purpose of this study is therefore to explore the impact of mathematics in Level 1 on the academic performance of undergraduate engineering students in Level 2.

MATERIALS AND METHODS

The study was conducted with 626 engineering students from seven different disciplines at the Faculty of Engineering, University of Moratuwa, Sri Lanka for the academic year 2011/2012. Data were collected from Examination division, University of Moratuwa after due permission was taken. Seven different engineering disciplines used for the study are namely; Chemical and Process Engineering (CH), Civil Engineering (CE), Computer Science and Engineering (CSE), Electrical Engineering (EE), Electronic and Telecommunications Engineering (ENTC), Materials Science and Engineering (MT) and Mechanical Engineering (ME).

Students' examination marks of mathematics courses in both semesters in Level 1: semester 1 (S1) and semester 2 (S2) and all compulsory courses other than mathematics courses in both semesters in Level 2: semester 3 (S3) and semester 4 (S4) were utilized. Average marks of these courses were considered as the students' academic performance for S3 and S4 separately. Furthermore, academic performance of these courses irrespective of S3 and S4 was considered as an average of S3 and S4.

Explanatory data analysis was carried out initially followed by ANOVA to examine the significant differences in mean marks of mathematics courses in Level 1 among various engineering disciplines. Regression models were developed using the stepwise method and furthermore, multivariate regression was applied to the academic performance of S3 and

S4.

RESULTS AND DISCUSSIONS

Explanatory Data Analysis

Table 1 presents descriptive statistics for each of the explanatory and response variables irrespective of engineering students' disciplines. It is clear that both mean and median marks in S1 are higher compared with corresponding values in S2 indicating student performance of mathematics in S1 is better than that in S2. However, such a difference in both mean and median was not observed in average marks in S3 and S4.

Table 1: Descriptive Statistics of Students' Marks

Variable	Mean	SE of Mean	Median
Math_S1	68.9	0.48	69.3
Math_S2	57.2	0.54	56.4
Mean_S3	66.3	0.33	66.6
Mean_S4	66.4	0.33	66.9
Mean_composite	66.4	0.31	66.8

The box plots in Figure 1 and Figure 2 exhibit the distribution of mathematics marks in S1 and S2 by engineering disciplines respectively. According to Figure 1, the highest average mark for the mathematics course in S1 is from ENTC discipline (79.7) followed by CSE discipline (77.1) while the lowest average mark is from MT discipline (48.7). Most of the mathematics marks (Math_S1) in all disciplines except MT discipline have lied between 50 and 90 region. However, few students in CE, CH and CSE disciplines have obtained higher marks than the highest mark obtained by ENTC discipline indicating high marks by individuals were obtained by students in CE, CH and CSE disciplines.

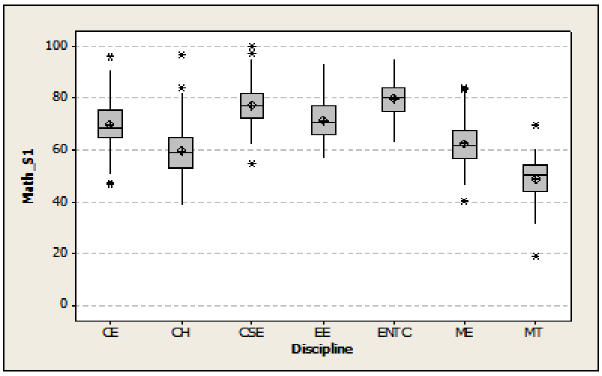

Figure 1: Distribution of Mathematics Marks in S1 by Engineering Discipline

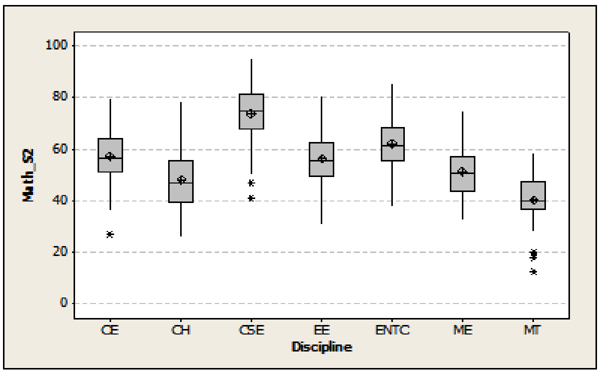

Figure 2: Distribution of Mathematics Marks in S2 by Engineering Discipline

Figure 2 shows that the variations of all distributions of mathematics marks in S2 are higher than that in S1. Most of the students in all disciplines except CSE discipline, obtained between 40 and 70 percent for mathematics course in S2. Students of CSE discipline have obtained the highest average mark (73.9) while students from MT discipline have obtained the lowest average mark (40.1) for mathematics in S2. Comparing both figures 1 and 2, it is clear that the performance of mathematics has decreased from S1 to S2 in all disciplines. The overall best performance in both mathematics courses are from students of ENTC and CSE disciplines while the least performance is from students of MT discipline.

Comparison Among Engineering Disciplines

ANOVA was conducted for students' mathematics marks in S1 and S2 separately for a randomly selected sample size of 100 students in order to compare mathematics marks among engineering disciplines. This was repeated five times with replacement sampling. The null hypothesis tested was there is no significant difference between mean marks of mathematics course among engineering disciplines. The summary of the ANOVAs carried out for each sample are shown in Table 2. Results concluded that both mean marks of mathematics courses in S1 and S2 among engineering disciplines are significantly different.

Table 2: ANOVA for Mathematics Courses

Sample		1	2	3	4	5
P - value	Math_S1	0.000	0.000	0.000	0.000	0.000
	Math_S2	0.000	0.000	0.000	0.001	0.000

Impact of Mathematics Marks on Students' Performance

Table 3 shows the correlation coefficient between marks of mathematics and response variables and found that correlation coefficients for all pairs are significantly greater than zero ($P < 0.01$). Furthermore, results indicate mathematics course in S2 is strongly correlated with students' overall performance than mathematics course in S1 indicating that more impact can be expected from marks of Math_S2 on the overall performance in Level 2 than that of marks of Math_S1.

Table 3: Correlation Coefficient Between Marks of Mathematics and Response Variables

	Mean_S3	Mean_S4	Mean_composite
Math_S1	.487**	.418**	.481**
Math_S2	.501**	.524**	.541**
**. Correlation is significant at the 0.01 level (1-tailed).			

Table 4: Correlation Coefficient Between Marks of Mathematics and Responses by Discipline

Criterion	Predictors	CE	ENTC	ME	EE	MT	CH	CSE
		(N=125)	(N=96)	(N=96)	(N=99)	(N=44)	(N=71)	(N=95)
Mean_S3	**Math_S1**	0.314**	0.332**	0.238*	0.461**	0.393**	0.483**	0.482**
	Math_S2	0.485**	0.631**	0.575**	0.606**	0.556**	0.603**	0.501**
Mean_S4	**Math_S1**	0.342**	0.224*	0.233*	0.372**	0.198	0.446**	0.492**
	Math_S2	0.490**	0.617**	0.613**	0.600**	0.482**	0.600**	0.507**
Mean_composite	**Math_S1**	0.360**	0.307**	0.253*	0.439**	0.308*	0.486**	0.507**
	Math_S2	0.534**	0.659**	0.634**	0.635**	0.541**	0.630**	0.524**
**. Correlation is significant at the 0.01 level (1-tailed)								
*. Correlation is significant at the 0.05 level (1-tailed)								

Furthermore, the correlation between marks of Math_S1 and Math_S2 and the average marks of the courses in S3 and S4 as well as Level 2 with respect to engineering discipline are shown in Table 4. Results show significant correlation between predictors and response variables for all disciplines at the 0.05 level except the correlation between mathematics course in S1 and average marks of S4 of MT discipline. Moreover, the correlation between mathematics course in S2 and students' overall performance are stronger compared with the correlation between mathematics course in S1 and students' overall performance.

Multiple Linear Regression (MLR)

Stepwise regression analysis was carried out on the three students' academic performance outcomes: average marks of S3, average marks of S4 and composite of S3 and S4, irrespectively to their discipline. Table 5 denotes model statistics, ANOVA F-statistics as well as coefficients.

Table 5: Summary of the Fitted Model Irrespective of the Disciplines

	Mean_S3	Mean_S4	Mean_Composite
Constant	41.185	44.226	42.501
Math_S1	0.198	0.105	0.155
Math_S2	0.200	0.261	0.231
ANOVA F statistic	135.69	127.13	152.52
P-value	0.000	0.000	0.000
Std. Error of the Estimate	6.91	6.88	6.41
R-sq	30.4	29.0	32.9
R-sq (adj)	30.1	28.8	32.7

Predictors: (Constant), Math_S1, Math_S2

Dependent Variable: Average marks

Models with average marks of S3 (Mean_S3) and average marks of S4 (Mean_S4) as the outcome measure, explained 30% and 29% of the variation in students' academic performance respectively. Similarly, model with the composite outcome explained 33% of variation in students' academic performance. Though the amount of variance explained by the fitted model is not sufficient, P-values for the F statistic denote that all three fitted models are significant at the 0.05 level. Moreover, both predictors: Math_S1 and Math_S2 are significant ($P < 0.01$) in all three models. However, residual analyses suggest that all fitted models are not adequate due to the violation of normality assumption.

Furthermore, regression analysis was carried out for engineering student discipline wise, to identify the impact of mathematics separately. Mean_composite was considered as the response variable and the model statistics, ANOVA F-statistics and coefficients are provided in Table 6.

Table 6: Summary of the Fitted Model by Discipline

	CE	ENTC	ME	EE	MT	CH	CSE
Constant	45.615	40.690	37.970	41.300	40.250	35.330	19.280
Math_S1	0.132			0.174			0.335
Math_S2	0.249	0.443	0.460	0.293	0.454	0.618	0.290
ANOVA F statistic	29.88	71.97	63.32	42.23	17.41	45.49	29.76
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Std. Error of the Estimate	4.42	5.24	4.96	3.84	6.67	8.31	5.84
R-sq	32.9	43.4	40.3	46.8	29.4	39.7	39.3
R-sq (adj)	31.8	42.8	39.7	45.7	27.7	38.9	37.9

Dependent Variable: Mean_composite

R-square values for all seven models, illustrated that the fitted models explained 29% to 47% of the variation in students' academic performance. F statistics of ANOVA output imply that all seven fitted models are significant at the 0.05 level. However, mathematics course in S1 is significant at the 0.05 level in three fitted models only and that is for CE, EE and CSE disciplines. Mathematics course in S2 has the strongest influence on students' academic performance in all engineering disciplines. Moreover, observations on the t-value indicate that mathematics course in S2 is a high significant predictor in determining students' performance. Furthermore, residual analysis confirmed that all the fitted models are adequate.

Multivariate Multiple Linear Regression

In order to determine how mathematics courses in S1 and S2 effect on academic performance in S3 and S4, multivariate multiple linear regression analysis was utilized as it consider multiple responses and multivariate tests provide a way to understand the relationships of predictors across separate response measures.

Table 7 shows the Pearson correlation between Mean_S3 and Mean_S4 discipline wise. According to these results, it is clear that academic performance of S3 and S4 (Mean_S3 and Mean_S4) are highly correlated for all disciplines and this was suggested that multivariate MLR could be applied for Mean_S3 and Mean_S4 as the outcomes with respect to engineering disciplines separately.

Table 7: Pearson Correlation Between Mean_S3 and Mean_S4

Discipline	CE	ENTC	ME	EE	MT	CH	CSE
Correlation coefficient	0.665	0.793	0.738	0.813	0.834	0.817	0.851

Table 8 presents the multivariate MLR model summaries for each discipline separately. Results in Table 8 show that Math_S2 is significant at 0.05 level for all fitted models, while Math_S1 is significant only for three disciplines; CE, EE and CSE in both semesters S3 and S4. F statistics and residual analysis confirmed the adequacy of all fitted models in both semesters. R-squared values for all models, illustrated that the fitted models explained 23% to 45% of the variation in students' academic performance. Furthermore, these results indicate that in some disciplines, academic performance in S3 is more predictable than academic performance in S4 from mathematics courses in Level 1.

Table 8: Discipline Wise Multivariate MLR Model Summary

	CE	ENTC	ME	EE	MT	CH	CSE
Dependent Variable: Mean_S3							
Constant	48.31**	29.26**	34.97**	39.55**	34.43**	29.43**	19.98**
Math_S1	0.111**	0.15	0.071	0.212**	0.156	0.207*	0.319**
Math_S2	0.227**	0.449**	0.429**	0.297**	0.389**	0.466**	0.279**
ANOVA F statistic	22.11**	32.82**	23.78**	39.38**	10.27**	21.89**	25.65**
Std. Error of the Estimate	4.59	6.11	5.62	4.24	6.41	8.24	6.03
R-sq	26.61	41.38	33.84	45.07	33.38	39.17	35.8
R-sq (adj)	25.4	40.12	32.41	43.92	30.13	37.38	34.4
Dependent Variable: Mean_S4							
Constant	42.54**	41.91**	34.57**	43.06**	42.21**	28.49**	18.71**
Math_S1	0.156**	0.015	0.057	0.135**	-0.03	0.176	0.349**
Math_S2	0.274**	.383**	0.463**	0.29**	0.466**	0.561**	0.299**
ANOVA F statistic	23.91**	28.7**	28.5**	31.88**	6.24**	20.41**	26.79**
Std. Error of the Estimate	5.54	5.12	5.46	4.14	7.87	9.53	6.39
R-sq	28.16	38.16	38.00	39.91	23.33	37.51	36.8
R-sq (adj)	26.98	36.83	36.67	38.66	19.59	35.67	35.43
M1 test - F statistic	0.73	3.39*	0.05	3.05*	3.88*	0.10	0.26
M2 test - F statistic	1.07	1.79	0.31	0.03	0.75	1.06	0.19
* p<0.1; ** p<0.05							

The first multivariate test (M1 test) revealed that the parameter for Math_S1 is the same for the academic performance of S3 (Mean_S3) and S4 (Mean_S4) in four disciplines; CE, ME, CH and CSE. In other words, the parameter for Math_S1 is not the same for the academic performance of S3 and S4 in ENTC, EE and MT disciplines. The parameter for Math_S2 is the same for the academic performance of S3 (Mean_S3) and S4 (Mean_S4) in all seven disciplines is exposed from the second multivariate test (M2 test).

These results suggest that if a student who studied in any engineering discipline, was able to perform well in the mathematics courses in Level 1, it is likely that he/she would perform well in courses in Level 2 as well.

CONCLUSIONS

It can be inferred that students' performance of mathematics in Level 1 is significantly different among various engineering disciplines. The impact of mathematics in Semester 2 was significantly higher than the impact of mathematics in Semester 1 on the students' academic performance in Level 2 irrespective of the engineering disciplines. Moreover, the effects of mathematics courses in Level 1 are equally performed on students' academic performance in S3 and S4. The performance in mathematics in Level 1 is a good indicator to judge student academic performance in engineering programs in Level 2. This analysis is recommended to carry out for more years before implement various decisions.

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