World Academy of Science, Engineering and Technology
International Journal of Educational and Pedagogical Sciences
Vol:10, No:3, 2016

Multivariate Analysis of Students' Performance in Math Courses and Specific Engineering Courses

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***Abstract*—**The aim of this research is to study the relationship between the performance of engineering students in different math courses and their performance in specific engineering courses. The considered courses are taken mainly by engineering students during the first two years of their major. Several factors are being studied, such as gender and final grades in the math and specific engineering courses. Participants of this study comprised a sample of more than thousands of engineering students at Lebanese University during their tertiary academic years. A significant relationship tends to appear between these factors and the performance of students in engineering courses. Moreover, female students appear to outperform their male counterparts in both the math and engineering courses, and a high correlation was found between their grades in math courses and their grades in specific engineering courses. The results and implications of the study were being discussed.

***Keywords*—**Education, engineering, math, performance.

I. Introduction

ENGINEERS can be found in an extraordinarily wide range of careers, from designing next generation Formula One cars to working at the cutting edge of robotics, and from running their own business creating new autonomous vehicles to developing innovative indices for leading global financial institutions. Nevertheless, many students question if they will ever really need to know the quantity of math studied as part of their engineering major.

Not realizing how useful math can be, some students choose to only fulfill the minimum requirements demanded by their institution.

The objective of teaching mathematics to engineering students is to find the right balance between practical applications of mathematical equations and an in-depth understanding of real-world problem solving [15].

The mathematics course requirements taken for different branches of engineering is more or less the same during the first and second year, but tends to be more specific and complicated at later years.

In the last 10 years, Lebanese University has given mathematical courses relating to engineering courses that include linear algebra, calculus and numerical methods. These courses are given in the first two years in all engineering branches. This study investigates whether there is a relationship between the performance of engineering students on the mathematical course and their performance on the engineering courses. Some students come to Lebanese University with advanced standing or college credit from high school, others not, and mathematics is one way to strengthen their engineering degree.

At Lebanese University, mathematics courses are organized so that engineering students can easily strengthen their degree programs by taking different kinds of mathematics courses which contain complex and challenging-level problems that are directly related to engineering. Mathematics courses in the Faculty of Engineering focus on the art of applying mathematics to complex real-world problems. It combines mathematical theory, practical engineering and scientific computing to address today's technological challenges.

For many years, concerns have been expressed about underachievement in mathematics. The poor results recorded in mathematics achievement indirectly affects the students' overall academic performance. As international research studies have also reported some underachievement in mathematics [8], [1], [12], [3], there is a strong need to investigate the influencing factors contributing to the underachievement in mathematics education. Inspired by this, this study is conducted to achieve a better understanding of the relationship between a student's performance in mathematics courses and their achievement in engineering courses.

Poor academic performance in engineering courses has been a global issue among stakeholders in engineering learning. Much of the research in this area has attributed poor performance to specific factors that include: students' performance in mathematics courses and gender [14].

In most countries, very little difference is recorded in the results of female and male students studying mathematics. However, in most parts of the world, compared to their male counterparts, fewer girls and women choose to study the subject and pursue a career in mathematics-related fields [17], [18]. However, gender issues in math are not limited to achievement in tests and the selection of courses. The idea that mathematical knowledge is objective, rational and abstract, rather than subjective, emotional and concrete, reinforces opposition that feeds into wider gender inequalities. This study investigates, in addition to the relationships between a student's performance in math courses and their performance in engineering courses, whether there is a difference in a student's achievement in math and engineering courses in relation to gender.

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The results obtained in this study will help Lebanese University, Faculty of Engineering and other universities to understand whether students' achievement in math courses affect their performances in engineering ones and whether there is a significant effect of students' gender on their performance in math courses as well as in engineering ones.

II. Literature Review

Numerous literatures have revealed students' underachievement in mathematics across various levels of studies, including engineering. The urgency to raise student achievement in engineering courses at all levels has led to the identification of a host of factors, which are said to contribute to the differences in student performance. Mathematics knowledge, universally, had been documented as an essential variable in the discussion of university students' achievement [8], [12]. The literature indicated that a lack of basic skills and knowledge in mathematics was one of the three major reasons for students to fail their calculus course [8]. According to [21], students who did poorly in their mathematics courses or did not take the subject at all usually scored poorly in first year basic mathematics and basic calculus examinations at university level. Besides, students having learned only simple mathematics do not have sufficient mathematical skills to learn advanced mathematics or engineering courses at university level [21]. Further, [9] revealed the significance of prior knowledge over self-beliefs in predicting students' mathematic achievement. The role of gender on students' mathematic achievement has continued to interest many researchers in the field of education, psychology and sociology [4]. While some studies reported on higher mathematical achievement among male students as compared to female students [6], [13], recent studies have showed that the gender gap has gradually minimized around the world. In China, [16] reported on no gender differences in the overall mathematics achievement among 1078 high-school seniors in the 2002 College Entrance Examination. This is an interesting result that may carry an explanation to an underlying trend of gender differences in mathematical achievement among students at public university.

III. Methodology

This study looks into the relationship between two factors, the grades of students in math courses and their grades in engineering courses. It also assesses whether gender has any effect on their overall performance in both the math and engineering courses. The study employed ex post facto research design. In an ex post facto research, the relationships and effects among the variables are studied as they occur in a natural setting [20]. This study looked into the factors that influenced the students' performance in engineering courses and examined the possible relationships with the chosen math courses.

A. Respondents and Instruments

In this study, respondents consisted of 4779 full-time students from Lebanese University, a public university in Lebanon. The data of the respondents were taken for 11 consecutive years from students registered in the Faculty of Engineering, where students are supposed to enroll in 12 math courses in their first two years, then choose the specific engineering major. The research will investigate the relationship of the performance of students in math courses with their performance in engineering courses throughout their academic career. The instruments of this study consisted of students' grades from 12 major mathematics and engineering courses selected from the university data base over 11 years and includes the gender of the students.

The data are analyzed by using Statistical Package for Social Sciences (SPSS). Descriptive statistics, such as mean and standard deviation are calculated and used for organizing, summarizing and classifying the performance scores of students in engineering and mathematics courses. The mean and standard deviation are used as the measures of central tendency and variability, respectively. Pearson product-moment correlation coefficients are calculated to identify correlations, if any, for the course grades of engineering courses and the influencing factors. Multivariate regression analysis is performed to determine whether the grades of mathematics courses contribute significantly to the variation in engineering course grades. Multivariate statistics concerns understanding the different aims and background of each of the different forms of multivariate analysis and how they relate to each other. The practical implementation of multivariate statistics to a particular problem may involve several types of univariate and multivariate analyses in order to understand the relationships between variables and their relevance to the actual problem being studied [10]. Step-wise discriminant analysis is carried out to develop a predictive model for the performance of engineering courses with respect to mathematics courses. And an independent t- test is performed to distinguish whether there is a significant difference in gender among students' performance in math and engineering courses.

B. Results

This section reveals the results of the data analysis that is carried out to study the relationship between the grades of students in the math courses and their grades in the engineering courses, and the possible relationships of the gender factor from the public university in Lebanon.

1. Descriptive Statistics

The mathematics courses in this study are as follows: algebra, calculus, differential geometry and computers. The engineering courses are static, optic, electricity, descriptive, perspective and thermodynamics. The average pass rate is 50%.

Tables I and II show mean and standard deviation of student grades in math and engineering courses in first year, semester one and two.

Tables I and II reveal the average grades of 2597 students in their first year and the increase in grade averages that appears in their second semester, especially in the engineering courses.

TABLE I
DESCRIPTIVE STATISTICS

	N	Mean	Std. Deviation
Algebra I	1412	64.26	16.479
Calculus I	1412	68.70	17.127
Computer I	1412	66.25	18.718
Optics	1412	67.01	17.187
Static	1412	66.71	17.152
Descriptive	1412	67.97	14.455

TABLE II
DESCRIPTIVE STATISTICS

	N	Mean	Std. Deviation
Algebra II	1185	67.85	12.571
Calculus II	1185	69.49	12.774
Computer II	1185	71.09	16.330
Mechanics I	1185	70.03	12.615
Electricity II	1185	71.57	13.339
Perspective	1185	78.93	8.135

Tables III and IV show the mean and standard deviation of student grades in math and engineering courses in second year, semester one and two.

TABLE III
DESCRIPTIVE STATISTICS

	N	Mean	Std. Deviation
Diff. Geom	1154	71.85	11.670
Calculus III	1110	74.47	10.972
Computer III	1110	70.75	12.073
Electricity II	1110	68.99	12.804
Mechanics II	1110	73.00	11.578

TABLE IV
DESCRIPTIVE STATISTICS

	N	Mean	Std. Deviation
Calculus IV	1069	76.57	12.566
Numerical Methods	1069	72.79	11.307
Modern Phys	1069	70.43	10.481
MDM	1069	72.79	12.835
Electricity III	1069	71.46	10.705
Thermodynamic I	1069	71.82	12.635
Drawing in Arch	1069	77.91	9.840

Tables III and IV, above, reveals a higher average in student's grades in their second year during the first and second semester, which may reflect the relationship of the math courses with the engineering courses. Multivariate regression analysis is a statistical way to explain the relationship between the math courses and engineering courses.

2. Multivariate Analysis

The hypothesis in the generalized linear model is

- H_a: Average grades on math courses has a relationship with grades on engineering courses
- H_0: Average grades on math courses has no relationship with grades on engineering courses

This hypothesis is repeated for each semester during a student's first two years of their major.

The model is as follows:

$$Algebra\ I + Calculus\ I + ComputerI = \alpha + \beta_1 Optics + \beta_2 Statics + \beta_3 descriptive$$

Table V shows multivariate analysis for the effect of the independent variables on the dependent variables, first year, first semester.

TABLE V
TESTS OF BETWEEN-SUBJECTS EFFECTS

Source	Dependent Variable	Type III Sum of Squares	F	Sig.
Corrected Model	Optics	275299.205[a]	913.145	.000
	Descriptive	174118.702[b]	677.087	.000
	Statics	286250.527[c]	1042.661	.000
Intercept	Optics	4465.238	44.433	.000
	Descriptive	32818.222	382.856	.000
	Statics	3079.235	33.648	.000
Algebra I	Optics	19170.183	190.758	.000
	Descriptive	5032.926	58.714	.000
	Statics	14330.528	156.596	.000
Calculus I	Optics	17119.674	170.354	.000
	Descriptive	11675.172	136.202	.000
	Statics	16367.352	178.853	.000
Computer I	Optics	6392.122	63.606	.000
	Descriptive	11334.387	132.226	.000
	Statics	12931.705	141.310	.000
Error	Optics	141496.724	100.495	
	Descriptive	120693.107	85.720	
	Statics	128850.088	91.513	
Total	Optics	6756604.000		
	Descriptive	6818325.000		
	Statics	6698214.000		
Corrected Total	Optics	416795.929		
	Descriptive	294811.809		
	Statics	415100.615		

a. R Squared = .661 (Adjusted R Squared = .660)
b. R Squared = .591 (Adjusted R Squared = .590)
c. R Squared = .690 (Adjusted R Squared = .689)

The table reveals a strong relationship between individual math courses on each of the engineering courses, and the same strong relationship appears when all the math courses are tested together on the engineering courses, which leads to rejection of the null hypothesis and acceptance of the alternative.

Similar models are tested for each semester to examine whether this relationship appears in subsequent semesters and engineering courses. In the first year, second semester, a similar hypothesis was tested but applying the following model:

$$Algebra\ II + Calculus\ II + ComputerII = \alpha + \beta_1 mechanics + \beta_2 ElectricityI + \beta_3 Perspective$$

The results are revealed in Table VI.

Table VI Multivariate analysis for the effect of the independent variables on the dependent variables, first year, second semester.

TABLE VI
TESTS OF BETWEEN-SUBJECTS EFFECTS

Source	Dependent Variable	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	Mechanics	81637.907[a]	13606.318	150.094	.000
	Electricity I	98516.800[b]	16419.467	172.465	.000
	Perspective	3541.748[c]	590.291	9.294	.000
Intercept	Mechanics	3179.222	3179.222	35.071	.000
	Electricity I	810.081	810.081	8.509	.004
	Perspective	31169.057	31169.057	490.738	.000
Algebra II	Mechanics	21504.508	21504.508	237.220	.000
	Electricity I	14938.221	14938.221	156.906	.000
	Perspective	86.838	86.838	1.367	.243
Calculus II	Mechanics	4521.186	4521.186	49.874	.000
	Electricity I	7912.016	7912.016	83.105	.000
	Perspective	148.704	148.704	2.341	.126
Computer II	Mechanics	1206.856	1206.856	13.313	.000
	Electricity I	6279.721	6279.721	65.960	.000
	Perspective	1243.206	1243.206	19.574	.000
Error	Mechanics	106788.282	90.652		
	Electricity I	112151.136	95.205		
	Perspective	74820.297	63.515		
Total	Mechanics	5999267.000			
	Electricity I	6281060.000			
	Perspective	7460681.000			
Corrected Total	Mechanics	188426.189			
	Electricity I	210667.936			
	Perspective	78362.046			

a. R Squared = .433 (Adjusted R Squared = .430)
b. R Squared = .468 (Adjusted R Squared = .465)
c. R Squared = .045 (Adjusted R Squared = .040)

In Table VI a significant relationship appears between the grades on the mathematics courses and the engineering courses in the second semester, first year except for the engineering course perspective, where there isn't any significant relationship between math courses and this course.

For the next model, second year, first semester, Table VII reveals a significant relationship

Similar hypothesis is tested, the model is

$$Calculus\ I\ II + ComputerII\ I = \alpha + \beta_1 mechanicsI\ I + \beta_2 Electricit\ yII$$

The results of the model are revealed in Table VII.

Table VII Multivariate analysis for the effect of the independent variables on the dependent variables, second year, first semester.

A high significant relationship appears between grades of students in math courses with engineering courses in their second year, first semester.

The last model also presenting the relationship between math courses in the students second year, second semester and the engineering courses and reveals a significant relationship

Similar hypothesis is tested, the model is

$$Calculus\ IV + NumericalMethod = \alpha + \beta_1 Ther\,\mathrm{mod}\,ynamics + \beta_2 ElectricityIII$$

The results appear in Table VIII.

Table VIII shows multivariate analysis for the effect of independent variables on dependent variables, second year, second semester.

TABLE VII
TESTS OF BETWEEN-SUBJECTS EFFECTS

Source	Dependent Variable	Type III Sum of Squares	F	Sig.
Corrected Model	Electricity II	69449.554[a]	227.813	.000
	Mechanics II	63856.141[b]	277.507	.000
Intercept	Electricity II	1821.774	17.928	.000
	Mechanics I	6176.300	80.523	.000
Calculus III	Electricity II	34253.648	337.084	.000
	Mechanics II	35527.737	463.191	.000
Computer III	Electricity II	8346.371	82.135	.000
	Mechanics II	4417.611	57.594	.000
Error	Electricity II	112287.445		
	Mechanics II	84755.769		
Total	Electricity II	5461824.000		
	Mechanics II	6059933.000		
Corrected Total	Electricity II	181736.999		
	Mechanics II	148611.910		

a. R Squared = .382 (Adjusted R Squared = .380)
b. R Squared = .430 (Adjusted R Squared = .428)

TABLE VIII
TESTS OF BETWEEN-SUBJECTS EFFECTS

Source	Dependent Variable	Type III Sum of Squares	F	Sig.
Corrected Model	Electricity III	34082.050[a]	152.185	.000
	Thermodynamic	63058.651[b]	210.895	.000
Intercept	Electricity III	16934.788	226.854	.000
	Thermodynamic	3597.496	36.095	.000
Calculus IV	Electricity III	40.717	.545	.460
	Thermodynamic	12187.898	122.285	.000
Numerical Method	Electricity III	20273.914	271.584	.000
	Thermodynamic	12170.773	122.113	.000
Error	Electricity III	73605.414		
	Thermodynamic	98273.015		
Total	Electricity III	5139685.000		
	Thermodynamic	5274645.000		
Corrected Total	Electricity III	107687.464		
	Thermodynamic	161331.666		

A significant relationship appears between math courses and engineering courses for second year students during second semester. There is no significant relationship between calculus IV and Electricity III; however, this could be due to the fact that students do not need apply material in calculus IV to electricity III.

As a result, it appears mathematic courses bear a significant relationship to engineering courses during the first two years for students enrolled in engineering majors.

3. Gender Analysis

The analysis of gender in the mathematics courses reveals a slightly significant difference between the average grades of male and female students, in favor of females, with the exception of the computer II course, where the grades of male students was slightly higher. This could be due to the fact that

the course focuses on coding, which attracts less interest from female students.

Table IX shows the mean and standard deviation of the grades of males and females in mathematics courses in their first two years of their major.

TABLE IX
GROUP STATISTICS

	Gender	N	Mean	Std. Deviation
Algebra I	Male	917	63.34	17.549
	Female	495	65.95	14.146
Calculus I	Male	917	67.85	18.324
	Female	495	70.27	14.540
Computer I	Male	917	66.16	19.966
	Female	495	66.41	16.171
Algebra II	Male	742	67.46	12.725
	Female	441	68.54	12.155
Calculus II	Male	742	69.65	12.736
	Female	441	69.24	12.869
Computer II	Male	742	72.07	16.172
	Female	441	69.54	16.414
Calculus III	Male	712	73.89	11.412
	Female	397	75.53	10.070
Computer III	Male	712	70.38	12.408
	Female	397	71.44	11.443
Calculus IV	Male	675	76.06	12.491
	Female	394	77.44	12.660
Numerical Method	Male	676	71.74	10.795
	Female	393	74.58	11.941

TABLE X
GROUP STATISTICS

	Gender	N	Mean	Std. Deviation
Optics	Male	917	65.78	18.416
	Female	495	69.28	14.385
Statics	Male	917	66.10	18.502
	Female	495	67.83	14.269
Descriptive	Male	917	66.67	15.984
	Female	495	70.37	10.683
Mechanics I	Male	742	69.80	12.625
	Female	441	70.41	12.592
Electricity I	Male	742	71.41	13.238
	Female	441	71.93	13.432
Perspective	Male	742	78.08	8.481
	Female	441	80.39	7.292
Electricity II	Male	712	68.29	13.262
	Female	397	70.28	11.856
Mechanics II	Male	712	71.78	11.959
	Female	397	75.22	10.529
Electricity III	Male	676	71.09	9.959
	Female	393	72.08	11.866
Thermodynamic	Male	676	71.19	12.309
	Female	393	72.91	13.123

Looking at the average of grades of students in the engineering courses in their first two years; female students have higher grade averages in these courses than male students. Tables IX and X reveal this difference.

A t- test of independent groups also reveals a significant difference among gender in both mathematics and engineering courses. This appears in Table XI. The hypothesis of this model is:

- H_a : Average marks on math and Engineering courses are different between males and females,

$$H_a : \mu_{males} \neq \mu_{females}$$

- H_0 : Average marks on mathematics and engineering courses are the same between males and females,

$$H_0 : \mu_{males} = \mu_{females}$$

Table X shows the t- Test for the difference in means between males and females in both mathematics and engineering courses.

Table XI reveals a significant difference in the average marks of students among gender, except for the math courses: Computer I and III, Algebra II, Calculus II and IV and engineering courses: Mechanics, Electricity I and III.

TABLE XI
INDEPENDENT SAMPLES TEST

	t-test for Equality of Means		
	t	df	Sig.
Algebra I	-2.848	1410	.004
Calculus I	-2.538	1410	.011
Computer I	-.241	1410	.810
Algebra II	-1.440	1181	.150
Calculus II	.534	1181	.594
Computer II	2.587	1181	.010
Calculus III	-2.390	1107	.017
Computer III	-1.403	1107	.161
Calculus IV	-1.735	1067	.083
Numerical Methods	-3.978	1067	.000
Optics	-3.665	1410	.000
Statics	-1.813	1410	.070
Descriptive	-4.622	1410	.000
Mechanics	-.809	1181	.419
Electricity I	-.647	1181	.517
Perspective	-4.769	1181	.000
Electricity II	-2.489	1107	.013
Mechanics I	-4.792	1107	.000
Electricity III	-1.450	1067	.147
Thermodynamics	-2.140	1067	.033

C. Discussion

This study investigates whether a relationship exists between mathematics and engineering courses in the first two years of students majoring in engineering, analyzing results of students over a period of 11 years at the public university in Lebanon.

The results appear to support the claim that there is a significant relationship between mathematics courses studied and overall student performance in engineering courses. Such results should help other universities in Lebanon to adopt a

similar curriculum and syllabus to that which is applied at Lebanese University, as it is proven to improve student academic achievement in the engineering courses.

The results indicated that the mathematics courses directly affected a student's academic performance in engineering courses, the thing which suggests that additional mathematics courses significantly influence the performance of engineering students at the university level. This finding is supported by [5], [15].

The result is also consistent with many researches [21], [7], [9] which documented basic mathematics knowledge as an essential variable in the discussion of university students' mathematical achievement.

Further, this study shows that female students outperformed male students in most of mathematics and engineering courses. Gender played a role in affecting the course marks of mathematics and engineering courses. This finding resembles those reported by [2], [19], [11]. Although mathematics grades appear to influence engineering course grades, as appears in the regression multivariate model, serious considerations on the influencing factors are important to counter the problems of student underachievement in engineering courses. It is recommended that future intakes of university students for engineering programs consider good grades in mathematics since our results indicate that mathematics is a good predictor of performance and grade levels in engineering courses.

ACKNOWLEDGMENT

Authors thank Lebanese University, Faculty of Engineering for their cooperation in this study, with special thanks to the Dean.

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