Prediction of Student Performance in Academic and Military Learning Environment: Use of Multiple Linear Regression Predictive Model and Hypothesis Testing

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Abstract

The variance in students' academic performance in a civilian institute and in a military technological institute could be linked to the environment of the competition available to the students. The magnitude of talent, domain of skills and volume of efforts students put are identical in both type of institutes. The significant factor is the physical training, students undergo in a military college. It is important to couple the dominating factor which is academic perceivable effort under a different environment with each students learning capability. This paper determine whether there is a relationship between students' performance and influencing factors like academic aptitude, military or physical training, and the time spent on training need analysis (TNA) modules. A sample of 242 first year- undergraduate students from four different engineering programs (Marine, System, Civil, and Aeronautical) at Military College was used to explore this relationship. The multiple regression model used for predicting the students' performance is adequate for independent variables of aptitude test score, time spent in physical training, and time spent in TNA modules. The values of R^2 indicate that at least one of the predictor variables contributes to information for the prediction of the students' performance. The model makes it possible to predict moderately the possibility of attrition in engineering program. This study verifies that military academy has a very defined and directed core engineering course load and TNA course load which every student must take. Therefore, choice of specific discipline have less impact than at civilian institutions. The early detection of students at academic risk is a useful instrument that can help to design mentoring strategies right from the end of admission process.

Keywords: Student's performance, Multiple linear regression, Hypothesis testing, Military learning environment

1. Introduction

A common observation shared by educators and researchers is that the students' performance is dependent on curricular and extra-curricular activities. The authors of this paper have experienced variance in performance while teaching in both civilian institutes and in military technological institutes. The performance could be linked to the environment of competition available to the students. There is no doubt about the magnitude of talent, domain of skills and the volume of effort students put in, which is identical in both type of institutes. However, the significant factor is the physical training students undergo in a military college. Often educators are unable to predict success of a student even if they know the amount of effort a student is putting in, and the dedication he/she demonstrates (Eric, 2012). It is important to couple the dominating factor, which is academic perceivable effort, under a different environment with each students learning capability.

In athletics this variance is easily understood. The individual who works hard in developing new skills or capabilities realizes the greatest success (Ericsson et al. 1993). According to Malcom Gladwell (2008) it takes 10,000 hours of practice to fully master a skill and become an expert, Whereas Peter Doskoch (2005) presents a 10 year rule in perseverance of a talent and achievement of significant objectives. It is evident that professional will and workmanlike diligence are the attributes for success in any career.

The instructor has limited time and resources to put into each students desires for success. It is up to the student to determine how he/she benefits himself/herself from these resources. It is also up to the institute to set up the admission criteria and make decisions typically based on merit, high school performance and standard entrance tests. The admission process is based on known and trusted predictors, hence the results can be forecasted. The resource allocation decision is another predictor that measures outcome alignment with the input, especially for freshman class'.

There are many other factors that can influence students' performance, such as gender (does not apply at Military college under study as all students were male), high school background, academic aptitude, military or physical training, socio-demographic variables, and emotional & psychosocial characteristics.

The purpose of this study is to determine whether there is a relationship between students' performance and influencing factors like aptitude test, time spent on physical training, and time spent on TNA modules; to explore the relationship between educational aptitude and academic performance in a sample of 242 first year - undergraduate students from four different engineering programs (Marine, System, Civil, and Aeronautical) at a military college. The early detection of students who are vulnerable to suffering academic failure is useful in helping to design mentoring strategies right from the end of admission process. This study is based on published empirical-observational data and its comparison with available data of the MTC students' academic performance during first year of their B. Eng. program. The novelty of the proposed method of this study is that it verifies the impact of different environment in a military academy on academic performance due to academic load. In a military academy with a core engineering course load every student must take TNA course load too. Therefore, choice of specific discipline has less impact than at civilian institutions.

2. Hypotheses

The hypotheses of this study are:

H_1: There is an association between academic aptitude tests and academic performance.

H_2: There is an association between academic performance and time spent in physical training.

H_3: In a military academy there is a stronger association between magnitude of physical training and academic performance.

There are a number of theories presented by researchers focused on students' performance and its relation to their decision to dropout (Bean and Metzner's Student Attrition Model, 1985), and also to the interactions of the students with the academic institution (Tinto's Student Integration Model, 1975). A review of published studies at an international level suggests that independent variables like gender, high school background, academic aptitude, military or physical training, socio-demographic circumstances, and emotional & psychosocial characteristics need to be tested under standardized hypothesis testing scores.

3. Insignificant Variables

The use of linear regression between factors like age, sex, socio-demographic origin, socio-economic characteristics; and academic performance conducted over 5000 undergraduate university students by Betts and Morell (1999) indicates that there is not a significant relationship. Similarly in another study Lorenzano & Ferraro (2003) used a sample of 516 undergraduate students who passed a number of subjects during the first semester and found that factors like age, sex, socio-demographic origin, and socio- economic characteristics are insignificant. However, the study conducted by Porto and DiGresia (2004) based on voluntary survey of 4,676 students of economic science revealed that factors like sex and age are less significant than others.

4. Significant Variables

4.1 Academic Aptitude or Entrance Tests

Noble and Sawyer (1997) used statistical theoretical analysis for measuring academic attitude and reported that a linear relationship between aptitude tests and academic results exists. Medina & Tapia (2004) used a sample of 120 students admitted through entrance tests (ATE) and 87 students without (under direct entry into bachelor program) at the University of Chile, and reported that ATE showed a better academic performance. Gallacher (2005) analyzed the predictive power of aptitude tests by using 91 freshman students and 90 graduates and concluded that aptitude tests are a useful tool even when the predictions derived from them are far from perfect.

4.2 High School Background

Eno, D et al (1999) used a sample of 12,000 undergraduate students of Virginia Tech University; Pike and Saupe (2002) used a sample of 8,764 undergraduate students; Beguet, et al (2001) used a sample of 324 undergraduate students between two cohorts; and Foio and Espinola (2004) used a sample of 4632 undergraduate students during the first year at the university, reported that a good performance in high school results predicts a good performance at the university. However, the ratio of high school GPA to university GPA was 7.67/5.69 which correspond to higher academic activity at university.

4.3 Variables in Military Studies

Castro Solano & Casullo (2002) used a sample of 363 students from a military academy made up of 89% of male and 11% female, all 18-22 years old, for analysis to identify and determine variables of high and low performing students. They concluded that most successful students show an assertive and ambitious trend with lower acceptance of standards. They captured concrete, tangible and observable data, less focused on details and more related to a large number of students. Eric Buller's (2012) findings on the relationship between grit and academic, military and physical training at US military academy indicated that the relationship, though statistically significant, is not particularly strong, and therefore not a good measurement of success. He reported that regression analysis indicates that grit provides a statistically significant explanation for variability in factors like aptitude tests and academic achievements. The effect of age, sex, and ethnicity were insignificant, and therefore not a predictor for success at the military academy.

5. Methodology

The multiple linear regression model presented by Shakil (2008 and 2009), and hypothesis testing undertaken by Angela et al. (2013) is used in this study for a sample of 242 students. The constraints associated with our data are:

(a) There is invariability in high school background, hence assumed constant.

(b) There is no standardized assessment for physical training, hence time spent in physical training is considered as a dependent variable.

(c) Lack of variability in nature and type of physical training activity.

The predictor or the response variable Y in the following multiple linear regression equation

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

represents the academic performance. The independent variables X_1, X_2, and X_3 are the examination results, aptitude test results, and time spent in physical training respectively. All five assumptions used by Shakil (2009 and 2001) and Shakil and Singh (2001) considered applicable to our data. The study made at an Argentinian military academy is more relevant (Castro, 2002) in objectivity as it was to identify the factors associated to academic and military performance of undergraduate students.

5.1 Participants

A non-random sample of 242 first year undergraduate students of a 2014 cohort belonging to Aeronautical, Civil, Marine, and Systems Bachelor of Engineering (B. Engg.) and Diploma in Higher Education (DipHE) program were chosen. The socioeconomic level of sampled students is homogeneous, and a majority of them belonged to medium and medium to high income sectors of society.

5.2 Instrument of Data Analysis

The results of the academic aptitude test is applied to students after being admitted in the military institute. The aptitude tests consist of the IELTS score, Mathematics, Science, elements of mechanical reasoning and numerical ability. The observational analysis of the faculty of the general foundation program was considered as highly reliable and sufficiently intercorrelated within the array of aptitude tests.

The details of military activities collected from the military department at college, were translated into time dependent physical training. This instrument showed a good validity when compared with the physical training program of other military academies in the world.

The results of course work (30-40%) and final examinations (60-70%) of the students' in their first academic year was collected from the examination department and used to measure the academic performance. The similar approach has been used worldwide in defining the cognitive profile for each student. The attrition in four engineering departments was measured in terms of number of students dropped out during the year. The students dropped out from Aeronautical Engineering, Civil Engineering, Marine Engineering, and Systems Engineering was 23, 20, 20, and 25 respectively.

6. Procedure

For analysis of the aptitude test, a general linear model of Searle (1971) was used. The selection of the final model was based on the Akaike Information Criterion (AIC) Statistics (Sakamoto et al. 1986) in which the parameters selected have a p-value less than 0.05. The multiple regressions were constructed to analyze the relationship of each dependent variable with academic performance for students of four engineering departments. The coding technique was used for students who were dropping-out.

7. Interpreting the Results and Discussion

The average and standard deviation of the examination results of common engineering modules (Engineering Mathematics-I, Engineering Science, Engineering Material & Hardware, Electrical Engineering Principles, Introduction to Electrical Engineering, Introduction to Civil Engineering, and Engineering System Design-I) is presented in table 1. The grade distribution of the same modules is shown in table 2. The final examination grade distribution of these engineering modules are shown in tables 3-8. The table 9 presents the distribution of cohort among engineering departments.

Table 1. Average and standard deviation of exam results by module

Module	Average	Standard deviation	Sample size (N)
Engineering Maths-1	58.6	14.75	242
Engineering Science	66.8	10.84	242
Eng. Materials & Hardware	47.1	11.88	242
Electrical Eng. Principles	61.0	9.92	242
Intro. to Electrical Eng.	60.8	12.55	242
Intro. to Civil Engineering	68.6	6.74	32
Eng. System Design-1	72.7	11.32	242
Overall	62.2	11.14	NA

Table 2. Grade distribution (%)[1] in common engineering modules

Module	A	B	C	D	F
Engineering Maths-1	25.6	21.1	16.9	0.4	36.0
Engineering Science	38.8	34.7	0.40	0.0	26.0
Eng. Materials & Hardware	5.0	9.5	32.6	3.3	49.6
Electrical Eng. Principles	22.7	34.7	22.7	0.4	19.4
Intro. To Electrical Eng.	24.8	39.5	22.4	1.0	12.4
Intro. To Civil Engineering	59.4	34.4	0.0	0.0	6.3
Eng. System Design-1	70.2	14.5	2.9	0.0	12.4
Overall	35.2	26.9	14.0	0.7	23.1

1. A = > 70%; B = 60-69%; C = 50-59%; D = 40-49%; and F = < 40%

Table 3. Final examination grade distribution of Engineering Mathematics

Performance (Grade)	Aeronautical Engineering	Civil Engineering	Marine Engineering	Systems Engineering	Average
F	9%	44%	54%	48%	38.75%
D	15%	28%	26%	26%	23.75%
C	21%	19%	12%	11%	15.75%
B	19%	9%	3%	6%	09.25%
A	36%	0%	6%	8%	12.50%

Table 4. Final examination grade distribution of Engineering Science

Marks	Aeronautical Engineering	Civil Engineering	Marine Engineering	Systems Engineering	Average
F	10%	59%	15%	31%	28.75%
D	10%	19%	32%	32%	23.25%
C	12%	19%	24%	16%	17.75%
B	22%	3%	6%	11%	10.50%
A	46%	0%	24%	9%	19.75%

Table 5. Final examination grade distribution of Engineering Materials and Hardware

Performance (Grade)	Aeronautical Engineering	Civil Engineering	Marine Engineering	Systems Engineering	Average
F	10%	59%	15%	31%	28.75%
D	10%	19%	32%	32%	23.25%
C	12%	19%	24%	16%	17.75%
B	22%	3%	6%	11%	10.50%
A	56%	0%	24%	9%	22.25%

Table 6. Final examination grade distribution of Electrical Engineering Principles.

Marks	Aeronautical Engineering	Civil Engineering	Marine Engineering	Systems Engineering	Average
F	9%	22%	21%	26%	19.50%
D	27%	13%	35%	36%	27.75%
C	26%	19%	24%	21%	22.50%
B	19%	19%	15%	8%	15.25%
A	19%	28%	6%	8%	15.25%

Table 7. Final examination grade distribution of Introduction to Electrical Engineering.

Performance (Grade)	Aeronautical Engineering	Marine Engineering	Systems Engineering	Average
F	10%	6%	15%	10.33%
D	15%	29%	29%	24.33%
C	28%	15%	29%	24.00%
B	27%	26%	22%	25.00%
A	20%	24%	5%	16.34%

Table 8. Final examination grade distribution of Engineering Systems Design 1.

Performance (Grade)	Aeronautical Engineering	Civil Engineering	Marine Engineering	Systems Engineering	Average
F	0%	15%	2%	4%	05.25%
D	0%	7%	21%	0%	07.00%
C	9%	0%	18%	17%	11.00%
B	0%	0%	26%	19%	11.25%
A	91%	78%	33%	60%	65.50%

Table 9. Distribution of cohort among engineering departments.

Department	Number of students
Aeronautical Engineering	78
Civil Engineering	32
Marine Engineering	34
Systems Engineering	98
Grand Total	242

The coefficient of determination (R^2) values obtained for each engineering program shows that the academic performance is explained by the given independent variables. The most suitable regression model dictates that aptitude test does not relates significantly to the academic performance. The Excel multiple regression summary output for regression statistics and analysis of variance is given in table 10.

Table 10. The summary output of final examination grades data for independent variables

Regression Statistics	
Multiple R	0.984908
R Square	0.970044
Adjusted R Square	0.440088
Standard Error	0.011712
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	0.008883304	0.00296	32.3821	0.128302193
Residual	2	0.000274328	0.00014		
Total	5	0.009157632			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.830396	0.578526936	-3.16389	0.08705	-4.31959658	0.658804423
X1	2.080784	0.733415115	2.83712	0.10503	-1.074846235	5.236414862
X2	0.080514	0.014107521	5.70715	0.02936	0.01981396	0.141213491
X3	0	0	65535	0	0	0

Based on table 10, the regression equation, with coefficient values for each independent variable, and the response variable ("Y" represent the academic performance) is:

$$Y = -1.8303 + 2.0808X_1 + 0.0805X_2 + 0.0X_3.$$

$$S = 11.14, \qquad R^2 = 97\%, \qquad R^2_{(adj)} = 44\%$$

From the ANOVA in table 10, we observe that the P-value is 0-0.10, which implies that the model estimation is significant at a significance level of 0.05. The P-values for the estimated coefficients of X_2 and X_3 are 0.029 and 0.0 respectively, indicating that both are significantly related to predictor variable. However, the P-value of X_1 is 0.105, indicating that probably it is not related to Y. The coefficient of multiple determination (R^2) shows that only 97% of the total variations of the Y values about their mean are explainable by the predictor variable, indicating moderate goodness of fit of the multiple regression model and the model has adequate predictive ability.

The smallest value of coefficient of variation (CV) is another measure of model's suitability of model in rendering precise predictions. The CV value of 0.179 indicates that standard deviation of the students' performance is only 17.9% of their mean.

Hypothesis testing by t- distribution

This hypothesis can be tested using a t- distribution test statistic given by:

$$t = (\beta_i - 0)/ Se(\beta_i)$$

Assuming that the variation of observations about the line are normal, we can use (1-α) = 100% confidence limits for critical values of β_i by calculating

$$\beta_i \pm t \{ n\text{-}2, 1 - (\alpha/2)\}. Se (\beta_i)$$

Where {n-2, 1 – (α/2)} is the (1-α) = 100% percentage points for t- distribution, with n-2 degree of freedom

Test of significance for each independent variable

H_o: $\beta i = 0$ versus $H_1 \neq 0$

Table 11.

Null Hypothesis	t- critical values (3, 0.975)	$\lvert t \rvert$	Inference	Conclusion
H_o: $\beta_1 = 0$	3.182	2.83	Do not reject H_o	In the presence of X_2 and X_3; X_1, is not a good predictor of Y.
H_o: $\beta_2 = 0$	3.182	5.70	Reject H_o	In the presence of X_1 and X_3; X_2, is a good predictor of Y.
H_o: $\beta_3 = 0$	3.182	0.0	Do not reject H_o	In the presence of X_1 and X_2, X_3, is a poor predictor of Y.

The absolute values of "t" shown in table 11 is taken from table 10. However, the t-critical values in table 11 are calculated by taking significance level 0.05. The Inference and conclusion in table 11 are drawn by comparing the absolute value of "t" with t-critical values. Hence is the test of null hypothesis (H_o) against alternative or research hypothesis (H_1).

Hypothesis testing by F- test

H_o: $\beta_1 = \beta_2 = \beta_3 = 0$ (regression is insignificant) versus H_1: at least one of β_i's $\neq 0$ (regression is significant).

$$F = MS_{reg}/MS_{res} = 21.61$$

The hypotheses can also be tested using the F-statistics with the following decision rule.

Reject H_o if $\lvert t \rvert > \{n\text{-}2,\ 1 - (\alpha/2)\}$. The t- statistics values for different β_i's are based on summary output of the multiple linear regressions are shown in table 10. By comparing F values with the critical values of F at given degree of freedom and 1-α values, we reject H_o that is the regression is insignificant. Therefore, the overall regression is statistically significant. Hence, it can be concluded that at least one of the predictor variable contributes information for the prediction of Y. According to the best regression model for each independent variable, the time spent in physical training ($p < 0.0293$) and time spent in TNA modules ($p < 0.0$) are related significantly to students' academic performance. Whereas, test results score in aptitude test is insignificant in a military college environment.

8. Conclusions

The multiple regression model used for predicting the students' performance is adequate for independent variables of aptitude test score (X_2), time spent in physical training (X_3), and time spent in TNA modules. The values of R^2 indicate that at least one of the predictor variables contributes to information for the prediction of the students' performance. The rejection of null hypothesis indicates that the regression is not significant and the overall regression is statistically significant. The time spent in physical training is an instrument that allows estimating students' performance in the first academic year of an undergraduate program. The model makes it possible to predict moderately the possibility of attrition in engineering program. These results slightly differ from the findings of Eric Buller (2012) who found that academic achievement (in terms of GPA) also depend on chosen major, and general education requirements of the specific campuses. This study verifies that military academy has a very defined and directed core engineering course load plus TNA course load which every student must take. Therefore, choice of specific discipline has less impact than at civilian institutions. This study also verifies that the impact of military training environment does make a difference in academic performance.

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