

A Statistical Analysis of the Influences of Educational and Attitudinal Factors on the Academic Performance in a Construction Materials and Testing Class

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Given the importance of construction materials and testing (CMT) course in the construction curriculum, antecedents of better academic performance in CMT should be investigated. Evidence has shown that university students' educational experience and attitudinal factors may affect their academic performance. This paper aims to investigate the role of educational and attitudinal factors in driving the examination scores of undergraduate students of two CMT classes at the University of Texas at San Antonio (UTSA). A survey was conducted to 50 undergraduate students majored in construction science and management. A set of statistical analyses were performed to answer four research questions about the driven factors of academic performance in CMT, the correlation among educational and attitudinal factors, the impacts of educational experience and ultimately, the feasibility of developing a prediction model of the students' academic performance in CMT. Findings indicates that certain factors are more influential than others. This study contributes to the body of knowledge by providing empirical evidence about the role of educational background and attitudes in CMT.

Keywords: Construction materials and testing class, survey, attitudes, statistical analysis

Introduction

The Construction Materials and Testing (CMT) course is an elementary and critical component in the construction curriculum. It prepares the students for other construction courses such as structure, estimating, scheduling and construction capstone projects. A typical CMT course includes the introduction to the production, properties and testing, applications and management of main construction materials including concrete, soils, cement, aggregates, metals, asphalt, wood and masonry. It involves engineering, mathematical and physics contents, which may suggest difficulties for those who didn't have previous knowledge. In addition, evidence has shown that psychological factors such as attitudes can significantly affect the students' academic performance in general (Richardson et al. 2012). Therefore, this study aims to investigate the role of the students' previous educational experience and attitudes in the academic performance of a CMT course. In particular, the following questions are to be answered:

1. What are the driven attitudinal and educational factors of students' academic performance in a CMT class?
2. If attitudinal and educational factors are correlated?
3. Can educational background, especially years in college and previous experience with mathematics, physics and engineering courses, affect students' performance in a CMT class?
4. Can we predict students' academic performance in a CMT class?

The remainder of this paper introduces the background, methodology and statistical analysis results.

Literature Review

Educational factors, such as years of schooling and courses taken, refer to those directly related to a person's educational background and experience (Krämer et al. 1998), while attitudinal factors are about the subjective attitudes

of a person that influences the decision-making process (Mokhtarian and Salomon 1997). The impacts of educational and attitudinal factors on academic performance have been investigated widely. In a recent study, Richardson et al. (2012) investigated the relationship between the university students' grade point average (GPA) scores and 50 antecedents that can be grouped into five categories: personality traits, motivational factors, self-regulatory learning strategies, students' approaches to learning, and psychosocial contextual influences. Their study found strong correlations between 41 of 50 factors and the GPA scores. Another study done by Robbins et. al. (2004) examined the relationship between psychosocial and study skill factors (PSFs) and academic outcomes by meta-analyzing 109 studies. Building on the educational persistence and motivational theory models, Robbins et. al. categorized PSFs into nine clusters: achievement motivation, goals, institutional commitment, perceived support, involvement, academic self-efficacy, self-concept, academic-related skills and contextual influences. Their findings suggested that the students' achievement motivation exerts strong influences on their academic performance. Murray and Wren (2003) examined cognitive, academic, and attitudinal predictors of college GPA among students with learning disabilities (LD). The studied population included 84 youth who attended a large private university in the Midwestern United States. Measures of cognitive and academic functioning, along with a self-report measure of study habits and study attitudes, were used to predict college GPA. The findings suggested that variables other than traditional academic skills are important for determining the performance of youth with LD during college. Singh et.al. (2002) investigated the effects of three education-related constructs - motivation, attitude and academic engagement - on students' achievement in mathematics and science. Although cognitive abilities of the students are important predictors of achievement, Singh et.al. (2002) argued that affective variables are emerging salient factors. They used the nationally representative sample drawn from the National Education Longitudinal Study 1988. Structural Equation Models were used to estimate the test the hypothetical relationships of two motivation factors, one attitude factors and one academic engagement factor, on achievement in mathematics and science. Results showed strong positive effects of motivation and attitudinal factors. Following the previous studies, this study designed a questionnaire to solicit students' educational background and attitudes directly related to CMT.

Methodology

In order to answer the three research questions listed above, a survey was performed followed by a set of statistical analyses. 50 students of two CMT classes were surveyed, regarding their educational experience, attitudes and basic demographic information. Then the final examination scores of these 50 students were used as indicator of their academic performance in this course. A comprehensive literature review has been conducted to identify influential factors of students' academic performance in a CMT class, but it has been found that there is a lack of literature on this subject. Therefore, the general pedagogical literature has been used to prepare the survey (Richardson et al. 2012). Univariate correlation analysis (Lee Rodgers and Nicewander 1988), multivariate correlation analysis (Lee Rodgers and Nicewander 1988), and Analysis of Variance or ANOVA (Miller Jr 1997) were applied to identify the top driven factors of academic performance in a CMT class. Correlation among the factors and the impacts of educational background have also been examined respectively. In addition, a regression analysis was used to develop a performance prediction model. Fig.1 shows the body of surveyed students. Among 50 students, 40% (n=20) were sophomore, 34% (n=17) were junior students and 26% (n=13) were senior students.

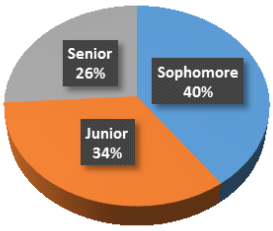

Figure 1. Surveyed students (n=50)

The full score of the examination is 120 points (100 points from regular questions and 20 points from bonus questions). Fig.2 illustrates the distribution of examination scores. The mean score was 85.21, with a standard deviation of 19.99. The distribution fitting found that a normal distribution N (85.21, 19.99) can describe the score distribution well.

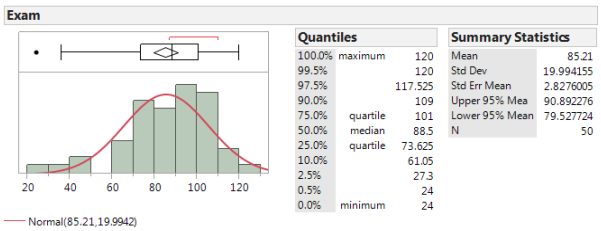

Figure 2. Distribution of examination scores (n=50)

Survey Analysis

Overview

The students were asked 14 questions about their educational background and attitudes, which are:

- X1 Your years in college?
- X2 Have you taken Physics in high school?
- X3 Have you taken Math in high school?
- X4 Have you taken Physics in college?
- X5 Have you taken Advanced Math in college?
- X6 Have you taken engineering courses in high school?
- X7 Have you taken engineering courses in college?
- X8 How would you score the importance of a material course for your future career?
- X9 What's your perceived importance of knowing the physical nature of materials?
- X10 What's your perceived importance of knowing the mechanical properties of materials?
- X11 What's your perceived importance of knowing the calculation of materials?
- X12 What's your perceived importance of knowing the testing procedures of materials?
- X13 Which materials are you mostly interested in?
- X14 Your overall interest in this class?

Questions 2 through 7 are educational background questions about the students' previous experience with physics, mathematics and engineering. These questions require "yes/no" answers. For example, for question 2 "*Have you taken Physics in high school?*" the students can only answer "yes" (show as 1) or "no" (show as 0). The results of this kind of questions follow binominal distributions, which can be interpreted as two possibilities of outcomes. For example, for question 2, 18% of students didn't take physics in high school, while 82% did. Questions 8 through 14 are attitudinal questions. These questions aim to understand the students' attitudes towards the importance and usability of CMT in their curriculum and future career. Their interests in particular materials and overall class were also asked. The students were required to give 1 through 5 Likert scale answers, whereby 1 means the least useful or minimum interest and 5 means very useful or very interest. For example, in question 8 "*How would you score the importance of a material course for your future career?*" selecting 1 means "useless" and 5 means "very useful". The results of most attitudinal questions follow asymmetric distributions. It indicates that the students' attitudes lean to one side.

Question 1: Driven Factors of Academic Performance

In order to evaluate the impacts of all factors on the academic performance, a Pearson's correlation analysis was performed. The Pearson's correlation coefficient is obtained by dividing the covariance of the two variables by the product of their standard deviations (Lee Rodgers and Nicewander 1988):

$$\rho_{x,y} = corr(x,y) = \frac{cov(x,y)}{\sigma_x \sigma_y} = \frac{E[(x-\mu_y)(x-\mu_y)]}{\sigma_x \sigma_y} \quad (1)$$

where $\rho_{x,y}$ is the correlation coefficient between two variables *x* and *y*, cov(x,y) is the covariance, and σ_x and σ_y are the standard deviations of *x* and *y* respectively. The correlation coefficient ranges from -1 to 1. If the absolute value of correlation coefficient is closer to 1, a stronger correlation exists between two variables. Literature has suggested that when $\rho_{x,y}$>0.3, correlation is moderate, and when $\rho_{x,y}$>0.5, correlation is strong (University of Strathclyde 2014). Therefore this study defines influential factors as those with a correlation coefficient bigger than 0.3 (at least moderate correlation). The correlation coefficient between each of the 14 factors and the examination score was calculated. Table 1 summarizes the results. In terms of influence, X12 "*What's your perceived importance of knowing the testing procedures of materials?*" ranks the highest (rho=0.52), followed by X14, X8, X10, X11 and X3. To be noted, most of these factors are attitudinal; the only educational factor that can be considered influential is X3 "*Have you taken Math in high school?*" (rho=0.34).

Table 1.
Rank order of the driven factors based on Pearson's correlation coefficient

ID	ρ	Survey Question
X12	0.52	What's your perceived importance of knowing the testing procedures of materials?
X14	0.43	Your overall interest in this class?
X8	0.42	How would you score the importance of a material course for your future career?
X10	0.38	What's your perceived importance of knowing the mechanical properties of materials?
X11	0.37	What's your perceived importance of knowing the calculation of materials?
X3	0.34	Have you taken Math in high school?
X9	0.23	What's your perceived importance of knowing the physical nature of materials?
X6	0.20	Have you taken engineering courses in high school?
X1	0.12	Which year are you in college?
X4	0.11	Have you taken Physics in college?
X5	0.10	Have you taken Advanced Math (e.g., calculus) in college?
X13	0.05	Which materials are you mostly interested in?
X2	0.05	Have you taken Physics in high school?
X7	-0.03	Have you taken engineering courses in college?

Question 2: Correlation among the Factors

This study is also interested in the correlation among 14 factors. 91 correlation coefficients were calculated. The relationships between any pair of two factors were ranked based on the correlation coefficients (Fig 3):

A	B	Rho	Factor A	Factor B
X14	X8	0.79	Your overall interest in this class?	How would you score the importance of a material course for your future career?
X10	X8	0.77	What's your perceived importance of knowing the mechanical properties of materials?	How would you score the importance of a material course for your future career?
X11	X8	0.74	What's your perceived importance of knowing the calculation of materials?	How would you score the importance of a material course for your future career?
X12	X10	0.72	What's your perceived importance of knowing the testing procedures of materials?	What's your perceived importance of knowing the mechanical properties of materials?
X11	X10	0.70	What's your perceived importance of knowing the calculation of materials?	What's your perceived importance of knowing the mechanical properties of materials?
X11	X9	0.70	What's your perceived importance of knowing the calculation of materials?	What's your perceived importance of knowing the physical nature of materials?
X12	X8	0.70	What's your perceived importance of knowing the testing procedures of materials?	How would you score the importance of a material course for your future career?
X14	X11	0.70	Your overall interest in this class?	What's your perceived importance of knowing the calculation of materials?
X9	X8	0.70	What's your perceived importance of knowing the physical nature of materials?	How would you score the importance of a material course for your future career?
X14	X10	0.69	Your overall interest in this class?	What's your perceived importance of knowing the mechanical properties of materials?
X12	X9	0.65	What's your perceived importance of knowing the testing procedures of materials?	What's your perceived importance of knowing the physical nature of materials?
X12	X11	0.63	What's your perceived importance of knowing the testing procedures of materials?	What's your perceived importance of knowing the calculation of materials?
X14	X12	0.62	Your overall interest in this class?	What's your perceived importance of knowing the testing procedures of materials?
X10	X9	0.61	What's your perceived importance of knowing the mechanical properties of materials?	What's your perceived importance of knowing the physical nature of materials?
X14	X9	0.58	Your overall interest in this class?	What's your perceived importance of knowing the physical nature of materials?
X7	X5	0.54	Have you taken engineering courses in college?	Have you taken Advanced Math in college?
X7	X1	0.49	Have you taken engineering courses in college?	Which year are you in college?
X10	X3	0.48	What's your perceived importance of knowing the mechanical properties of materials?	Have you taken Math in high school?
X8	X3	0.47	How would you score the importance of a material course for your future career?	Have you taken Math in high school?
X14	X3	0.45	Your overall interest in this class?	Have you taken Math in high school?
X12	X3	0.44	What's your perceived importance of knowing the testing procedures of materials?	Have you taken Math in high school?
X3	X2	0.44	Have you taken Math in high school?	Have you taken Physics in high school?
X4	X1	0.43	Have you taken Physics in college?	Which year are you in college?
X9	X6	0.37	What's your perceived importance of knowing the physical nature of materials?	Have you taken engineering courses in high school?
X5	X1	0.34	Have you taken Advanced Math in college?	Which year are you in college?
X12	X6	0.33	What's your perceived importance of knowing the testing procedures of materials?	Have you taken engineering courses in high school?
X5	X4	0.30	Have you taken Advanced Math in college?	Have you taken Physics in college?

Figure 3. The correlation among 14 factors (n=50)

The results reveal several inspiring findings. For example, a strong relationship (rho=0.79) exists between X14 and X8, suggesting that the students' overall interest in CMT is highly associated with their perceived importance of CMT knowledge in their future career. Moreover, X8 is highly correlated with X10 (rho=0.77) and X11 (rho=0.74), which indicates that knowing the mechanical properties and the testing procedures of materials contribute a lot to the CMT knowledge in their future career.

Question 3: Impacts of Educational Background

The research questions 3 aims to investigate the impacts of the students' previous educational experience on their academic performance. ANOVA analysis was conducted to find out if significant different exist between two groups (Miller Jr 1997). The total error of data can be divided into two parts:

$$SS_{total} = SS_{groups} + SS_{error} \quad (2)$$

where SS_{total} is the total sum of squares, SS_{groups} is component attributable to groups and SS_{error} is the part of pure errors. Then ANOVA constitutes a F-statistic for hypothesis analysis:

$$F = \frac{SS_{groups}/(I-1)}{SS_{error}/(n_T - I)} \quad (3)$$

where I is the number of groups (in this study I=2) and n_T is the total number of data points (in this study n_T=50). In this study, ANOVA analysis was performed for each of the six educational factors. Students who didn't take the selected courses were labeled as group 0 and who took relevant courses were group 1. The ANOVA examines if a significant difference exists between two groups of students in terms of their examination scores. Fig. 4 shows the analysis results.

X2: Physics in high school? X3: Math in high school? X4: Physics in college?

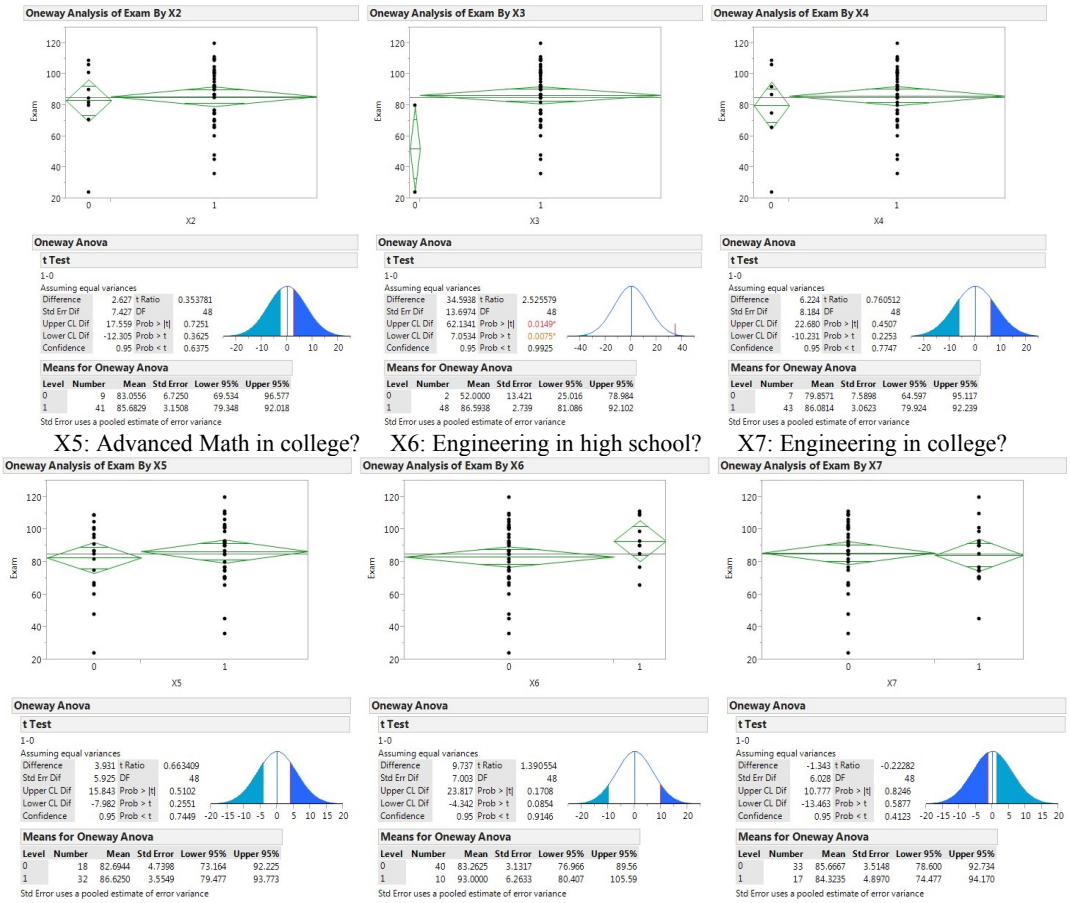

Figure 4. ANOVA results of educational background

As illustrated in Fig.4, the only educational factors that help classify students is X3 "*Have you taken mathematics in high school?*" However, it must be mentioned that only two out of 50 students didn't take mathematics in high school. The significant difference in sample sizes between two groups may cloud the conclusion. As a result, the general answer to research question 3 is that a student's educational background has little impacts on his/her academic performance in a CMT class. However, it worth noting that if relaxing the significance level in the hypothesis test, X6 "*Have you taken engineering courses on high school?*" shows an impact on the a student's examination score. The average score for those who had experience with engineering in high school was 93.0, while it is 83.3 for those who didn't take engineering courses in high school. It may indicate that an early exposure to engineering knowledge helps succeed in a CMT class.

Question 4: Prediction of Academic Performance

Research question 4 aims to develop a prediction model of the students' academic performance based on the factors mentioned above. A multivariate regression model was developed to achieve this goal. Multivariate regression analysis is a statistical process for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and more independent variables (Mardia et al. 1979). A regression model relates Y to a function of **X** and $\boldsymbol{\beta}$:

$$Y \cong f(\mathbf{X}, \boldsymbol{\beta}) \tag{4}$$

Where the approximation is usually formalized as $E(Y|\mathbf{X}) = f(\mathbf{X}, \boldsymbol{\beta})$. To carry out regression analysis, the form of the function f must be specified. In this study only the first order f was used. Fig.5 illustrates the analysis result. It shows a R-square of 0.44. Referring to the R-Square values of most similar studies, it suggests a satisfactory prediction.

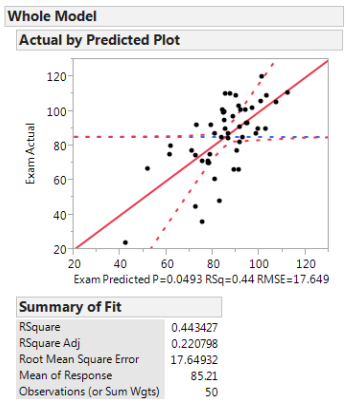

Figure 5. Multivariate Regression Analysis result

Discussion and Conclusion

The CMT course is important in the construction curriculum, which sets the foundation of many other construction courses. As a result, it's worth more efforts to investigate the antecedents of better academic performance in a CMT class. Literature has proven the relevance of educational and attitudinal factors to the students' academic performance. Building on previous findings, this study investigated the role of educational background (mainly the mathematics, physics and engineering courses taken in prior to the CMT class) and attitudinal factors in driving the examination scores of undergraduate students of two CMT classes at UTSA. A survey was conducted to 50 undergraduate students majored in construction science and management. A series of statistical analyses were performed to answer four research questions about the driven factors of academic performance in CMT classes, the correlation among all educational and attitudinal factors, the impacts of educational experience and the feasibility of building a prediction model of the students' examination scores.

Results have shown that the following factors have moderate to strong influences (ranked from highest to lowest influences):

- X12 What's your perceived importance of knowing the testing procedures of materials?
- X14 Your overall interest in this class?
- X8 How would you score the importance of a material course for your future career?
- X10 What's your perceived importance of knowing the mechanical properties of materials?
- X11 What's your perceived importance of knowing the calculation of materials?
- X3 Have you taken Math in high school?

The investigation also found that strong correlations exist among the 14 factors. 27 out of 91 pairs of factors are highly correlated. It indicates a complex mechanism behind the students' education, attitudes and academic performance in a CMT class that deserves further investigation. This study also revealed that a student's previous educational experience has little impacts on his/her academic performance in a CMT class. However, it worth noting that if relaxing the significance level, X6 "*Have you taken engineering courses on high school?*" shows an impact on the students' examination scores. The average score for those who had experience with engineering in high school is higher. It may suggest that an early exposure to engineering knowledge improves the performance in a CMT class. Finally, this study built a multivariate regression model that can predict the examination score of a student based on his/her answers to the 14 questions. The R-square is 0.44, which suggests a useful prediction. The contribution of this study is that it provides new empirical evidence about the role of certain educational and attitudinal factors in a CMT class. The findings will help us improve the curriculum in the future. Another major finding of this study is that the overall perception of the usefulness of material knowledge can improve the academic performance in a CMT class as well. As a result, it is critical for the students to value the importance of material knowledge. An effective way is to invite guest speakers including material testing personnel and project managers to talk about the role of material testing in construction project management. The direct opinions of industry practitioners will encourage positive thinking in a CMT class. A potential limitation of this study is that only 50 students participated in the survey; although a rule of

thumb in statistics validates the use of any sample size larger than 30, bigger sample size would improve the representativeness of this study and will be a major future research agenda item of this study.

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