HOW TO IMPROVE STUDENTS' ABILITIES TO APPLY STEM RELATED KNOWLEDGE?

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ABSTRACT

There are numerous factors affecting students' abilities to apply knowledge of statistics, mathematics, and engineering. Even though the literature is replete with various methods to identify such factors, there is little research dedicated to exploring them using statistical modeling. This study employed multinomial logit model to analyze the senior exit survey data with the aim to flag out the statistically significant factors which influence the students' abilities of engineering and mathematics knowledge. Among a set of factors, some of them such as "years spent on campus for obtaining the degree" were determined as the most influential factors.

INTRODUCTION

The assessment and evaluation implemented by the civil engineering program at California State Polytechnic University, Pomona (or, CPP) consist of three distinct processes which are used to address:

1. Mission and program objectives,
2. Student outcomes
3. Course objectives.

A wealth of information and tasks flow in a continuous cycle from student and alumni achievements to data collection, analysis, program changes and back to student and alumni achievements. The processes include the program's key stakeholders: students, alumni, industry, and university faculty and administration. Considering many engineering program objectives are student-centered, many studies have been centered on exploring the strategies for enhancing students' learning outcomes. Hence, the literature is replete with the documentation [1] [2] [3] regarding the influential factors for students' ability to apply knowledge of mathematics, science, and engineering, which is one of the main objectives of many engineering programs. Most of these studies are based on the qualitative and or descriptive analysis with very few utilizing the quantitative analysis. To fill this gap, the authors proposed to identify the statistically significant factors of aforementioned students' abilities using the popular multinomial logit regression models for the categorical outcomes.

The following sections first describe the data utilized, followed by the description of methodology and results, and finally wrap up the paper with a brief summary.

DATA COLLECTION

Senior Exit Survey is routinely conducted at the Department with the target of the students close to satisfaction of all degree requirements. The information collected including student name, admission status, years spent at CPP, the level of participation in various professional societies or clubs, senior project they join, and self-assessment of various student outcomes, and so on. In this study, the main focus is on the evaluation of students' ability to apply knowledge of statistics, mathematics, and engineering. For such outcome, students were asked to rate their capabilities on a scale of 1-5: (1) Poor; (2) Fair; (3) Average; (4) Good; (5) Excellent. Since majority students rated their abilities as average or above, the authors regrouped the response to three categories: 1-Average or Lower; 2-Good; and (3) Excellent. The data spanning 2014-15 were utilized and the pertinent response distributions are shown in Figures 1~3.

FIGURE 1. Student Responses to Participation Level of Extracurricular Activities

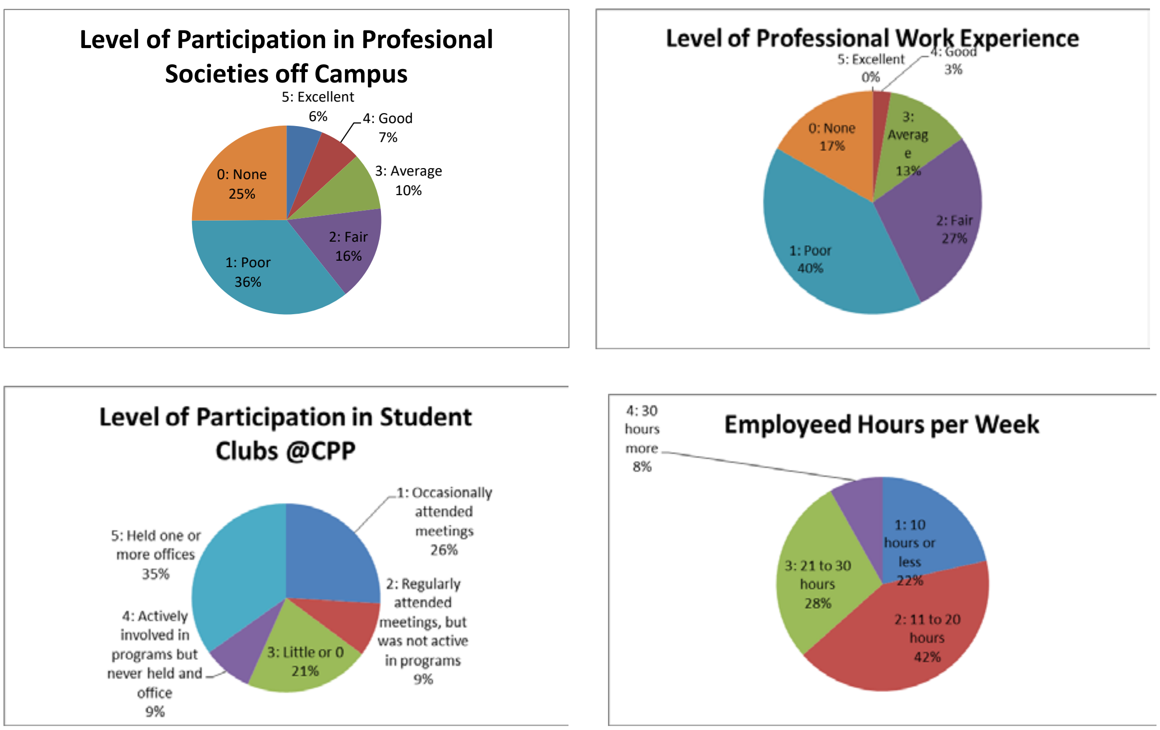


FIGURE 2. Student Responses to Engineering-in-Training Exam Related Questions

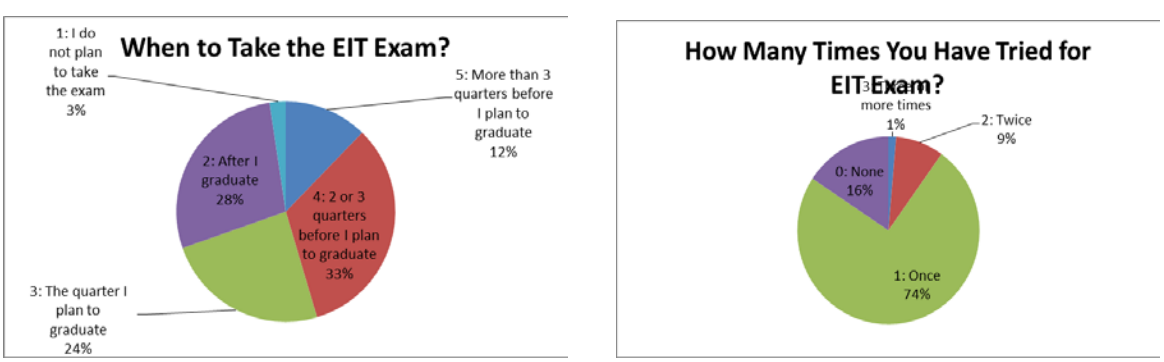
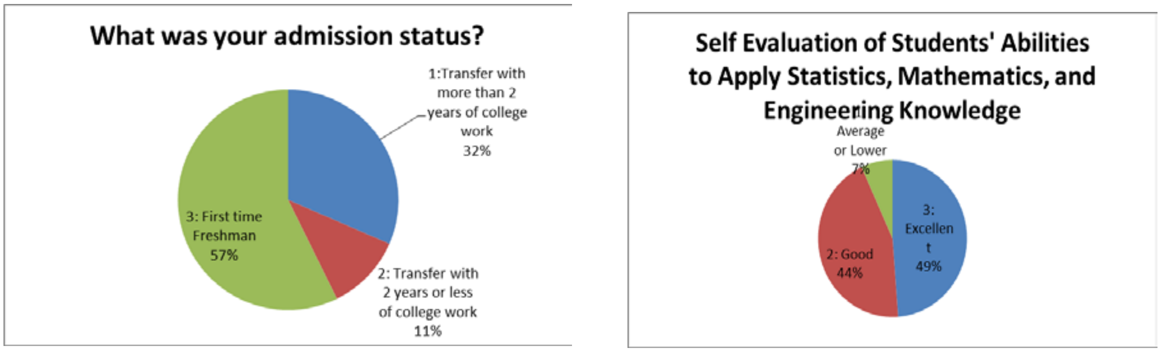


FIGURE 3. Student Responses to Admission Status and Student Outcomes



METHODOLOGY

The model used in this project is the Generalized Linear Model (GLM). GLM is a class of statistical model, which explains how a dependent variable can be described by a set of explanatory variables. As stated before, in this study the response variable showing students' self-evaluation of capabilities of applying Engineering and Mathematics knowledge has more than two levels:1-Average or Lower; 2-Good; and (3) Excellent. Therefore, Multinomial Logistic Regression Model (MLR) was used, which is a type of GLM. MLR models how the multinomial response variable depends on a set of explanatory variables [4] [5]. It estimates the individual effects of categorical and continuous independent variables on the categorical dependent variable. The model can be expressed by the following equation:

$$\text{Log}((\text{Pr}(Y=i))/(\text{Pr}(Y=i^{\prime}))) = \beta o + \beta 1\ X1 + \beta 2\ X2 + \ldots + \beta k\ Xk \quad (1)$$

The intercept βo is the value of Y when all of the independent variables are equal to zero. β1, β2,...., βk are the regression coefficients of X1, X2,…, Xk . This model estimates the effect of each explanatory variable on the probability of Performance Level 3 (Excellent) or Level 2 (Good) over Level 1 (Average or lower).

RESULTS

When using the MLG model, the performance level 1 (average or lower) was set as a base level. The initial model was named "model1", which explores the correlation of all of the independent variables with Self Evaluation of the performance level. After running the multinomial logistic regression model, the statistically significant factors at 95% confidence interval were identified at "Model 2". Based on the result as shown in Figure 4, "years spent at CPP for obtaining the degree", "level of professional work experience", and "when the students plan to take the EIT exam" were determined as the most influential factors.

FIGURE 4. Screen Shot of Multinomial Logit Regression Model with Level 1 (Average or Lower) as the Baseline

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                      Estimate Std. Error t-value  Pr(>|t|)
2:(intercept)         -0.23788    1.42393 -0.1671 0.8673259
3:(intercept)          2.22030    1.23701  1.7949 0.0726720 .
2:Time_Cpp_yrs        -0.23836    0.12370 -1.9270 0.0539839 .
3:Time_Cpp_yrs        -0.53362    0.13836 -3.8568 0.0001149 ***
2:Prof_Experience      0.69123    0.32986  2.0955 0.0361268 *
3:Prof_Experience      0.81303    0.33145  2.4530 0.0141671 *
2:When_EIT2            3.00269    1.25540  2.3918 0.0167655 *
3:When_EIT2            1.18247    1.04419  1.1324 0.2574554
2:When_EIT3            2.23019    1.29145  1.7269 0.0841885 .
3:When_EIT3            1.09042    1.06654  1.0224 0.3065985
2:When_EIT4            2.88402    1.30134  2.2162 0.0266788 *
3:When_EIT4            1.94359    1.08879  1.7851 0.0742470 .
2:When_EIT5            2.50837    1.41093  1.7778 0.0754336 .
3:When_EIT5            1.18894    1.22427  0.9711 0.3314774
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Log-Likelihood: -236.98
McFadden R^2:  0.095189
Likelihood ratio test : chisq = 49.862 (p.value = 1.4775e-06)
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Interestingly, the two negative signs associated with "Time_cpp_yrs" indicate that the fewer years the students spent on campus on satisfying the degree requirement, the higher level of performance of applying engineering and mathematics knowledge. In addition, the students who are more ambitious about the EIT exam-taking (or, who decide to take the EIT exam earlier) tend to have higher self-evaluation of the above-mentioned knowledge.

SUMMARY

Based on 200+ students' responses to senior exit survey, the study intends to explore the influential factors of students' abilities to apply knowledge of statistics, mathematics and engineering. "years spent at CPP for obtaining the degree", "level of professional work experience", and "when the students plan to take the EIT exam" were determined as the most influential factors.

ACKNOWLEDGEMENTS

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