The Use of Discriminant Analysis to Investigate the Influence of Non-Cognitive Factors on Engineering School Persistence

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ABSTRACT

This study identified post-enrollment attitudes and perceptions that influence students' decisions to remain in an engineering curriculum. Non-cognitive factors including expectations and perception of the engineering profession, assessment of personal attributes, and subject-matter confidence were investigated. Discriminant analysis functions were developed to distinguish among three mutually exclusive groups: those who remained in the engineering school, those who remained at the university in a different school, and those who left the university altogether. Self-reported confidence in college-level math/science ability and the belief that an engineering degree enhances career security at a respectable salary were found to be significant predictors of both short-term and long-term persistence in engineering.

Keywords: engineering freshmen, longitudinal study, discriminant analysis

I. INTRODUCTION

Researchers have expounded numerous explanations for the high dropout rate experienced by four-year undergraduate institutions [1–6]. The prevailing general theory of student persistence is based on Tinto's Interactionalist Theory which postulates that persistence is a function of student attributes as well as institutional fit. Although multi-institutional studies of persistence can help identify trends, single-institution studies are needed to understand the phenomenon of persistence which reflects an individual's decision to stay or leave a particular institution [1].

The lack of student persistence toward a science, technology, engineering, or mathematics (STEM) degree has been the focus of several important national studies [7–12]. One NSF-funded study indicates the STEM persistence-to-graduation rate is 41 percent [7]. Many STEM students decide to leave before the end of the freshman year; for others, however, the decision is made much later in their college career [8]. A recent multi-institutional study by Zhang et al. [12] supported the use of two cognitive variables (high school grade point average and SAT math scores) to predict engineering student graduation. The authors observed that these cognitive factors explained only a small percentage of the variability in college student persistence and that other factors needed to be investigated. In an older single-institution study, Levin and Wyckoff [13] investigated the predictive ability of a combination of cognitive and non-cognitive factors. They found that several non-cognitive variables, combined with high school grade point average and SAT scores, were predictive of freshman year persistence. However, models based on post-enrollment data for the first and second years of college were composed entirely of cognitive variables (science and math grades). The authors concluded that effective persistence models change as the engineering student progresses through the college curriculum. Based on a cross-institutional study, Besterfield-Sacre, Atman and Shuman [14–16] found that attitudes held by freshman engineering students when they entered college differed as a function of gender and institutional characteristics. Within their own institution, the researchers found significant differences in certain attitudes between students who left engineering in good standing and those who left in poor standing. Their data indicated that SAT math, high school rank, participation in a specialized program, and financial motivation for studying engineering were significant predictors of freshman-year attrition.

These studies suggest that non-cognitive variables should be considered as part of any model that seeks to explain persistence at a specific institution. The purpose of the study reported here was to build a preliminary model of how students' attitudes held after attending college for one year affect both short-term and long-term persistence in engineering. The ultimate goal is to develop a specialized theory of persistence toward graduation for undergraduate engineering students.

II. METHOD

A. Data Collection Instruments

The primary instrument was the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS) that was administered to students enrolled in a required engineering course during the second semester of their freshman year. The PFEAS, which was designed by Besterfield-Sacre to elicit students' attitudes and beliefs about certain variables which have been associated with persistence [14], yields scores on 13 factors (CAREER, JOBS, PERC, SOC, MATH, EXACT, FAMILY, BASIC, COMM, ENGINE, GROUPS, STUDY, ABIL). Internal consistency, as measured by Chronbach's alpha, has been reported as 0.8 or better for each of the factors [17]. The second data source was a database that is updated annually by the university's Office of Institutional Research. The author obtained permission from the university's Institutional Review Board to combine data from these two instruments into a single database and use this data to conduct a retrospective study of persistence.

B. Participants

This study was based on a longitudinal sample from the 138 students who entered the School of Engineering (SoE) as freshmen in the fall of 2000. Twenty-three names were eliminated from the data analysis because of missing information. Thirty-four percent of the sample was female. Sixty-four percent of the participants classified themselves as White-Caucasian; twenty-six percent as African-American. The participants were divided into three mutually exclusive groups based on their college enrollment status. Tables 1 and 2 summarize the composition of the persistence groups. The 1YR suffix is used for status one year after entering college; the 3YR suffix signifies status three years after entering college.

C. Statistical Analysis Technique

Discriminant analysis has been conceptually described as a fusion of the three essential functions of statistical analysis (data reduction, inference, and identification of association among variables) [18]. It is used to classify individuals into groups based on one or more predictor variables or to distinguish groups based on linear combinations of variables [19]. In that regard, it is similar to multiple regression, except that the criterion variable in multiple regression is quantitative and the criterion variable in discriminant analysis is qualitative. Furthermore, multiple regression is used to fit a single model to a given set of variables; whereas discriminant analysis can produce several discriminant functions for a given set of predictor variables [20]. There are three assumptions of discriminant analysis that have an impact on the significance of the tests. These are (1) multivariate normality, (2) homogeneity of population variances and covariance, and (3) independence between participants [19]. SPSS for Windows 11.5 was used to conduct the analysis.

D. Variables

The focus of this study was to determine the extent to which students' attitudes could be used to predict persistence. Therefore, pre-enrollment cognitive variables (high school grade point average and SAT scores) and post-enrollment cognitive variables (college grade point averages) which have been shown to be associated with persistence at our school of engineering [21, 22] were not included in the model. Due to the small sample and uneven group size, attempts to model persistence status using all thirteen PFEAS attitudinal factors and three criterion groups based on persistence one year after entering college were not advisable [20]. Tests of normality on the current data set indicated that data for six of the factors were not normally distributed, and they were eliminated from further consideration for this statistical method. The remaining factors were grouped as follows: (1) expectations and perception of the engineering profession (JOBS, CAREER, PERC); (2) assessment of personal attributes (ENGINE, ABIL); and (3) confidence indicators (BASIC, COMM). Correlation analyses showed that the three measures of the engineering profession were highly correlated; therefore JOBS was selected to model career expectations. Similar analyses showed that the two measures of personal attributes were correlated; ENGINE was selected. The two confidence measures were not correlated; both were selected as potential non-cognitive predictors of student persistence.

Enrollment Status Fall 2001	No.	Code
Not enrolled in the university	6	Leaver1YR
Enrolled in the university but not in the SoE	12	Switcher1YR
Enrolled in the SoE	97	Stayer1YR

Table 1. Study 1 enrollment categories.

Enrollment Status Fall 2003	No.	Code
Not enrolled in the university	17	Leaver3YR
Enrolled in the university but not in the SoE	14	Switcher3YR
Enrolled in the SoE	84	Stayer3YR

Table 2. Study 2 enrollment categories.

III. Results

The results of two discriminant analysis procedures that predict membership into three groups (Stayer, Switcher, Leaver) based on the criterion (dependent) variable persistence in engineering using four non-cognitive predictor (independent) variables (JOBS, ENGINE, COMM, BASIC) are presented. Study 1 results used registration status one year after entering college to determine group membership; study 2 used registration status three years after entering college.

For study 1, the Box's M Test, which tests the null hypothesis of equal population covariance matrices, was non-significant; thus the assumption of the homogeneity of the variance-covariance matrices was supported. Since there were three grouping categories, two discriminant functions were developed. The overall Wilks' lambda was significant, $\Lambda = 0.829$, $X^2\,(8) = 20.77$, $p < 0.008$. This test indicated the four predictors differentiated among the three persistence groups (Leaver1YR, Switcher1YR, and Stayer1YR). The residual Wilks' lambda was not significant; therefore we only evaluated the first discriminant function. The canonical correlation was used to evaluate the effect size. The canonical correlation is a function of the eigenvalue (λ) which is the ratio of the between-group sum of squares to the within-group sum of squares for a one factor ANOVA which used the groups as the levels of the factor and the values of the discriminant function as the dependent variable. By squaring the canonical correlation value, we determined that 15.6 percent of the variability in the discriminant function scores was accounted for by differences among the three student groups. The standardized canonical coefficients for the selected discriminant function are shown in Table 3.

We were able to correctly classify 85.2 percent of the individuals in the sample. The leave-one-out method yielded 83.5 percent

Predictor Variable	Coefficient
ENGINE	-0.619
COMM	-0.046
BASIC	0.751
JOBS	0.645

Table 3. Study 1 standardized function coefficients.

correct classifications, thus assessing how well the classification procedure would predict in a new sample.

For study 2, which evaluated persistence status three years after entering college, the Box's M Test was also non-significant. The overall Wilks' lambda was significant, $\Lambda = 0.785$, $X^2\,(8) = 26.7$, $p < 0.001$. This test indicated the four predictors (JOBS, ENGINE, COMM, BASIC) differentiated among the three persistence groups (Leaver3YR, Switcher3YR, Stayer3YR). The effect size was larger than for study 1. The function had an eigenvalue of 0.259 and a canonical correlation of 0.454. Thus, we determined that 20.6 percent of the variability in the discriminant function scores was accounted for by differences among the three student groups. We were able to correctly classify 76.5 percent of the individuals in the sample. The leave-one-out method yielded 74.8 percent correct classifications. Table 4 shows the standardized coefficients for the discriminant function.

IV. Discussion

With respect to groupings based on student status one year after entering college, univariate tests of the equality of group means showed strong differences among the groups for two of the factors: BASIC ($F(2,112) = 4.565$, $p < 0.012$) and JOBS ($F(2,112) = 3.964$, $p < 0.022$). At the end of one year of college, the Stayers possessed higher confidence in their basic academic skills in calculus, chemistry, physics, and engineering ($M = 3.69$) than did the Leavers ($M = 3.02$). Interestingly, the math/science confidence level of the Switchers ($M = 3.52$) was closer to that of the Stayers than the Leavers. With respect to the JOBS factor, the Stayers held the strongest positive views ($M = 3.54$) of the three groups. However, the mean JOBS score for the Switchers ($M = 3.17$) was closer to that of the Leavers ($M = 3.06$) than the Stayers. Although the Switchers were relatively confident of their math/science ability, they were less enamored with engineering as a career at the end of their freshman year. Also, the JOBS score suggests that they might have entered the school of engineering with less intrinsic motivation than the Stayers. These results can be compared with Levin and Wyckoff [13] who found that a focus on status and money was negative predictor for persistence in engineering through the freshman year.

With respect to groupings based on student status three years after entering college, univariate tests of the equality of group means were significant for the same two factors: BASIC ($F(2,112) = 5.005$, $p < 0.008$) and JOBS($F(2,112) = 8.889$, $p \leq 0.000$). Students who chose to remain in engineering for at least three years (Stayer3YR) possessed higher confidence in their basic academic skills in calculus, chemistry, physics, and engineering at the end of one year of college ($M = 3.73$) than did the those who were no longer enrolled ($M = 3.28$). The math/science confidence level of the Switchers ($M = 3.55$) was about halfway between the other two groups. With respect to the JOBS factor, the Stayers held the strongest positive views ($M = 3.59$) of the three groups. The mean JOBS score for the Switchers ($M = 3.41$) was closer to that of the Stayers than the Leavers ($M = 2.97$).

Predictor Variable	Coefficient
ENGINE	-0.370
COMM	0.177
BASIC	0.634
JOBS	0.807

Table 4. Study 2 standardized function coefficients.

The results of this research suggest that lack of confidence in math and science ability, combined with motivation for studying engineering, are associated with attrition from our school of engineering. For students whose interest in engineering is genuine, efforts to increase their math/science confidence could result in reduced attrition. For those Switchers who lack confidence in their math/science skills, and whose main attraction to engineering was the expectation of high pay and good job opportunities, the decision to leave may have been the best for them. The long-term persistence results suggest that impressions that students form with respect to their math and science abilities during the freshman year are reflected in their decision to leave engineering as much as two years later.

The study reported here has several limitations. First, since this was a single-institution study at a small teaching-oriented school of engineering, the results may not be generalizable to students at other types of engineering schools. Besterfield-Sacre has shown that certain freshman student attitudes vary significantly from institution to institution [16]. Second, since we analyzed post-survey results collected in April, the attitudes of early leavers were not represented in this study. A future study which uses data from the pre-survey data which was collected in during orientation in August might give us insight into their views. Third, due to the small sample size, we did not differentiate between those who left in good standing versus those who left in poor standing. Previous research indicates that attitudes toward engineering vary between these two groups [15]. Finally, by using only a subset of the 13 factors available in the survey instrument, we may have overlooked some important interactions with other variables that would produce a different model. Although our sample comprised 84 percent of the population of entering freshmen, the small class size makes it difficult to conduct a multivariate analysis based on a large number of factors. Studies conducted by schools with much larger entering freshman classes would be needed to help us understand the interrelationships among larger sets of non-cognitive variables and their potential effect on persistence.

V. Conclusions

The persistence patterns of a cohort of students who entered engineering school as full-time freshmen in the fall 2000 semester were tracked over a three year period. Our prediction model shows that end-of-freshman-year attitudes can be used to effectively predict persistence status one year or three years after entering engineering school. Specific to this study, confidence in college-level math and science ability, and the belief that an engineering degree enhances career security were significant predictors of persistence. This research does not negate the importance of other cognitive variables, especially science and math grades earned in college. Instead, this research confirms that non-cognitive factors such as attitudes and beliefs formed during the freshman year should be considered by investigators when they develop persistence models for

their institutions. The systematic collection of non-cognitive as well as cognitive data is an important step as we work toward developing a specialized theory of persistence for undergraduate engineering students.

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