A STRUCTURAL MODEL OF ENGINEERING STUDENTS SUCCESS AND PERSISTENCE

Brian F. French¹, Jason C. Immekus² and William Oakes³

Abstract – This study examined a model of student success and persistence at two levels: university and engineering major. The model, based on theoretical and empirical evidence, included both cognitive and noncognitive factors. Cognitive factors included High School Rank, Scholastic Aptitude Scores, and University Grade Point Average. Noncognitive factors included motivation, as well as faculty and student integration. Outcome variables in the model were grade point average, enrollment at the university, as well as within engineering. Through the use of path analysis, several significant relationships among the factors were found. For instance, grade point average was significantly related to enrollment in both the university and engineering major. Increased levels of student interactions were significantly related to continued enrollment in engineering. Interestingly, student with higher faculty integration were more likely to change majors. Implications and directions for future research are discussed.

Index Terms – Retention, Path Analysis, Persistence, Student Success.

INTRODUCTION

The academic success and retention of engineering students is a central issue in engineering education [26, 25]. Retention in engineering has been the subject of a great deal of research and activity as the demand for qualified engineers threatens to outpace the number of graduating engineers [6]. Models of student success and persistence provide a way to examine the effects of cognitive and noncognitive factors on specific academic outcomes. Among engineering students, cognitive indicators have been shown to be the best predictors of achievement and persistence [18, 11, 25]. However, academic success and persistence cannot be fully explained without the consideration of noncognitive factors. To answer the question of what set of factors should be considered as relevant to predicting specific outcomes in college, researchers have turned to the examination of theoretical models of academic success and persistence. Through such research, the possibility exists to characterize the key determinants of these outcomes in order to guide resource allocation and program development for freshmen engineering students.

Students decide to pursue an engineering major for a variety of reasons. Work characteristics and high school math and science courses have been reported to play a key role in a student’s decision to pursue an engineering degree [22]. Student attitudes toward engineering and its relationship to persistence in an engineering program have been considered [5]. The stability of prior academic attainments as predictive measures of subsequent academic outcomes also has been reported [1, 16]. In addition, high school rank was found to be a key predictor of the academic success of minority and nonminority students [1]. However, success and persistence in engineering cannot be solely accounted for by prior attainments. To address this issue, researchers have developed instruments to measure the affective processes of students who may persist in an engineering major and those who may transfer to another area [26].

Reference to student characteristics is central to explanations of academic outcomes. Motivation is perhaps the most commonly considered student characteristic in relation to academic outcomes. Motivation can be defined as the engagement in a task for its own sake [32]. Characteristics of motivated students include persistence, goal setting, and resilience [2]. In the context of academic outcomes, students with heightened levels of motivation are hypothesized to utilize available resources in order to satisfy their goals of desired grades and a college degree. Both experimental and causal studies have provided support for the role of motivational processes on students’ academic attainments [8, 13]. For instance, higher levels of academic self-efficacy, a motivational process, were related to academic success and adjustment among 1st-year college students [13].

Faculty and student integration are additional factors that have been recommended to consider in models of student success and persistence [3, 4]. Accordingly, it is hypothesized that socialization is a determinant of the degree students become integrated into the college environment. In models of persistence, for example, students who are more socially integrated into the college environment are considered more likely to persist compared to students with minimal social contacts [36, 38]. A positive relationship between social integration and persistence also has been reported [4]. Specifically, they note that students with early institutional involvement in the university were more likely
to stay committed to the standards of the institution and persist.

Environmental factors also should be considered in reference to student success and persistence. For example, first-year seminars are a common university resource to facilitate the transition to college for freshman students. In general, the intent of these programs is to introduce students to the expectations of the university, provide students the opportunity to build a social network, and expose students to employment opportunities after graduation. Although the efficacy of these programs has been reported [15, 21], it is largely unknown whether student success and persistence can be attributed to the retention program or characteristics unique to the student. For instance, students may enroll in a first-year seminar for a variety of reasons, such as motivation to succeed. Without this consideration in mind, many investigations of the effects of retention programs on achievement and persistence did not account for student characteristics that may influence a student’s decision to continue the pursuit of a college degree [20, 35]. Investigation of a model of persistence that accounts for students who did and did not participant in a first-year seminar in addition to specific measures of cognitive and noncognitive factors would provide information regarding the influence of these factors on subsequent academic performance and persistence.

There are several hypothesized models that characterize the nature of academic success and retention at the college level [10, 12, 36, 37]. In general, these are mixed models that emphasize the interaction among personal, social, and environmental factors and how they influence student success and persistence. Differences between models exist with regard to the variables considered most critical in each model (e.g., finances, motivation). Regardless, prior and current academic attainments, such as high school rank and Scholastic Aptitude Test (SAT) scores, represent cognitive factors. Both factors represent a student’s academic performance, which can be referenced to the success of other students. Examples of noncognitive factors include motivation, faculty and student integration, and whether or not a student was enrolled in a first-year seminar. Indeed, models of student success and persistence can vary substantially, depending on which factors are selected for study. In large, student background characteristics, motivation, and faculty and student integration have been most subjected to empirical investigations with regard to their associations with student success and persistence. Investigations within single- and multiple institutions have yielded key evidence of the role of these factors on students’ academic performance and persistence [9].

Research in engineering student success and persistence reflects the necessity to characterize and identify the key indicators of these outcomes. Current state-of-the-art methods utilizing student data provides a fruitful avenue for researchers to test theoretical models of student success and persistence. As educators become more familiar with the characteristics of the students entering college with the intent to pursue an engineering degree, the more able they will be to guide subsequent program planning. Based on this premise, the purpose of the present investigation was to examine the relationship among theoretically articulated cognitive and noncognitive factors and their influence on academic achievement and persistence. Results are intended to shed light on the value of the inclusion of specific factors in models designed to explain engineering student success and persistence.

**METHOD**

**Participants and Procedures**

Participants included first year engineering undergraduate students (N = 678) from a large Midwestern university from the 2000-2001 academic year. Males comprised 82.9% of the participants, and all participants began college as engineering majors. Roughly half (47.9%) of the participants completed a freshman orientation seminar during their first semester and were originally part of a larger study [19]. Students were asked to participate during their first academic semester. Students who participated agreed to complete two surveys at the end of the first seminar and to allow their academic progress to be monitored throughout their university career.

**Measures and Variables**

Ten variables used in this study included participation in a first-year seminar, academic motivation, institutional integration (faculty and student), high school rank, Scholastic Aptitude Test scores (SAT math and verbal), cumulative grade point average (GPA), enrollment status, and declared academic major. The latter six variables were obtained through university records. SAT scores and high school rank were included in the model because individual attributes, precollege school experiences, and record of achievement can help explain why students persist. Table I contains descriptive statistics for the variables included in the model.

**Motivation.** The Academic Intrinsic Motivation Scale (AIMS) [17] was used to assess the students’ level of motivation for academic work. The scale is comprised of four subscales that assess four types of intrinsic motivators including challenge, control, curiosity, and career outlook [27, 28]. Reliability and validity evidence have been favorable for the instrument [17]. Internal consistency reliability (coefficient alpha) was assessed for this study (r = .91).

**Institutional Integration.** Institutional integration addresses the degree students perceive themselves integrated, both socially and academically, within the college environment [10, 37, 38]. A revised version of the Institutional Integration Scale (IIS) [18, 31] was used to

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**Session T2A**

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assess the students' level of social and academic integration to the university. The IIS contains 5 subscales including (a) Peer-Group Interactions, (b) Interactions with Faculty, (c) Faculty Concern for Student Development and Teaching, (d) Academic and Intellectual Development, and (e) Institutional and Goal Commitment. For this study, coefficient alpha was .91, .86, and .87 for the total scale score, the faculty, and the student scale scores, respectively.

**TABLE I**

<table>
<thead>
<tr>
<th>Measures</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIMS</td>
<td>4.37</td>
<td>0.39</td>
</tr>
<tr>
<td>Faculty Integration</td>
<td>3.74</td>
<td>0.63</td>
</tr>
<tr>
<td>Student Integration</td>
<td>3.95</td>
<td>0.52</td>
</tr>
<tr>
<td>SAT-verbal</td>
<td>571.87</td>
<td>60.38</td>
</tr>
<tr>
<td>SAT-math</td>
<td>642.92</td>
<td>54.64</td>
</tr>
<tr>
<td>High School Rank</td>
<td>85.30</td>
<td>10.36</td>
</tr>
<tr>
<td>GPA</td>
<td>2.78</td>
<td>0.62</td>
</tr>
</tbody>
</table>

**Percentages**

| Class (0 =no seminar, 1= seminar) | 0 (52.1%) | 1 (47.9%) |
| Enroll (0 = no, 1 = yes)          | 0 (10.3%) | 1 (89.7%) |
| Major (0 = no, 1 = yes)           | 0 (23.6%) | 1 (76.4%) |

*High School Rank.* High school rank provides an index of each student’s relative standing to their grade peers prior to entering college.

*SAT Scores.* Student’s SAT Verbal and Mathematics scores were included in the model to provide background information of students’ academic aptitude.

*Cumulative Grade Point Average.* Cumulative grade point average (GPA) included grades from students’ first three semesters at the university.

*University Enrollment.* A student was considered enrolled if they entered the university in the Fall 2000 semester and were enrolled in the Spring 2002 semester.

*Major Enrollment.* A student was considered enrolled in the Engineering department if their declared major had not changed.

*Class.* This variable indicated if a student enrolled in a first-year engineering orientation seminar.

**Analysis**

Path analysis was used to test the hypothesized recursive causal model with seven exogenous variables (high school rank, SAT math and verbal scores, academic motivation, faculty and student institutional integration, and participation in a first-year seminar) and three endogenous variables (GPA, persistence at the university, and persistence in engineering). Participants with missing data were excluded from the analysis.

The model, see Figure 1, was evaluated via Mplus 2.02 [30]. For this model, the standard analysis of covariance was inappropriate due to the inclusion of categorical and continuous exogenous and endogenous variables [7, 23, 30]. The possible violation of distributional assumptions with the use of estimation procedures (e.g., maximum likelihood) can lead to inaccurate parameter estimates. Specifically, categorical variables with few categories increase the attenuation of the coefficient estimates [7]. Therefore, probabilities of the categorical outcomes, an asymptotic covariance matrix, and weighted least squares estimation were used.

The three equations in the analysis allow for examination of the estimated total, direct, and indirect effects of the variables in the model. Path coefficients were tested for significance with t-tests. Suggested guidelines for interpretation of the standardized path coefficients are values around (a) .10 represent small effects, (b) .30 represent a medium effect, and (c) .50 represent a large effect [14]. Interpretation of the coefficients is important because the significance test reflects not only the magnitude of the coefficient but other factors (e.g., sample size) [24]. Model fit was determined by the chi-square goodness-of-fit statistic ($\chi^2$) and the generalized squared multiple correlation ($R^2_m$) [33]. The chi-square statistic indicates the extent to which the original and estimated matrices are similar. Thus, a nonsignificant value is desirable. The $R^2_m$ is interpreted as the proportion of variance accounted for by the set of variables.
RESULTS

Model fit, as judged by the generalized squared multiple correlation coefficient ($R^2_m = .35$) and the chi-square statistic ($\chi^2 (6) = 12.78, p > .01$) was good. The completely standardized values for the total effects are provided in Figure 1. The first equation evaluated the effects of SAT scores, high school rank, academic motivation, and enrollment in a first-year seminar on grade point average (GPA) after 3 academic semesters. As shown in Table 2, of the exogenous variables, high school rank ($\gamma = .08$), SAT-Math ($\gamma = .16$), and academic motivation ($\gamma = .10$) had significant positive effects on GPA (all $p < .05$). However, these variables explained only 4% ($R^2 = .04$) of the variance in GPA.

The second equation evaluated the effects of academic motivation, faculty and student integration, enrollment in a first-year seminar, high school rank, and GPA on persistence at the university. As provided in Table 3, GPA was the only variable to have a significant positive effect on persistence ($\beta = .48$). The variables in this equation accounted for approximately 24% ($R^2 = .238$) of the variance in persistence.

The third equation evaluated the effects of academic motivation, faculty and student integration, enrollment in a first-year seminar, high school rank, and GPA on persistence at the university as an engineer major. As shown in Table 4, six variables, GPA (beta = .27), faculty integration (gamma = -.17), and student integration (gamma = .46) had significant effects on persistence as an engineering major. Faculty integration had a negative effect on students remaining in engineering, whereas GPA and student integration had positive effects. These variables explained approximately 11% of the variance in students’ decision to remain in engineering ($R^2 = .106$).

DISCUSSION

The purpose of this study was to evaluate the effects of SAT scores, high school rank, academic intrinsic motivation, institutional integration, and participation in a first-year seminar on college student success and persistence. Specifically, participation in a first-year engineering seminar, academic intrinsic motivation and faculty and student institutional integration were hypothesized to have significant positive effects on student persistence, all of which were not observed. Motivation did have a significant effect on GPA, which in turn had a significant effect on persistence at the university and as an engineer major. This is consistent with previous persistence studies [1, 29, 34]. In addition, faculty and student integration had significant effects on continuing as an engineer student. However, higher faculty integration scores were associated with
students changing majors, whereas higher student integration scores were associated with students not changing majors. After three academic semesters, approximately 24% of the students in this sample had changed majors.

The negative correlation between faculty integration and persistence in major may be partially explained by the fact that the students have the option of choosing to take a first year seminar course with a faculty member. Advisors tend to encourage students to enroll in these small classes if they are not as sure about selecting engineering as a major. The result may skew students who are inherently more likely to change majors to have more faculty contact. It should be noted that while these students changed their majors out of engineering, they were retained at the university. Further examination of this phenomenon is a subject of future work.

Consistent with previous research [25], the student precollege variables, SAT Math and high school rank did significantly influence GPA. Interestingly, SAT Verbal scores did not have a significant effect on GPA. Participation in the engineering first-year seminar did not seem to affect GPA or persistence. The persistence rate after the first three academic semesters was 89.7%, a slightly higher rate of persistence compared to the overall university rate of approximately 86%.

The student, as the one who is solely responsible for persistence, has been the focus of models of student departure [37]. From this perspective, measured variables are based on the student’s perspective of how well he or she has adjusted to the college environment. Findings from this investigation are consistent with suggestions that research also should be focused at the institutional level [9]. Factors related to financial opportunities and organizational structures of the institution need to be considered in models of persistence and academic success [9]. For instance, multi-institutional research may consider the cost associated with degree attainment at each school to understand the relationship between financial cost and persistence to degree attainment. As measured in this study, motivation and integration were operationalized at the individual level (i.e., the student perspective). This is one possible explanation for why motivation and faculty and student integration did not significantly influence persistence at the university level.

Academic and social integration are claimed to be critical components in models of student departure. However, little empirical support exists for academic integration playing such a role. For instance, only moderate support for academic integration was found in a review of 39 single institution studies [9]. The role of academic and social integration may need reconsideration or measured and conceptualized in a different manner. [9]. These constructs were measured with a revised version of the Institutional Integration scale. Scores were based on a two-factor model, with the student and faculty factors representing aspects of social and academic integration respective to each group. However, results were still consistent with the previous findings [9] except for persistence as an engineering major.

Student integration appeared to positively affect a student’s decision to continue in the engineering program and faculty integration had the opposite effect. This somewhat counterintuitive result is consistent with compensatory relationships among variables [31].

The limitations of this study must be addressed in future research. First, models with variables at the institutional level need to be evaluated [9]. This needs to occur, not at single institutions, but across multiple institutions using common measures. Second, results may be strengthened with longitudinal data of persistence behavior. The effects in this study may be inaccurate, as students who were considered non-enrollees were students who did not return for the fourth academic semester. This is not an indication that these students simply dropped out of college. They may have transferred to another institution or temporally suspended their education. Third, examination of noncognitive variables, such as academic motivation, over time may be useful. Models of student persistence may be more informative if assessments of motivation at critical times in students’ academic career are included [1].

Results from path analysis should be considered in conjunction with findings obtained through the use of other research methods. This combination is necessary in order to illuminate causal mechanisms [24] involved in student success and persistence. There remains much variance to be accounted for in the explanation of GPA and persistence behavior as indicated by this model (e.g., 65%). To assist in accounting for this variance, additional important variables need to be evaluated, such as financial aid and parents’ level of education [1, 29]. The examination of the combination of these variables is necessary in order to more thoroughly understand the student decision process as well as design more effective programs focused on student success and persistence.

REFERENCES


Session T2A
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