A Study of Non-Academic Factors Contributing to the Success of Undergraduate Engineering Students

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Abstract

In recent years, engineering educators have placed considerable focus on designing and implementing effective strategies for retaining students, improving student performance and increasing retention and graduation rates. According to the American Society for Engineering Education (ASEE) 2012 report on student retention *"Going the Distance-Best Practices and Strategies for Retaining Engineering, Engineering Technology and Computing Students"*, a main reason for the attrition of engineering students is how well they perceive that their learning environment engages and motivates them as they matriculate in their academic program. In an effort to quantify how non-academic factors contribute to the success of undergraduate engineering students, this paper describes a preliminary study that explores academic motivation, institutional commitment, scholastic conscientiousness and social integration, among other non-academic factors, that contribute to the persistence of engineering students. An Electrical and Computer Engineering student sample is utilized and quantitative analyses are performed on the collected data. Descriptive analyses are used to analyze the distribution of each of the factors and to determine significant relationships between variables. The results of this preliminary study contribute to the advanced knowledge of the impact of psychosocial factors on engineering student success.

Keywords

Persistence Factors, Retention, Pre-Engineering program

Introduction

With a significant shift in demographics among racial minorities in the United States and with 2008 Census Bureau[1] projections that these groups will comprise 50% of the U.S. population, it has become important for higher educational institutions to educate this diverse population in order to maintain a competitive global economic edge. This has become most germane in the fields of science, technology, engineering, and math (STEM); however, based on IES's STEM attrition report[2], there continues to be an insufficient production of highly-trained STEM workers, especially among African-Americans. Center for Institutional Data Exchange and Analysis statistics[3] show that freshmen entering college intending to major in science and engineering (S&E) either change their majors or do not graduate at all. Additionally, nearly 50% of all undergraduates who had initial intentions to major in STEM switched out of these fields within their first two years of college. Academic motivation is a significant reason for student success in an engineering program. This revelation is contrary to the notion that academic under-preparedness and low student performance are the main reasons for high attrition. Moreover, the ASEE report asserts that there is still a high degree of variability in retention and graduation rates among different race, ethnic and gender groups. Of more concern is that underrepresented groups of African and Latino Americans are more likely than Whites and Asian Pacific Islanders to switch to a non-science major, leaving the STEM fields altogether. While it has been well documented that there is an urgent need to develop a diverse and well prepared engineering workforce[4], STEM degree attainment rates among historically underrepresented minorities, particularly African-Americans, continue to lag behind[5].

In response to these trends, many educational pathways have been designed nationwide to increase the labor supply of highly-trained engineers including the implementation of pre-engineering programs, where students must demonstrate proficiency prior to matriculating into major engineering courses. In an effort to respond to the importance of pre-college preparation in the success of minority students in STEM majors, these pre-engineering programs are university-based intervention programs, as noted by Harvey[6], that work with pre-college populations to emphasize high academic achievement and positive goal orientation and have the potential of increasing African-American college entrance and completion. Palmer, Davis, Moore, and Hilton[7] noted in research focused on African-American male students' college entrance and persistence, that offering comprehensive programs that include not only weekend or summer courses, but also academic help, financial aid counseling, mentoring, and other social supports increased college access, degree completion and could possibly strengthen preparedness in critical STEM courses. Other empirical research[5] has shown that social and psychological factors, in part, are related to college success in undergraduate students. Peer, faculty member, and mentor support affects academic achievement, especially among African-American males and underrepresented minorities in STEM fields[8-10]. Tsui[11] notes in her review of the literature that, *"The availability of academic and psychosocial support services is critical in light of the finding that what seems to distinguish those who persist from those who transfer out of STEM has less to do with ability, and more to do with the manner in which students respond to the barriers that they encountered"* (p. 556).

A formal structured pre-engineering program was implemented in 2004 at the Florida A&M University-Florida State University College of Engineering (FAMU-FSU COE) to provide uniformity in academic experiences of new students and to ensure appropriate levels of academic preparedness. The pre-engineering program has gone through several revisions since its inception to accommodate unexpected and unintended consequences and to adequately satisfy the academic requirements of both universities. However, since 2009 it has remained a fairly stable pre-engineering program. All incoming engineering majors are required to matriculate as pre-engineering students until program requirements are met. Upon completion of the pre-engineering program, a student is coded into one of three categories: (1) good standing and the student is permitted to transfer to the department; (2) conditional transfer; student must satisfactorily complete additional course requirements as determined; or (3) no transfer; student is not permitted to transfer based on unsatisfactory performance.

Previous research[12] on the persistence of engineering students at the FAMU-FSU COE suggests that the completion of the pre-engineering program requirements is a strong indicator of students' persistence to graduation. The data from the study showed that of the 1,997 first-time-in-college (FTIC) engineering students who entered the pre-engineering program in fall 2004, 46% of the FSU students completed the program requirements and only 25% of the FAMU students completed the program requirements. These results are disturbing and suggest there are major underlying factors that are impacting the persistence of pre-engineering students in the major at both institutions. In an effort to further investigate these results and provide some justification for implementing effective student support programs, a persistence study was implemented and its results are described in this paper. For consistency sake, it becomes necessary to define how the terms *persistence* and *retention* are used in this research. In this work "student persistence" describes those students who are matriculating in their engineering program after having completed the pre-engineering program. The term "student retention" describes those students who are currently matriculating in the pre-engineering program. A research study was designed to explore students' perception of themselves and their learning environment using common factors that impact persistence and retention.

Background

Tinto's[13] seminal retention model will be used to identify psychosocial factors related to the COE engineering students' persistence. Tinto proposed that students who academically and socially integrate into the campus community increase their commitment to the institution and to their goals and thus are more likely to graduate[14]. The two concepts in this theory interact with and enhance each other. Karp, Hughes, and O'Gara[15] note that in this model, academic integration occurs when students become attached to the intellectual aspect of college and social integration occurs when students develop positive relationships and connections inside and outside of the classroom. The concept of integration is so prominent that the assumption is if colleges provide sufficient opportunities for students to engage in the institution, then students become integrated and persist in their studies. In an expansion of his model, Tinto[14] noted that cultural barriers must be removed for underrepresented students so that they can connect to the campus community. With the low level of persistence in the engineering major, it will be instructive to utilize this theoretical model to identify specific factors that could positively impact academic and social barriers and, ultimately, student-persistence rates in engineering.

The literature on retention and persistence rates in higher education is plentiful as outlined by Palmer, et.al[7] Davidson, Beck and Milligan[16] identified eight primary themes that impact student retention and persistence rates. In this paper those themes were categorized into ten factors based on analysis results from previous studies [17]. The ten primary persistence factors that are identified in this study include: *academic integration (AI), social integration (SI), degree commitment (DC), collegiate stress (CS), academic motivation (AM), academic advisement (AA), scholastic conscientiousness (SC), institutional commitment (IC), financial stress (FS),* and *academic efficacy (AE)*.

Academic integration is a student's perception of how well their engineering curriculum and instruction aid in their achievement of their personal goals. Some variables that may influence academic integration include quality of instruction and feelings of intellectual growth [16]. Social integration is a student's perception of their sense of community, how similar they feel to their peers, their sense of belonging, etc. [16]. Degree commitment measures the value a student places on obtaining their engineering degree. Collegiate stress measures the degree to which academic stress influences a student's college life experiences. Academic motivation measures a student's desire to pursue excellence in academic tasks. Academic advisement refers to a student's perception of the quality and level of advisement they have received at their institution. Scholastic conscientiousness measures the value students place on their academic responsibilities, such as turning assignments in on time and arriving to class on time. Institutional commitment refers to how committed a student is to completing their degree at their current institution. Financial stress refers to a student's level of worry or difficulty in meeting their financial needs in college. Academic efficacy measures a student's belief in himself or herself to meet the academic performance goals.

Method

A persistence study was designed to analyze the impact of non-academic factors on persisting Electrical and Computer Engineering (ECE) students. The research was conducted in a junior-level Electrical and Computer Engineering Signals and Systems course. This is a required course for ECE students. Students in this course were at least one-year removed from having completed the pre-engineering program, thus, these results may be used to characterize successful models for pre-engineering program completion.

Participants

A sample of 56 ECE students participated in the study. The demographics of the sample were 14% female, 86% male; 25% African-Americans, 30% Hispanics and 41% Caucasians. Figure 1 shows a breakdown of the total fall 2014 undergraduate student enrollment at the College of Engineering ($N = 2318$). Of this population, there are 247 Electrical and Computer Engineering students, representing about 11% of the total undergraduate engineering student population. This number represents the percentage of students that are persisting in their major. In other words, they've successfully completed the pre-engineering program. The 56 participants in this study represent about 23% of the total ECE population, as illustrated in figure 2. Table 1 shows the categorization of the sample set by institution and major.

Table 1- Categorization of sample population relative to entire ECE population (in percent) by institution (FAMU and FSU) and major (Electrical Engineering and Computer Engineering)

	CompEng	EE	Totals
FAMU	30	28	29
FSU	14	25	21
Totals	18	25	23

It is worth noting that 48% of the total undergraduate student population is pre-engineering. Therefore, focusing efforts on program completion is critical for maintaining persistence in the major. This study contributes to this effort.

Data Collection

The instrument used for this study was the College Persistence Questionnaire Test Version 3 (CPQ-TV3)[17] which was designed to assess students' perceptions of learning-environment variables and their intentions to persist in their academic program. The CPQ-TV3 was derived from Beck's College Persistence Questionnaire CPQ-V2 instrument[16].

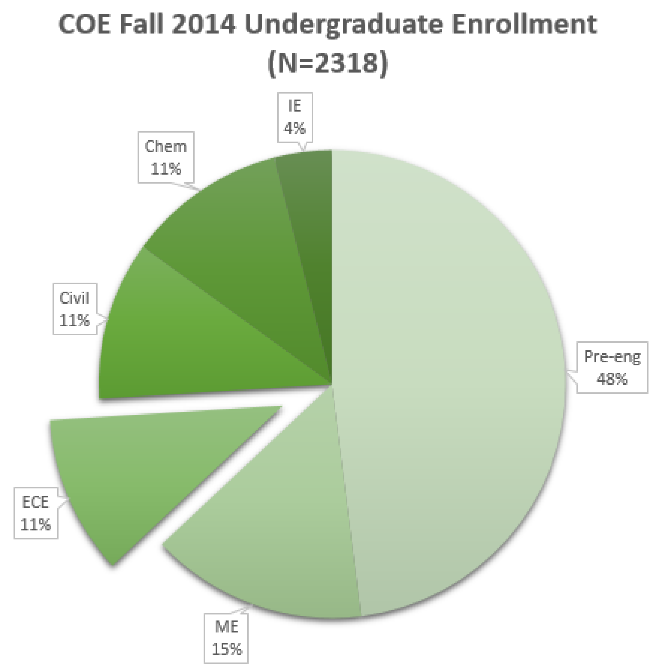

Figure 1-Total Undergraduate Student Enrollment at COE (Fall 2014)

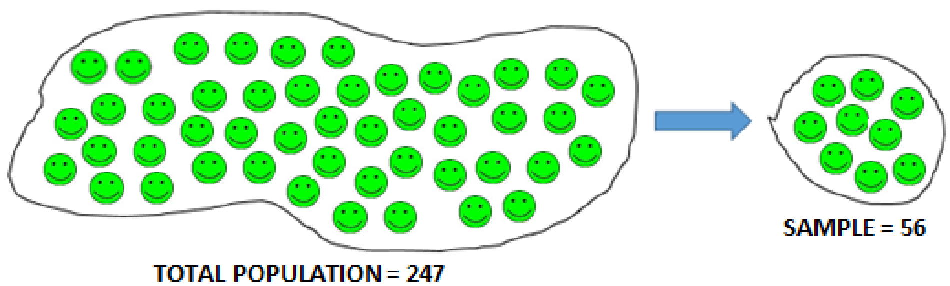

Figure 2-Sample contains 56 participants from a total population of 247 Electrical and Computer Engineering students

Lindheimer suggested that the newer version correlates better with identifying at-risk students. Responses for the following ten factors were recorded and analyzed: Institutional Commitment, Degree Commitment, Academic Integration, Social Integration, Scholastic Conscientiousness, Academic Efficacy, Academic Motivation, Collegiate Stress, Academic Advising and Financial Strain. Furthermore, the College Persistence Questionnaire demonstrated strong validity and reliability [16-17] with an average Cronbach alpha score of $\alpha = 0.70$ for all factors [18].

Questions were answered on a 5-point Likert scale with a sixth option denoting "not applicable". The item-response scale depended on the language of the question. For example, an item in the academic advisement category asked *"How satisfied are you with the academic advising you receive here?"* used an item-response scale ranging from (*very satisfied* to *very dissatisfied*). The data analysis phase converted these responses to a favorability scale which indicates a positive or negative feeling about the student's experience (+2 indicated *very favorable* to -2 indicating *very unfavorable*). All participants signed a consent form and approval to administer the questionnaire was obtained from the FAMU and FSU Institutional Review Board.

Participants were assured that their answers would remain confidential. The CPQ-TV3 was administered in pencil-and-paper format during the twelfth week of the fall semester of class. Most of the participants completed the CPQ-TV3 in less than 20 minutes.

Data Analysis

The data was coded using favorability scores to code item responses (+2 very favorable; +1 somewhat favorable; 0 neutral; -1 somewhat unfavorable and -2 very unfavorable). Descriptive and inferential statistics were used to measure the mean and variance of the data as shown in Table 2. All statistical tests were conducted using Minitab® Statistical Software. Figure 3 shows the histogram plot of each factor after conducting normality tests.

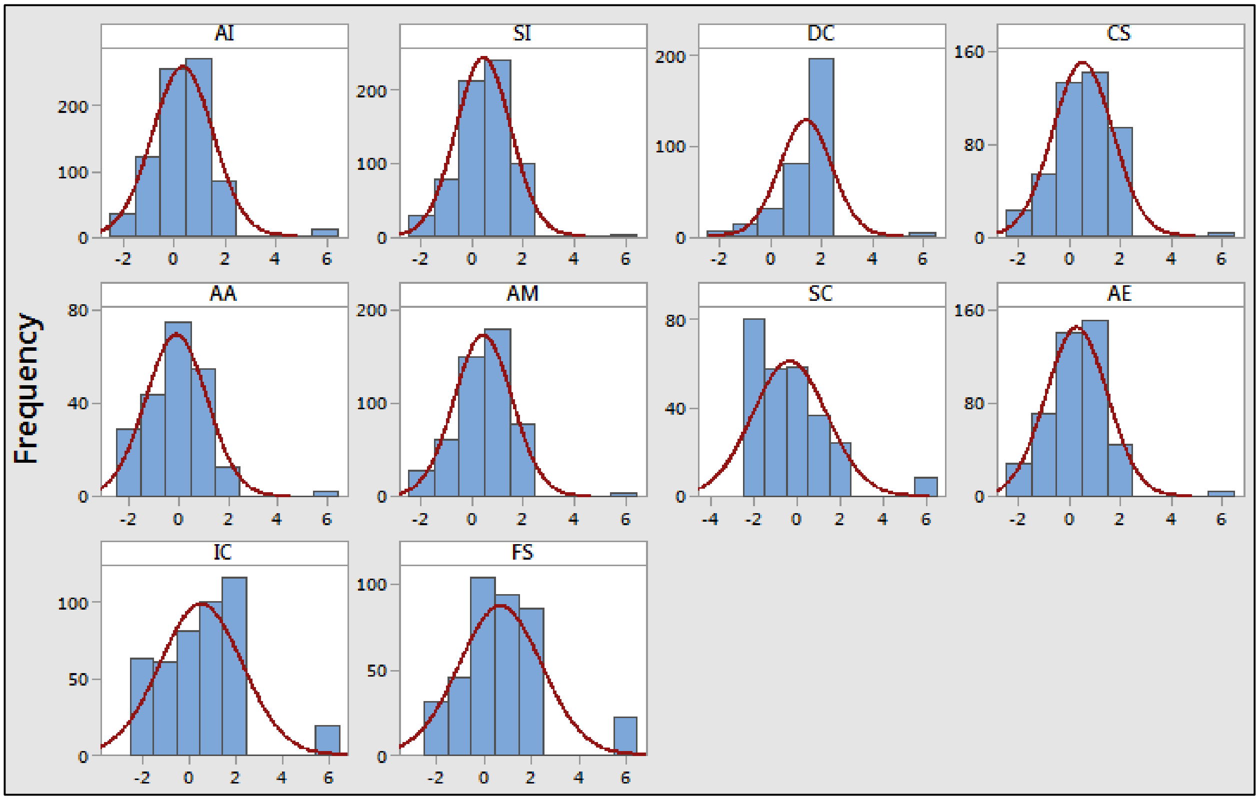

Figure 3-Histogram Plots of Persistence Factors based on favorability scale

Based on the normality tests, it was concluded that the each of the persistence factors followed a normal distribution pattern and basic statistical analysis methods could be used in analyzing the data. It is also worth noting a few observations about the data: (1) The "6" value indicated a "not applicable" response from the student; (2) the *degree commitment (DC)* factor is skewed in the positive or favorable direction. This observation can be explained by using the fact that this sample population has already completed the pre-engineering program and are nearing the last phase of their undergraduate curriculum, so they may have more determination and perseverance to finish their degree than lower-level students; (3) *institutional commitment (IC)* is also skewed in the favorable direction which may suggest that students in this sample population are committed to their institution at this stage in their program matriculation; and finally, (4) *scholastic conscientiousness (SC)* is negatively skewed, which may suggest that students place minimal value on their academic responsibilities, such as turning in assignments in a timely manner or arriving to class on time.

Table 2- Mean and Standard deviation scores for sample set of Electrical and Computer Engineering Participants

	Mean	Standard Deviation
AI	0.4108	1.205
SI	0.4887	1.085
DC	1.418	1.032
CS	0.5618	1.187
AM	0.4790	1.146
AA	-0.041	1.249
SC	-0.302	1.787
IC	0.5914	1.787
FS	0.7487	1.757
AE	0.3228	1.215

Correlational analysis was also performed on the data to determine relationships between primary factors. The results are presented in the next section along with a discussion of some observations.

Results and Discussion

Intercorrelational values were determined and a correlation matrix using the Pearson correlation coefficient method was constructed. The Pearson Method evaluates the strength to which two variables tend to change together in a linear fashion. It assumes normality among the data. Table 3 shows the results.

Table 3-Intercorrelation among retention variables (p-values in parenthesis)

	AI	SI	DC	CS	AM	AA	SC	IC	FS	AE
AI	1.00	0.126*	0.153*	0.163	0.135	0.047	-0.068	0.252*	0.198*	0.083
SI	--	1.00	0.152	0.047	0.06	-0.022	0.084	-0.059	0.108	0.021
DC	--	--	1.00	0.127	0.093	0.059	-0.013	0.087	0.110	0.065
CS	--	--	--	1.00	0.114	-0.004	-0.108	0.077	0.066	0.060
AM	--	--	--	--	1.00	0.085	0.144	0.108	0.113	-0.010
AA	--	--	--	--	--	1.00	0.028	0.178	0.042	0.084
SC	--	--	--	--	--	--	1.00	0.109	0.019	-0.001
IC	--	--	--	--	--	--	--	1.00	0.223*	0.079
FS	--	--	--	--	--	--	--	--	1.00	0.108
AE	--	--	--	--	--	--	--	--	--	1.00

N= 56, * p < .001

Using a p-value less than 0.05 (5% significance level) and only considering correlation relationships with $r > 0.2$ (i.e. factors at least having a moderate association), then we can make the following observations:

- With *academic integration (AI)* as the independent variable, the results show that *institutional commitment (IC)* and *financial stress (FS)* have the strongest impact on *academic integration (AI)* based on the threshold criteria$(p < 0.05)$ and $r > 0.2$. In some sense, a student's academic integration into their engineering program can be "moderately associated" with their commitment to the institution and their level of financial stress.

- With *institutional commitment (IC)* as the independent variable, the results show that FS has the most impact on IC based on the threshold criteria($p < 0.05$ and $r > 0.2$). In other words, a student's commitment to their institution can be "moderately explained or associated" with their level of financial stress.

For $p < 0.001$ the correlation data suggests that the *academic integration (AI)* may be very weakly correlated with the following additional factors: *social integration (SI), collegiate stress (CS)* and *academic motivation (AM)*. Furthermore with this p-value, we can be assured of the differences not being due to chance and are statistically significant.

Scatterplots help to determine linear relationships between variables. If there is a pattern or clustering, then regression analysis can be used to gain more insight to the type of relationship between variables. Based on the correlation matrix, graphical descriptions of correlated factors were plotted and no linear relationship could be observed from the data.

Limitations of the study

The results of this study are limited. The first limitation is that the data represents a small subset of the ECE population though the sample is diverse and is thought to be an accurate representation of the demographics of the entire ECE population. Another limitation of this study is that since it was completely anonymous the item-responses cannot be disaggregated to observe results by demographic groups. This limits the understanding of how non-academic factors may impact the persistence of underrepresented groups. Additionally, researchers used the Pearson Method for calculating intercorrelations between bivariate data. This method is commonly used for normal data and assumes a linear relationship between two variables. However, for highly-skewed data it may be ineffective in revealing patterns for other underlying relationships that may exist in the data[23]. More investigations should be performed to determine the validity of using the Pearson Method for this type of data set. Furthermore, this study relies on self-reported survey data. Despite some challenges to internal validity, self-reports are widely used in educational research and are generally considered valid if the information requested is known by the respondent, if the questions are phrased clearly, and if students deem the question worthy of a response[19].

Future Work

The current research describes a preliminary study of primary factors impacting the persistence of pre-engineering program completers with a diverse population as noted in previous work [17] as a limitation. This data can characterize a model of student success in the Electrical and Computer Engineering program. In this study as well as in previous work [17] the CPQ-TV3 permits institutional administrators to determine which variables have the greatest impact on persistence at their school. While the present correlations do not take the interrelations among predictor variables into account, persistence in major and retention may be affected by a collection of variables. These variables will need to be delineated in future work with a sample of underrepresented students at the present institution. Doing so will assist in gaining a broader perspective on persistence as administrators determine which variables need focus in any intervention programs.

More research must be conducted to evaluate the profile of an incoming ECE freshmen pre-engineering student relative to this successful student model to be able to identify at-risk students and implement early intervention strategies to help maximize student success.

Conclusions

In this paper, a research study that identifies primary non-academic factors impacting student persistence in an Electrical and Computer Engineering program is presented. Quantitative data collection methods were used and analyses were conducted using descriptive and inferential statistics. Based on the results, institutional commitment and financial stress are the two persistence factors that are moderately correlated with academic integration at a high level of confidence. This result suggests that a student's academic integration into the learning environment may be affected by their commitment to their institution, as well as the level of their financial stress. While the variables studied have been shown to be related they are not predictive in this present study. These variables will need to be delineated in future work with a sample of underrepresented students at the present institution. Clearly, these results warrant further investigation to gain deeper insight into persistence factors of engineering students.

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