AC 2007-1441: FOUNDATIONAL PREDICTORS OF SUCCESS IN THE COLLEGIATE ENGINEERING PROGRAM

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Foundational Predictors of Success in the Collegiate Engineering Program

Abstract

Several engineering and education faculty at Virginia Tech received a Department Level Reform (DLR) grant from NSF in 2004 to reformulate Freshman Engineering (also called General Engineering (GE)) and Bioprocess engineering using a spiral approach. The Office of Academic Assessment assisted the DLR investigators with the development and implementation of an assessment component of the DLR project for continuous improvement of the GE program. A central element of this component was a series of targeted assessments designed to identify predictors of success in the freshman year as well as ways to improve the curriculum. Beginning in fall 2004, data was gathered using: i) New Student Survey, ii) Learning Styles Questionnaire, and iii) Programming concepts test as a part of a GE course called "Engineering Exploration EngE1024." About 3000 engineering freshmen have participated in these surveys during 2004-06. A series of regression analyses were conducted to explore what factors predicted success for fall 2004 cohort, represented by the final semester grade in first engineering course (EngE 1024), cumulative GPA, and engineering retention two years later (i.e., end of spring 2006 semester). Results revealed that learning style preferences and demographic variables had a minimal influence on EngE1024 grade. SAT scores and programming concepts post-test scores were the best predictors of course grade. The paper also presents results related to the impact of prior college experiences on engineering major retention rates.

1. Background and Purpose

A new Department of Engineering Education (EngE) was created within the College of Engineering (COE) at Virginia Tech in May 2004 to improve engineering pedagogy. The EngE is responsible for conducting a year long freshman engineering program (also called General Engineering (GE) program). Approximately, 1200 engineering freshmen join GE program every year. Another primary mission of the EngE department is to carry out rigorous research in the area of engineering education and support the research agenda as brought out in the October 2006 issues of the Journal of Engineering Education [1]. Such rigorous research efforts in "engineering education" require collaboration between engineering and education faculty within and outside the university. A NSF supported planning grant under "Bridges for Engineering Education" program laid the foundation of engineering-education collaboration at Virginia Tech [2]. One objective of the planning grant was to create a contemporary framework for undergraduate engineering pedagogy, beginning with freshman engineering experiences. The investigators of this planning grant (engineering and education faculty) proposed to reformulate engineering curriculum using a spiral approach. This approach is adopted in a 4-year (2004-2008) implementation grant under a Department-Level Reform (DLR) program of the NSF (hereafter referred to as DLR project). As part of the DLR project, a number of EngE faculty members are collaborating with faculty from other engineering departments and the School of Education to reformulate the freshman engineering program within the EngE and the bioprocess program within the Biological Systems Engineering (BSE) department using a theme based spiral curriculum approach [3]. One of the objectives of the DLR project is to develop a continual assessment plan to measure the impact of the reformulated curricula, faculty improvement activities, and student learning. To accomplish this, the DLR investigators are collaborating with the Academic Assessment unit at Virginia Tech to develop and implement various formative and summative assessment tools. This paper will provide a brief description of the assessment tools and procedures. Further, analysis of assessment data is presented to identify and highlight predictors of success in the engineering program. A brief review of relevant literature is presented before discussing assessment data, analyses, and results.

2. Literature Review

Within the field of engineering education there has been prior work [4] that has examined predictors general academic success. For example, Besterfield-Sacre, Atman, and Shuman (1997) conducted a study to predict first semester GPA and retention in the engineering program. They [5] developed a survey (Pittsburgh Freshman Engineering Survey) that assessed students' perception and attitudes towards engineering. Specifically, the survey asked about students' perception of the engineering profession, enjoyment of math and science courses, reasons for studying engineering, confidence in background knowledge, skills, and their ability to succeed in engineering. The survey was administered to freshman engineering students. Besterfield-Sacre et al. (1997) were interested in using students' perception towards engineering as well as academic factors such as SAT scores and high school performance in the prediction of first semester GPA. High school rank and merit scholarship award were the best predictors of first semester GPA. Perceptions and attitudes towards engineering were more important in the prediction of program retention. Specifically, students who expressed more negative views regarding engineering, less enjoyment of math and science, and lower confidence in their ability to succeed in engineering were more likely to leave the program. In another related study, Scalise, Besterfield-Sacre, Shuman and Wolfe (2000) developed a model to predict academic probation among first year engineering students. They [6] also found that student confidence in their engineering ability was an important predictor of success. Specifically, those students with less confidence in their engineering ability were more likely to be on academic probation after their first term. Heywood (2005) has presented an excellent summary of various studies, mainly in the U.S. and U.K., on significance of first semester/year, engineering attrition rates and strategies that enhance retention [7]. Taken together, these studies make clear that background and attitudinal factors can, in some instances, aid in the prediction of success among first-year engineering students. Particularly useful, however, would be data that could provide early warning of potential student difficulties as well as information about attitudinal factors that, if more broadly known, could increase the likelihood of success.

3. Assessment Measures in First Engineering Course (EngE1024)

Engineering Exploration (EngE1024) is a freshman engineering course that is mandatory for all incoming engineering freshmen at Virginia Tech. The DLR project investigators, in collaboration with the staff of Academic Assessment unit at Virginia Tech, developed/adopted a number of tools to assess learning outcomes and prior experiences of engineering freshmen in EngE1024 course. A brief description follows.

3.1 New Student Survey

The New Student Survey was developed by the DLR investigators representing several years of teaching experience. Since the fall 2004, this survey has gone through revisions, specifically, eliminating items with no variance. The New Student Surveys assesses students' academic background prior to enrolling in college as well as the kinds of experiences that they have had involving computers, mechanics, and automobiles. An example of an item from the New Student Survey is "Have you ever installed software on a personal computer?" This survey has been implemented in EngE1024 since fall 2004.

3.2 Learning Styles

This survey developed by Felder & Soloman [8] measures learning style preferences on four dimensions and has been implemented in EngE1024 since fall 2004. About 2,000 engineering freshmen have completed this survey at the time of this writing. Figure 1 shows the learning style preferences of engineering freshmen at the present college during last 2 years.

3.3 Programming Knowledge (Pre- and Post-test).

In fall 2004, object oriented programming (OOP) concepts were incorporated into EngE1024 for the first time due to the addition of the Computer Science department into the College of Engineering at Virginia Tech. An OOP software called Alice (www.alice.org) was adopted to cover basic OOP concepts. A programming concept test, primarily constructed by the developers of Alice software, was adopted in fall 2004 to examine students' knowledge of basic fundamentals of OOP.

In addition, a number of other assessment tools like e-portfolio [9], clickers [10], focus groups [11, 12], exit surveys, etc. have been implemented in EngE1024 course. The scope of this paper is, however, limited to analysis of data collected using the tools discussed in sections 3.1, 3.2, and 3.3 above to identify the predictors of success.

4. Assessment Procedure

At the beginning of the fall 2004 semester, engineering freshmen enrolled in EngE1024 were instructed to complete two surveys including the New Student Survey and Learning Styles Questionnaire on-line. The Web server of the Office of Academic Assessment hosted the New Student survey. Students completed the Learning Styles Survey online from a website devolved by the creators of the survey (http://www.engr.ncsu.edu/learningstyles/ilsweb.html). After approximately 10 weeks of instruction, students completed the programming concepts pre-test in class. Students took the same test (i.e., the post-test) five weeks later after programming instruction concluded.

The analyses relating to predicting engineering success come from the sample of first-year engineering students who started in fall 2004 semester. For the purpose of analysis, cumulative GPA and retention data were collected (from the Office of Institutional Research) at the end of spring 2006 for the same fall 2004 cohort.

5. Data Analysis and Results

5.1 Demographic Data.

The majority of the freshman engineering class is male (85%) and white (80%). In regards to prior background experiences, approximately 50% of the class has an engineer in the family and also has prior programming experience. In addition, the majority of students did not take any pre-engineering courses in high school. When asked to indicate all of the engineering majors they were interested in, many students selected mechanical engineering (53%), followed by aerospace and ocean engineering (40%), electrical or computer engineering (37%) and civil or environmental engineering (33%). In regards to learning styles, the majority of the students are active, sensing, visual, and sequential learners (see Figure 1)

For the purpose of this paper success in engineering program for fall 2004 cohort is defined using three factors: i) cumulative GPA after four semesters (i.e., spring 2006 semester), ii) course grade in the first engineering course (i.e., EngE 1024), and iii) engineering major retention. Retention in engineering program is interpreted as the retention in engineering program at the end of 4th semester (i.e., spring 2006) of a student. The data for the present study was analyzed using SPSS 11 for Mac OS X. Forced entry multiple regression analyses conducted followed the recommended procedure as described by Pedhauzer [13].

5.2 Cumulative GPA.

Regression analysis was performed to predict cumulative GPA at the end of 4th semester using SAT scores and course grade in EngE1024 as predictors. Together, SAT scores and course grade in EngE1024 (taken in fall 2004) explained approximately 55% of variance in cumulative GPA at the end of Spring 2006. That is, higher GPAs at the end of 4th semester were associated with higher SAT and course grades in EngE1024 in their 1st semester. Course grade alone accounted for 47% of the variance in GPA (see also Table 1). The introductory EngE 1024 course is a 2-credit course and the average number of credits completed at the end of the fourth semester is approximately 60 credits.

Table 1

Summary of variables predicting cumulative GPA after 4 semesters.

Variable	Beta	Sig.	R-Square
Step 1			
SAT	0.004	0.870	0.080
Step 2			
Course Grade in EngE1024	0.741	0.000	0.552

n = 878

5.3 EngE 1024 Course Grade.

Since course grade was a strong predictor of cumulative GPA, a series of regression analyses were conducted to explore what factors including prior experiences predicted course grade. First, factor analysis, using varimax rotation, was used to help identify related items and construct scales for the New Student Survey. Based on the observed patterns, four underlying scales were computed (by averaging responses across the items) from the New Student Survey items. Factor one ($\propto = .76$) was comprised of items related to computer knowledge (e.g., *Do you know what open source software is?*). Factor two ($\propto = .70$) contained items related to mechanical/automobile knowledge (e.g., *Have you worked on the engine or transmission of an automobile?*). Factor three ($\propto = .72$) included items regarding engineering-related high school course work (e.g., *Did you take a mechanical drawing or drafting class during high school*?). Finally, factor four ($\propto = .52$) was comprised of items related to time spent studying and reading (e.g., *How many hours a day did you spend studying?*).

First, regression models that included demographic variables, prior experiences, and learning preferences (see Table 2 for descriptive statistics) were tested. Gender and race (whites & minorities) were entered into block one, followed by learning style preferences (block two), and finally the New Student Survey factors (block three). Gender and race together were significant predictors of course grade. This prediction was primarily a function of race. White students performed better in the course than minorities. As a set the learning style variables were marginally significant predictors of course grade above and beyond race and gender. This was a function of the active – reflective dimension. Specifically, reflective learners had a significantly higher course grade than active learners. Lastly, the four factors from the New Student Survey were also marginally significant predictors of course grade. The only New Student Factor to approach significance was the factor pertaining to computer knowledge. Taken together, gender, race, learning style preferences, and prior experiences as measured by the New Student Survey only explained five percent of the variance in course grade (see Table 3).

Table 2

Descriptive statistics for course grade for by demographic variables

Variable	n	Mean	S.D.
Gender			
Male	617	2.767	0.684
Female	115	2.872	0.591
Race			
White	447	2.858	0.655
Minority	84	2.664	0.652
Learning Preferences			
Active	569	2.701	0.730
Reflective	270	2.830	0.687

Note[1]. Only demographic variables that resulted in significant differences are included in this table.
Note[2]. Course grade was converted into a 4-point scale analogous to GPA.

Table 3

Summary of demographic and background variables predicting course grade.

Variable	Beta	Sig.	R-Square
Step 1			
Gender	0.660	0.206	
Race	0.129	0.009*	0.018
Step 2			
Active - Reflective	0.111	0.019*	
Sensing - Intuiting	0.026	0.590	
Visual - Verbal	0.033	0.487	
Sequential - Global	-0.018	0.699	0.036
Step 3			
Factor 1: Computer Knowledge	0.086	0.089	
Factor 2: Mechanical Knowledge	-0.069	0.184	
Factor 3: Prior Course Work	-0.072	0.134	
Factor 4: Time	-0.065	0.191	0.054

n = 443; * Statistically significant

A second set of regression models were tested to examine how well programming knowledge and SAT scores predicted course grade. SAT scores were entered into block one followed by programming pre- and post-test scores. SAT scores were significant predictors of course grade. Programming scores also explained a significant amount of variance beyond SAT scores. This was primarily a function of post-test scores. Students with higher programming post-test scores were more likely to do better in the course than students with lower post-test scores. Taken together, SAT and programming scores explained approximately 24% of the variance in course grade (see Table 4).

Table 4

Summary of quantitative variables predicting course grade.

Variable	Beta	Sig.	R-Square
Step 1			
SAT	0.359	.000*	0.202
Step 2			
Programming Pre-Test Score	0.053	0.162	
Programming Post-Test Score	0.194	.000*	0.243

n = 689; * Statistically significant

5.4 Engineering Retention.

Additional analyses were also conducted to examine what factors influenced engineering retention. That is, are there any specific background factors or prior collegiate experiences that relate to engineering retention rates? Again, for the purpose of this analysis a student is considered as “retained” in engineering if she/he was enrolled in the engineering program after the 4th semester of enrollment. Approximately 9% of the 1170 freshman students that completed EngE 1024 in the fall 2004 semester were no longer considered engineering major by the end of the spring 2006 semester. Due to small number of students who switched majors (approximately 100) and the significant amount of missing data on the New Student Survey, discriminate function analysis or logistics regression could not be conducted. Therefore, chi-square analyses were conducted on many of the individual items on the New Student Survey that were hypothesized to influence retention.

The strongest background predictor of engineering retention after four semesters was experience repairing an electronic device other than a computer. Specifically, students who indicated in their New Student Survey that they had not repaired an electronic device other than a computer prior to college were more likely to dropout of the engineering program than students who had such experiences. Some prior experiences with computers also influence retention rates. In particular, students who had no experience with DOS and did not know how to write computer programs were more likely to leave the engineering field than students who had worked with DOS and were able to write computer programs. Also, students who had worked with an engineer were less likely to drop out of engineering than students without such engineering related work experience. A list of the background variables that resulted in significant differences can be found in Table 5. There were also three quantitative variables that predicted engineering retention. SAT, programming post-test scores, and EngE 1024 course grades were significant predictors of retention. Specifically, students with higher SAT ($t\,(1128) = 2.84$, $p < .01$), programming post-test scores ($t\,(838) = 2.19$, $p < .01$) and EngE 1024 course grades ($t\,(952) = 4.85$, $p <. 01$) were more likely than students with lower SAT, programming post-test scores, and course grades to still be an engineering major.

Table 5

Background variables influencing retention

Variables from New Student Survey	Pearson Chi-Square	Sig.
Knowledge of writing computer programs	4.227	0.049
Repairing electronic device other than a computer	12.569	0.001
Replaced a fuse or reset a breaker	6.749	0.014
Worked on engine or transmission	4.813	0.031
Worked for an engineer	4.217	0.040
Math Level: Calculus I or higher	9.768	0.006

Note. Approximate sample size for variables is around 800.

6. Summary

Course grade in the first engineering class was the strongest predictor of cumulative GPA for engineering students after four semesters. As can be recalled course grade explained nearly 50% of the variance in cumulative GPA four semesters later. The regression analyses pertaining to course grade suggested that background factors and learning styles have only a minimal influence on success in an introductory engineering course. Programming post-test scores and SAT were much stronger predictors of course grade than any of the background or demographic variables. This information suggests that students can be successful in engineering despite a lack of prior relevant experiences (e.g., programming knowledge, engineering family member, developing a website, pre-engineering courses) before college.

The retention results reached a different conclusion regarding the influence of the background variables. Here, background experiences related to computers, mechanics, and prior course work (specifically math) did account for differences between students who decided to stay and leave engineering. In addition, quantitative variables also had a strong influence on engineering retention rates. Specifically, SAT scores, programming knowledge, and course grade in the introductory course all impacted student decisions to stay in the engineering domain. This paper highlights some specific variables that influence success in undergraduate engineering programs. Knowledge of such variables can aid in intervention efforts.

The authors now have access to data collected in each of the last three fall semesters (i.e., 04-06). Similar analyses will be carried out for the next classes to ascertain the predictive power of grade received in first engineering course. Also, the analysis will be updated for the cohort in this study to validate the variables influencing success (i.e., GPA) at the end of their engineering program.

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Figure One. Learning Style Preferences – Engineering Freshmen at Virginia Tech