Using the CIRP Survey to Develop a Strategy for Engineering Student Success

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Abstract - **Too often student surveys are conducted with minimal improvements in practice, yet surveys are a very powerful tool for continuous improvement in engineering student retention. In particular, surveys related to the characteristics of incoming freshmen have been shown to define both the attitudes and academic preparation of engineering students. However, there has not been consistency in the practice of engineering education in using these surveys to develop improved strategies for engineering student success.**

This paper will discuss a nine-pillar framework for freshman engineering academic success and retention combining the UCLA CIRP (Cooperative Institutional Research Program) survey with typical admissions measures. The significance of this research is that this engineering education literature-based framework has sufficient flexibility to be used by any engineering college. In a case study, steps in using the CIRP survey will be defined. Significant factors for freshman student success and retention including preparation in quantitative skills and confidence in quantitative skills will be discussed. Participants will leave with a framework for using the CIRP survey in an assessment of their incoming freshmen and a strategy for continuous improvement based on this assessment.

Index Terms – CIRP Survey, Engineering Retention Model, Framework for student success

INTRODUCTION

Often, to find out more about students' attitudes or preparation for the first year of engineering, a student survey will be conducted. Yet, to get the full benefit of the survey, it is not sufficient to simply present the results at a faculty or staff meeting. The faculty of an engineering college must provide the leadership to improve an approach to student success programs such as mentoring and tutoring and engaging first-year students in their learning processes in engineering.

In quality engineering, the Deming/Shewhart PDSA Cycle of Plan-Do- Study –Act is often used. Consider the use of a survey in the context of improving student retention. The PDSA cycle is a simple feedback loop that assures continuous improvement in the process. In this case, Plan and Do refer to conducting a survey, Study refers to studying the results of the survey and deciding what information helps us change a systems approach to student retention. For example, is there is gap in the perceived and actual preparation level of students being admitted to an engineering program? How can current academic programs be modified to improve freshman retention based on the knowledge of a gap in preparation level? Although preparation level is often discussed as an issue related to student success, it could be other student characteristics such as motivation or need for financial aid that are issues preventing a high student retention.

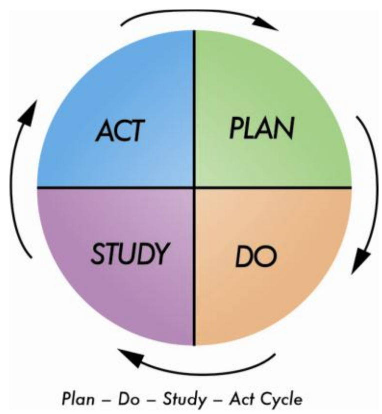

Figure 1

What is needed is a framework around which the issues of student success and retention can be discussed. Such a framework will be discussed in this paper. Once a framework is established, then significant factors can be determined and the PDSA Cycle can be applied to the significant factors. Although preparation levels are often important, the factors that are significant can vary with the engineering college.

In this paper, the UCLA/Higher Education Research Institute's (HERI) Cooperative Institutional Research Program survey (hereafter referred to as the CIRP survey) in combination with ACT component scores and high school GPA and class rank will be used as input to a nine-pillar framework for freshman engineering academic success and retention. A current CIRP survey is shown in [1]. Survey questions from the CIRP survey will be suggested for each of the nine pillars for engineering student success, including a pillar for quantitative skills and a pillar for confidence in quantitative skills. From this, recommendations for a factor analysis for each pillar and an overall regression analysis using the factors for each pillar will be discussed. In this discussion a case study using data from the freshman classes from the University of Michigan will be used.

In the broader picture, this paper attempts to address some of the issues of research in engineering education such applying the results of a retention study to the practice of engineering education in the context of continuous improvement of the educational processes. Beginning with a framework and discussing its use with a case study, suggestions for acting on the assessment and implementation of a multi-year approach will be discussed.

LITERATURE REVIEW

W. Edwards Deming recognized the need for a theory. He wrote, “Without theory, experience has no meaning”. [2] A number of education scholars have developed a theory of student retention, the most prominent being the research of Tinto and Astin. [3] [4]. In the engineering education field, the Adelman path model and the Watson and Froyd Transmission Line model are examples of relevant theories or models that have been proposed for engineering student retention.[5] [6] .

The 1992 Astin and Astin study was the first major research to identify significant factors for retention of engineering students [7] and used the CIRP survey. Most subsequent student retention research using the CIRP survey is for general college retention. Recent examples are the research of Oseguera [8] and Sax [9]. In the engineering education field, the Seymour and Hewitt study included results from a CIRP survey. [10] Shuman et al. used the CIRP variables to model student academic success and Nicholls used the CIRP survey to identify predictors for STEM retention versus non-STEM retention. [11] [12]. Veenstra, Dey and Herrin [13] summarize the engineering education research that identifies significant predictors for academic success and retention.

A FRAMEWORK FOR ACADEMIC SUCCESS AND RETENTION

The nine-pillar framework or model for freshman retention is based on Tinto’s Interactionalist theory which is extended to the freshman engineering experience. Reference [13] describes the framework as a model for freshman engineering retention. Literature from both engineering education and general college education research were reviewed to develop this framework. The nine-pillar framework is presented in Figure 2.

In the development of the nine-pillars, support for the Quantitative Skills and Confidence in Quantitative Skills pillars were specific to the engineering education literature. [13]. In this article, an extensive literature review of factors for freshman academic success (GPA) and retention are also presented.

With this nine-pillar framework, an overall conceptual model for freshman engineering retention, modified from Tinto’s theory for college retention, can be described (see Figure 3).

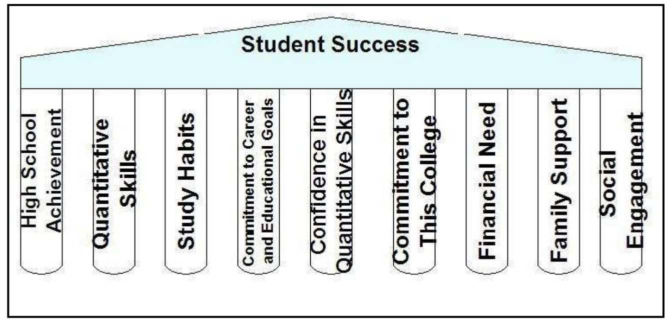

FIGURE 2
NINE-PILLAR FRAMEWORK FOR STUDENT SUCCESS

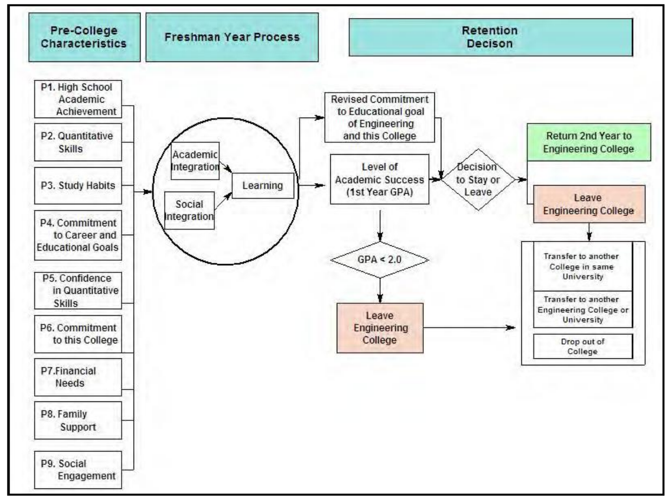

FIGURE 3
CONCEPTUAL MODEL FOR FRESHMAN ENGINEERING RETENTION (ADAPTED FROM [14])

THE CIRP SURVEY

The CIRP Freshman survey is administered by the UCLA Higher Education Research Institute. It was initially developed by Alexander W. Astin and Helen S. Astin and their research team and has been continuously used for over 40 years old. The CIRP survey is considered the leading national freshman survey in the U.S. It is administered to college freshmen during freshman orientation and documents “the changing nature of students’ characteristics, aspirations, values, attitudes, expectations and behaviors”. [15]

With the breadth of questions in the four-page survey, there is a wide selection of questions that can be applied to each of the nine-pillars in the student success framework. In addition, to the CIRP questions, the ACT components scores, the high school GPA and class rank, and college placement math and chemistry scores were included as appropriate data to describe the nine pillars associated with the framework. In all, 59 variables were included, with 54 of these variables from the CIRP survey. Table 1 lists the set of freshman pre-college characteristics that were considered for each of the pillars of student success.

TABLE 1
FRESHMAN CHARACTERISTICS

P1. High School Academic Achievement
1. High school GPA*
2. High school class rank*
3. ACT composite*
4. Self-rating of academic ability
5. Self-rating of cooperativeness (d)
6. Self-rating of leadership ability
7. Self-rating of writing ability (d)
8. Self-rating of self-confidence (intellectual)
P2. Quantitative Skills
1. ACT math score*
2. ACT science score*
3. UM math placement test score *
4. UM chemistry placement test score *
P3. Study Habits
1. Hours per week in the past year spent on studying/ doing homework
2. Hours per week in the past year spent talking to teacher outside of class
3. Hours per week in the past year spent reading for pleasure (d)
4. Frequency of using the Internet for research or homework(d)
5. Frequency of studying with other students
6. Frequency of asking a teacher for advice after class
7. Frequency of tutoring another student (d)
8. Frequency of coming late to class
9. Frequency of feeling overwhelmed by all a student had to do
10. Importance in deciding to go to college: to learn more about things that interest me (d)
11. Chance in the future to communicate regularly with your professors
P4. Commitment to Career and Educational Goals
1. Highest academic degree that you intend to obtain
2. Importance in deciding to go to college: to get training for specific career
3. Importance in deciding to go to college: to prepare myself for graduate or professional school
4. Importance in deciding to go to college: to be able to make more money
5. Chance in the future to change major field
6. Chance in the future to change career choice
7. Self-rating on drive to achieve (d)
8.Importance of making a theoretical contribution to science (d)

P5. Confidence in Quantitative Skills
1. Self-rating of computer skills
2. Self-rating of mathematical ability
3. Self-rating of creativity (d)
P6. Commitment to this College (U-M)
1. What choice is this college?
2. To how many other colleges other than this one did you apply for admissions?
3. Importance of coming to this college: college has good academic reputation
4. Importance of coming to this college: college has good reputation for social activities
5. Importance of coming to this college: rankings in national magazine
6. Importance of coming to this college: college's graduates get good jobs
7. Importance of coming to this college: my relatives wanted me to come here (d)
8. Importance of coming to this college: offered financial assistance
9. Importance of coming to this college: not offered aid by first choice
10. Chance in future you will be satisfied with this college (d)
P7. Financial Needs
1. Concern about ability to finance college education
2. How much of first year's educational expenses are expected to be from loans?
P8. Family Support
1. Education level of father
2. Education level of mother
P9. Social Engagement
1. Self-rating of Self-confidence (social)
2. Hours per week in past year socializing with friends
3. Hours per week in past year playing video/computer games
4. Hours per week in past year partying
5. Hours per week in past year working (for pay) (d)
6. Hours per week in past year volunteer work
7. Hours per week in past year student clubs/groups
8. Chance in the future you will join a social fraternity or sorority
9.Chance in the future you will play varsity or /intercollegiate athletics (d)
10. Chance in the future you will participate in student clubs/groups
11. Chance in the future you will participate in a study abroad program

The characteristics with an "*" indicates that they are non-CIRP survey student data. The characteristics with a "(d)" indicate that the characteristic was deleted in the factor analysis associated with the case study.

METHODOLOGY

Once the CIRP survey variables are chosen for each pillar, a factor analysis can be run including the pre-college characteristics for the data associated with the freshman class. Some pre-college characteristics will be found not to be contributors to the factor analysis and can be deleted from the factors. Once the factors have been established, regressions can be used for predicting the first year GPA, the most common measure for academic success and the retention rate. Because retention is a binary decision by the student (return, does not return), logistic regression is the most accepted approach to defining the factors for freshman retention. From Figure 3, it can be seen that there are three options for independent variables for predicting freshman engineering retention:

- Factors
- Individual pre-college characteristics associated with the factors or
- The first year GPA and student's revised commitment to an engineering career and college the student is attending

A CASE STUDY

Using the described framework with the CIRP survey for the 2004 and 2005 freshman cohorts at the University of Michigan College of Engineering, the described methodology was followed. Because both the SAT and ACT test scores are accepted for admissions, it was possible to include the ACT component scores. 76% of the students reported ACT test results. The limiting factor to a large sample size was the IRB requirement to obtain permission from all students to include their CIRP responses in the research. 75% of the students responded to the CIRP survey with an effective sample rate of 30% once permission was given for the combined two cohorts. The data from 184 students were included in the 2004 cohort regression analysis.

Reference [16] includes the details of the factor analysis and regression analyses for predicting the first-year GPA for engineering students. From the nine-pillars, 19 factors were generated. Table 2 summarizes the regression results using the significant factors for the first-year GPA. F4 has no CIRP variables and is based on the ACT Math and Science test scores and the math and chemistry placement tests.

To determine the significant predictors of freshman engineering retention, logistic regression is typically used since the dependent variable, retention is a binary variable, i.e. the freshman either returned or left engineering.

TABLE 2
RESULTS OF THE STEPWISE REGRESSION FOR GPA

Significant Factors	Coefficient	p-level
Constant	2.921	
F4 Quantitative Skills	0.233	0.000
F1 x F4 Interaction	0.205	0.000
F1 High School Grades	0.113	0.004
F11 Confidence in Quantitative Skills	0.096	0.017
F10 Career Goals	-0.087	0.019
Adj. R^2	0.38	

For the case study, the freshman (first-year engineering) retention rate was 93.9%. Logistic regression work best when the two groups are equally represented. In order to obtain a larger sample size for the students who left engineering, the 2004 and 2005 cohorts were combined. Based on the model in Figure 3, the first-year GPA was first used to predict the first-year engineering retention. The GPA was not a significant predictor. [13]. Due to the presence of missing data, it was difficult to use the factors in the logistic regression. As with any survey such as the CIRP survey, missing data can be expected. To reduce the amount of missing data and improve the prediction results, the original variables included in Table 1 were used as predictors in the logistic regression excluding the SAT and ACT test score variables. The total sample size was 735 students in the two cohorts, with 45 students who did not return to engineering after the first year. Table 3 summarizes the logistic regression from [3], p.188

TABLE 3
COLLEGE RETENTION STEPWISE LOGISTIC REGRESSION USING PRE-COLLEGE CHARACTERISICS

Predictor	Coefficient	S.E.	Wald	p-level
Constant	-6.020	3.132	3.694	
Math Ability	0.820	0.249	10.881	0.001
High School Rank	0.083	0.031	7.313	0.007
Concern about Finances	-0.717	0.267	7.197	0.007
Study Abroad	-0.500	0.189	7.001	0.008

. From these results, the logistic model for first-year retention, R, is:

$$\begin{aligned} \text{Ln}(R/(1-R)) = \; & -6.020 \\ & +0.820 * \text{Self-rating of math ability} \\ & +0.083 * \text{High School Rank} \\ & -0.717 * \text{Concern about Finances} \\ & -0.500 * \text{Chance to participate in a study abroad program} \end{aligned}$$

Due to missing data, the regression's sample size was 694. 71% of the 735 students were correctly classified as retained or students who left engineering.

A sensitivity analysis was conducted to predict the possible variability in the college retention based on variation in the four predictors. The resulting chart is presented in Figure 4.

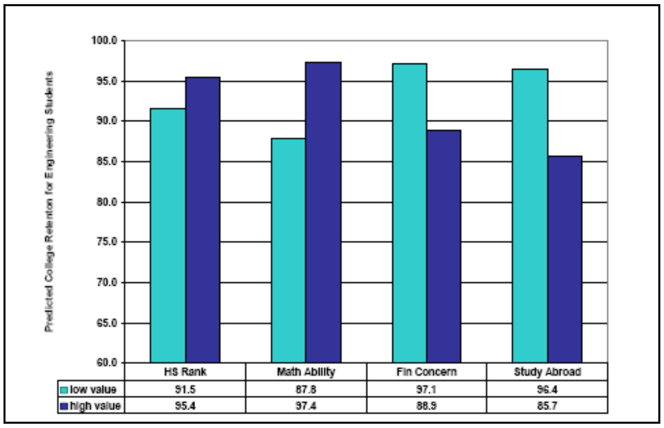

FIGURE 4
PREDICTED FIRST-YEAR ENGINEEING STUDENT RETENTION SHOWS A POTENTIAL VARIATION OF 88 TO 97%
(Adapted from [14])

DISCUSSION

A framework of the nine-pillars for student success and retention was presented with a case study. For the case study, Table 4 summarizes the presence of predictors for each of the nine pillars identified in Figure 2 and Table 1. Pre-college characteristics from six of the nine pillars were significant predictors for either the first year GPA or freshman retention for the freshman engineering students.

The mission and selection of students varies with each engineering college. It can be expected that there will be variation among engineering colleges as to the particular pillars that have significant predictors for academic success and retention.

In general, engineering students are some of the best high school students. Yet, at too many engineering colleges, the freshman retention rate can be less than 70% contributing to a graduation rate of less than 50%. This is occurring at a time when the engineering community and the national leaders recognize the need for more graduating engineers for placement in the workforce.

In the purview of continuous improvement, the results from the regressions can be used to analyze and plan for improved retention. For example, in the case study, as was showed in the literature review in [13], quantitative skills was a leading predictor of academic success. This is consistent with the purpose of engineering education to develop analytical thinkers. As many engineering colleges have done, an analysis determining the threshold for academic success using the ACT test scores and placement test scores could be conducted. The "Study" part of the

TABLE 4
SUMMARY OF ACADEMIC SUCCESS AND RETENTION RESULTS

Pillar	Predictor Present for Academic Success (GPA)	Predictor Present for Freshman Retention
P1. High School Achievement	X	X
P2/ Quantitative Skills	X	
P3/ Study Habits		
P4. Commitment to Career/Educational Goals	X	
P5. Confidence in Quantitative Skills	X	X
P6. Commitment to Enrolled College		
P7. Financial Needs		X
P8. Family Support		
P9. Social Engagement		X

PDSA cycle (see Figure 1) suggests that the gap between students who meet this threshold and students who don't be studied and an evaluation be conducted to determine what student success programs could be implemented to enable students below the threshold in quantitative skills to be successful and whether students the admissions requirements need to be revised. The "Do" part of the PDSA would then implement the recommendations of the "Study" results. This process could be conducted for each pillar that had significant predictors for academic success and retention.

In the second year, student success and retention could again be included in an assessment using the nine-pillar framework. An evaluation of whether the academic success and retention had improved would be conducted. Again, the question of the predictors for academic success and retention would be asked. This effort could be a continuous annual effort in retention improvement.

Because of the national use of the CIRP survey and the questions that are included in the survey, it lends itself to being used in the framework that is discussed in the paper. The framework is general enough that it also can be used for non-engineering STEM programs and general college retention. Examples are given in [14] and [16].

SUMMARY

With the current interest in the engineering education community to discuss best practices for moving research and scholarship to engineering education practice, a strategy is proposed for using a nine-pillar framework or model for freshman engineering academic success and retention for continuous improvement.

Often faculty counsel students that if they continue to study in the same way, they will get the same results; indicating to students the need to re-evaluate their study habits. Likewise, engineering colleges with low retention rates need to re-evaluate their admission and student support programs. No matter what the retention rate is, all engineering colleges are interested in improving their retention rate. The issue is the best way to do this. In this paper, one systematic approach using a framework based on the research literature is discussed. As has been shown with a case study, this framework can be useful in an assessment for significant predictors for academic success and retention. Because of the national presence of the CIRP survey and its wide range of survey questions that can be applied to engineering studies, its use is recommended and was discussed in this paper.

Often an engineering educator will conduct a one-year research study on engineering student retention and conclusions are drawn. This approach has enabled the engineering education community to understand the factors for student success. But for significant improvement in engineering student retention, all engineering colleges need to move to a continuous improvement approach. If the approach was modified to an annual study using the PDSA approach, where research findings are systematically used to improve the practice of engineering education, we would see more improvement in the national graduation rate of engineering colleges.

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