Using the CIRP Survey to Develop a Strategy for Freshman Engineering Retention

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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, more consistency in the use of surveys for the practice of engineering education is needed and could lead to improved strategies for engineering student success. This paper will discuss a nine-pillar model or framework for freshman engineering academic success and retention combining the UCLA/HERI 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. Using a case study, steps for using the framework will be defined and significant factors for freshman student success and retention 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, Freshman Engineering, Framework for student success, PDSA.

INTRODUCTION

A student survey will often be conducted to understand more completely freshman attitudes or preparation for the first year of engineering. Yet, to achieve the full benefit of the survey, it is not sufficient to simply present the results at a faculty or staff meeting. Faculty provides the leadership to improve a college's approach to student success programs and ideally, as a result of a survey, a faculty's discussion will lead to ideas and actions for improving student retention. This paper presents a survey-based framework that could help develop or refine a strategy for student success.

Inherent in the concept of the faculty's leadership is the idea of continuous improvement in student success year after year. From the quality engineering field and among some educators, the Deming/Shewhart Plan-Do- Study–Act (PDSA) Cycle has been used for continuous improvement (see Figure 1). PDSA is also referred to as Plan-Do-Check-Act (PDCA) [1].

Consider the use of a survey in the context of improving student retention. The PDSA cycle is a simple feedback loop that defines the continuous improvement 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 to change a strategy for student retention. Act refers to the actions and strategy taken by faculty to improve student success [1].

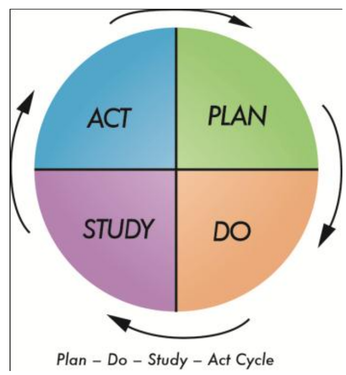

FIGURE 1

What is needed is a framework around which the issues of student success and retention can be discussed which can then provide a communication platform that engages faculty in a strategy for PDSA continuous improvement in student success.

Such a framework will be discussed in this paper. Once a framework is established, then significant factors can be determined and the PDSA Cycle for continuous improvement can be applied to the significant factors. Although preparation levels are often important, the significant factors may vary with each engineering college.

In this paper, questions from the UCLA/Higher Education Research Institute's (HERI) Cooperative Institutional Research Program survey (hereafter referred to as the CIRP survey and shown in [2]) in combination with ACT component scores and high school GPA and class rank will be used as input to a framework for freshman engineering academic success and retention. Survey questions from the CIRP survey will be suggested for this framework. A case study using data from the freshman classes at the University of Michigan will be discussed.

In the broader picture, this paper attempts to address the issue of 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 proposed.

LITERATURE REVIEW

W. Edwards Deming recognized the need for a theory before an improvement strategy can be implemented. He wrote, "Without theory, experience has no meaning" [3]. A number of education scholars have developed theories of student retention; the most prominent is the research of Tinto and Astin [4] - [5]. In the engineering education field, the Adelman path model and the Watson and Froyd Transmission Line model are examples of relevant theories or models for engineering student retention [6] - [7].

The 1992 Astin and Astin study was the first major research to identify significant factors for retention of engineering students [8] using the CIRP survey. Most subsequent student retention research using the CIRP survey is for general college retention. Recent examples are the research of Oseguera [9] and Sax [10]. In the engineering education field, the Seymour and Hewitt study included results from a CIRP survey [11]. 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 [12]-[13]. Veenstra, Dey and Herrin summarized the engineering education research that identifies significant predictors for academic success and retention including results using the CIRP and other surveys [14].

A FRAMEWORK FOR ACADEMIC SUCCESS AND RETENTION

Veenstra's research includes the development of a nine-pillar model or framework for freshman retention as shown in Figures 2 and 3 [14]-[15]. It is also referred to as the Veenstra model. As described in Veenstra, Dey and Herrin [14], it was concluded that Tinto's Interactionalist theory was the model best suited for statistical modeling. However, Tinto's theory is based on the entire undergraduate experience and a model for freshman engineering retention was desired. The nine pillars for the framework represent the categories of pre-college characteristics which were consistent with a literature review of significant predictors for academic success (GPA) and retention both for engineering students and general college students. Reference [14] describes the final nine-pillar framework as a model for freshman engineering retention. It includes extensive tables of a literature review for freshman and upper-class academic success (GPA) and retention for both engineering students and general college students.

With this nine-pillar framework, an overall conceptual model for freshman engineering retention, developed from Tinto's theory for college retention, can be described (see Figures 2 and 3). The pillars are also listed in Table I. 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 [14].

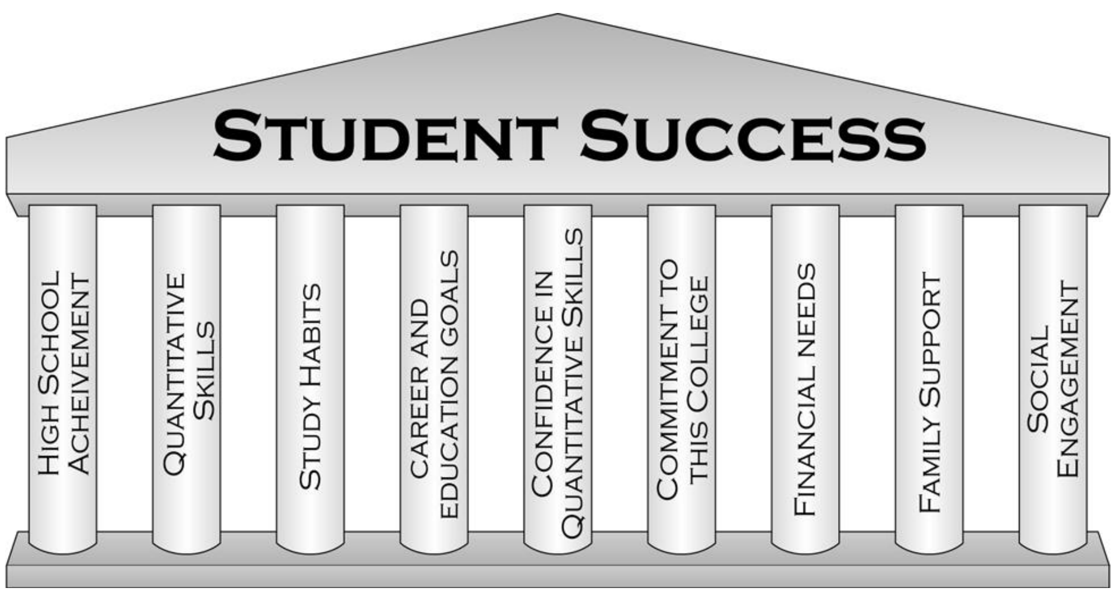

FIGURE 2
NINE-PILLAR FRAMEWORK FOR STUDENT SUCCESS
(ADAPTED FROM [14])

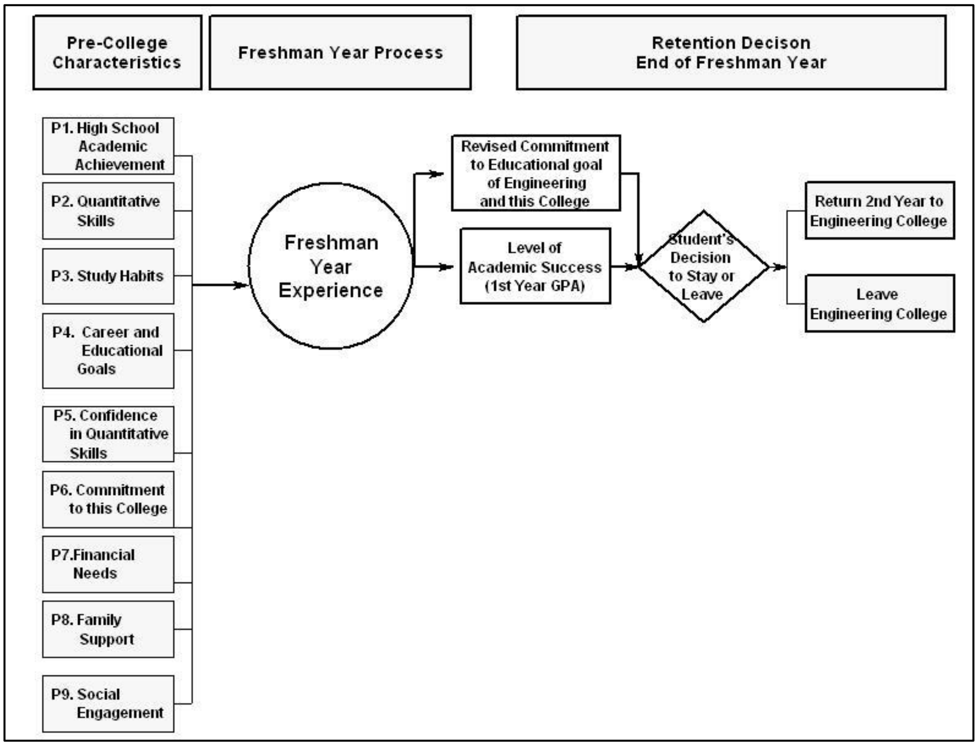

FIGURE 3
CONCEPTUAL MODEL FOR FRESHMAN ENGINEERING RETENTION USING FRAMEWORK (ADAPTED FROM [14] AND [15])

THE CIRP SURVEY

The CIRP Freshman survey is administered by the UCLA Higher Education Research Institute (HERI). It was initially developed by A. W. Astin and H. S. Astin and their research team and has been continuously used for over 40 years. The CIRP survey is considered the leading national freshman survey in the United States. It is administered to college freshmen during freshman orientation and documents "the changing nature of students' characteristics, aspirations, values, attitudes, expectations and behaviors" [16].

With the breadth of questions in the four-page survey, there is a large 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. As much as possible, variables were selected that were consistent with significant variables from the literature review. In all, 59 variables were included, with 54 of these variables from the CIRP survey. Table I lists the set of freshman pre-college characteristics that were considered for each of the pillars of student success. 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 [15].

METHODOLOGY (STEPS FOR USING THE FRAMEWORK)

Based on the Veenstra nine-pillar framework shown in Figure 2, appropriate CIRP variables can be chosen similar to the list in Table 1. After 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 run for predicting the first year GPA, the most common measure for academic success using the factors as independent variables.

Because retention is a binary decision by the student (return to or leave engineering), logistic regression is the most accepted approach for 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:

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

After the regressions are run, the significant factors can be reviewed and using the PDSA concept, the current

TABLE I
FRESHMAN CHARACTERISTICS USING THE CIRP SURVEY

Pillar 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)
Pillar P2. Quantitative Skills
1. ACT math score*
2. ACT science score*
3. UM math placement test score *
4. UM chemistry placement test score *
Pillar 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
Pillar 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)
Pillar P5. Confidence in Quantitative Skills
1. Self-rating of computer skills
2. Self-rating of mathematical ability
3. Self-rating of creativity (d)
Pillar 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)
Pillar 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?
Pillar P8. Family Support
1. Education level of father
2. Education level of mother
Pillar 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

Note: * denotes a non-CIRP survey characteristic
(d) denotes the characteristic was deleted in the factor analysis.

strategy for student success can be refined based on the significant factors from the regressions. In the second year, the regressions would be rerun and again, a PDSA analysis would be completed.

A CASE STUDY

Using the Veenstra nine-pillar framework with the CIRP survey for the 2004 and 2005 freshman class 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. Seventy-six percent of the students reported ACT test results. The IRB plan required student permission to include the students' CIRP responses in this research. Seventy-five percent 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 sample size for the 2004 cohort regression analysis was 184 using the ACT subset.

Reference [17] includes the results of the factor analyses and regression analyses for predicting the first-year GPA for engineering students. From the characteristics included in the nine pillars, 19 factors were generated. Table II summarizes the regression results using the significant factors for the first-year GPA. The first predictor, F4 Quantitative Skills includes no CIRP variables and is based on the ACT Math and Science test scores and the math and chemistry placement tests.

TABLE II
RESULTS OF THE STEPWISE REGRESSION FOR GPA

Significant Factors	Coefficient	p-level
Constant	2.921	0.000
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%. 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. a freshman either returned to or left engineering. Logistic regression works best when the two groups (stayers and leavers) are equally represented. To obtain a larger sample size for the students who left engineering, the 2004 and 2005 cohorts were combined. With the combined cohorts, the sample size was 735 students with 45 students who left engineering after the freshman year. Based on the overall model shown in Figure 3, the first-year GPA was first used to predict the first-year engineering retention and it was not a significant predictor [14]-[15].

It was desired to use the information about the leavers as much as possible in the logistic regression. Due to more missing data than desired for the factors in the group of leavers, the factors were not used in the logistic regression. (As with any survey, missing data can be expected.) To reduce the amount of missing data and improve the prediction results, the original variables (without factors) listed in Table I were used as predictors in the logistic regression excluding the SAT and ACT test score variables.

Table III summarizes the logistic regression from [15], p.187. Except for high school rank, the significant predictors are CIRP variables. While self-rating of math ability and concern about finances were consistent with the literature review, "chance in the future you will participate in a study abroad program" was unexpected.

TABLE III
COLLEGE RETENTION STEPWISE LOGISTIC REGRESSION
USING PRE-COLLEGE CHARACTERISTICS

Predictor	Coefficient	S.E.	Wald	p-level
Constant	-6.020	3.132	3.694	0.055
Self-rating of 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:

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

This prediction was considered successful with a sample size of 694. Using the regression equation (1), 71% of the combined freshman cohorts were correctly classified as stayers or leavers.

A sensitivity analysis was conducted to predict the possible variability in the college retention based on variation in the four predictors. The variability was defined by a low and high value for each predictor that encompassed 80-90% of the predictor's inherent variability. The resulting chart is presented in Figure 4 [15]. Thus, the variation in freshman retention can be estimated as 86% to 97% depending on the levels of the four predictors. With consistency from one freshman class to the next, an expected range on freshman retention is defined, not as a single number but as a variable range.

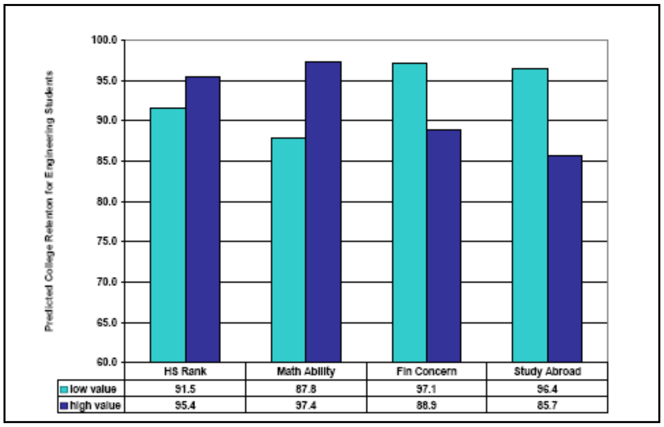

FIGURE 4
PREDICTED FIRST-YEAR ENGINEERING STUDENT RETENTION SHOWS A POTENTIAL VARIATION OF 86 TO 97 PERCENT [15]

DISCUSSION

The nine-pillar framework for student success and retention was presented with a case study. For the case study, Table IV summarizes the presence of predictors for each of the nine pillars identified in Figures 2 and 3 and Table I and they will be further discussed in this section. 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.

TABLE IV
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

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

Engineering students represent some of the best high school students. Yet, at too many engineering colleges, the freshman retention rate can be less than 75% contributing to a graduation rate of less than 50%. This is occurring at a time when the engineering community and national leaders recognize the need for more graduating engineers for placement in the workforce. At the same time, engineering colleges have a social responsibility to help admitted students become successful engineers.

More needs to be done than has been done in the past. Perhaps it is time to actively reconsider the success of quality engineering, the concepts of continuous improvement and the PDSA Cycle for higher education processes. Using the framework in Figure 2 and Table I, results from the regressions can be used to "Study" and "Act" for improved retention. For example, is there a 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? Are there other student characteristics such as motivation or financial aid that are influencing engineering student retention and what actions can be taken?

In the case study, and consistent with the literature review in [14], high school achievement (high school GPA and rank) and quantitative skills were leading predictors of academic success. The significance of F4 Quantitative skills is consistent with the purpose of engineering education to develop analytical thinkers [14]. 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 PDSA cycle (Figure 1) suggests that the gap between students who meet this threshold and students who do not meet this threshold should be studied. An evaluation would be conducted to determine what student success programs could be implemented to enable students below the threshold in quantitative skills to be successful. In addition, the admissions requirements may need to be revised. The "Act" 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.

Consider the predictors for retention (see Table III). This study showed a lower self-rating in math ability (in pillar P5) as students entered college contributing to attrition in engineering at the end of the freshman year [15]. Classroom and extracurricular activities that specifically build up confidence in mathematical skills could be included in a strategy for improved retention. The next significant predictor was high school rank; students with a lower high school rank were at more risk of leaving engineering. The "study" and "act" activities associated with PDSA could involve mentoring, tutoring and course placement programs that increase the academic performance (i.e. college GPA) of these students at a higher risk of leaving.

The third significant predictor was the CIRP-related variable "concern about finances" (in pillar 7) and is based on the question "do you have any concern about your ability to finance your college education?" This variable has three levels: none, some and major. The variation shown in Figure 4 represents the expected difference in freshman retention between students who responded "none" compared to students who responded "major". Obviously, the identification of students with a major concern about their finances and a consideration of scholarships, part-time campus jobs or grants may help these students in their path to graduation.

The last significant predictor for retention was "Chance in the future you will participate in a study abroad program." The response to this question includes four levels: no chance, very little chance, some chance and a very good chance. Its inclusion in the retention regression represents the interest that some students have in a study abroad semester with a lower retention rate for those students with a higher interest. More female students were interested in a study abroad experience than male students [15]. At this time when the studied cohorts would have completed their freshman year in 2005 and 2006, there was active campus discussion of study abroad programs. It was concluded that the variable was significant because there was a significant difference in the freshman retention rate among the four levels of the variable, with the lowest retention among the students who had the highest interest in studying abroad. One of the actions that would be considered in a PDSA cycle would be to review the study abroad options. Since this study, there has been an increase in the study abroad options in engineering.

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.

In this study, a freshman retention rate of 93.9% was reported for this study of the 2004 and 2005 freshman classes at the University of Michigan. Michigan Engineering is currently reporting an 80% 6-year graduation rate [18]. A graduation rate this high is possible due to a freshman retention rate over 90%. My research suggests this freshman retention rate is the result of a number of factors including the admissions criteria, the freshman engineering classes and student support activities. To maintain this retention rate, a paradigm of continuous improvement is needed.

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. Other surveys could also be used. The framework is general enough that it can also be used for non-engineering STEM programs and general college retention. Examples of non-engineering STEM and non-STEM freshman academic success and retention are given in [15] and [17].

SUMMARY

With the current interest within the engineering education community to discuss best practices for moving research and scholarship to engineering education practice, there is a demand for more effective strategies. A strategy is proposed for using the Veenstra nine-pillar framework for freshman engineering academic success and retention for continuous improvement. This strategy uses the very valuable information that can be gained from a student survey such as the CIRP survey.

One of points of this paper is that information from student surveys could be better utilized to improve student retention, especially when it is combined with a continual improvement paradigm such as the PDSA cycle.

With the national focus on increasing the number of engineers in the workplace, most engineering colleges are interested in improving their retention rate. One systemic approach using the nine-pillar framework based on the research literature was discussed. As has been shown with the 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, it is appropriate to use the CIRP survey with this framework, as discussed in this paper. Then from the assessment, the PDSA continuous improvement cycle can be used to develop an improved engineering student retention strategy.

Often a faculty member will conduct a one-year research study on engineering student retention and conclusions are drawn. This approach has enabled an engineering education community to understand the factors for student success. For significant improvement in the national engineering student retention, all engineering colleges need to move to a continuous improvement approach. If the current approach was modified to an annual study and review 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 freshman retention and graduation rates of students at engineering colleges.

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