Benchmarking Student Performance in Engineering: A Potential Technique for Identifying Factors Affecting Student Enrollment and Retention In Engineering Programs

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Abstract

In recent times, there has been an increasing emphasis on the performance of students in engineering. This has resulted in a considerable amount of research being done to analyze the performance of students in engineering, particularly at the freshman and sophomore levels. The objective of these research efforts has been to determine factors that may influence students to pursue engineering education or try something different. By determining these critical factors, researchers are hoping to make engineering education a more enjoyable and less tedious experience, thereby improving retention of students in these programs. The Foundation Coalition (FC) is one such research effort funded by the National Science Foundation (NSF). The FC consists of a selective set of students enrolled in the engineering program. These students are being provided with quality education in engineering by using various innovative teaching techniques identified by the National Science Foundation after considerable research. This paper examines this program by using the concept of Benchmarking, an industrial engineering concept, to compare performances, identify gaps between the comparison groups and determining the reasons for the existence of these gaps.

Introduction

It is common knowledge that engineering is a challenging field of study and requires considerable effort on the part of the students to successfully complete the degree requirements. However, it would be incorrect to say that engineering is an unduly tedious field of study, with no bright career opportunities. If such were the case, it would be difficult to explain why there are so many premier educational institutions, not only in this country but throughout the world, offering quality education in engineering. It would be even more difficult to explain the abundance of engineering jobs available today, with pay scales ranging from five to six figures.

It is discouraging that, despite these positive aspects, there has been a decline in student enrollment in engineering programs, and more alarmingly, a decline in retention of students in engineering programs. To give a clearer understanding of the extent of the problem, consider this fact: In 1975, attrition among engineering freshmen was about 12 percent; by 1990, freshman attrition had doubled and was over 24 percent[1]. According to Astin[2], only 47 percent of freshmen that start their academic career in engineering actually graduate with a degree in this course of study. Added to this, the fact that there has been a decline in engineering enrollment since the mid-1980s has further underscored the attrition problem[3]. This decline can be attributed to two major factors; decline in the college age population, and growing opportunities for careers in business and management but away from science and engineering[4].

Can anything be done to reverse this trend? There is a sense of urgency to solve this problem because the demand for engineering graduates is expected to rise by a sharp 25 to 30 percent by the end of the century[5]. In the hope of finding a solution, many premier institutions have designed various techniques to encourage student enrollment in engineering and subsequent retention. The Foundation Coalition (FC) is one such effort on the part of the National Science Foundation (NSF) to revive and retain student interest in engineering. To this effect, the FC has implemented a six-point program that has had reasonable success in retaining student interest in engineering and has also helped make the experience an interesting and educational one for the students. The six point program includes[6]:

- Curriculum Integration – Instruction which combines concepts from various courses into one course to assist student's understanding of relationships of material.
- Technology Enabled Learning – Promotes a through understanding of technology by using an assortment of software that would be needed in today's business world.
- Teaming – Faculty selects teams to create design projects. Within teams, students are assigned various roles to promote leadership qualities, as well as sharing of knowledge and cooperation.
- Tutoring – Provided by graduate students and able seniors to any student in need of assistance. Tutors communicate problem areas to faculty to improve quality of instruction.
- Innovative Design Projects – The students are assigned design projects that help them to better understand a subject, while at the same time making learning an enjoyable and competitive experience.
- Assessment and Evaluation – A process that allows the students and faculty to continuously evaluate themselves and each other, thereby creating room for improvement. It uses various methods of assessments such as the Force Concept Inventory (FCI) test and the Mechanics Baseline Test (MBT) to evaluate the performance of their students.

The success of this six-point program has led to a benchmarking exercise being performed at the College of Engineering, Texas A&M University-Kingsville. For more detailed information on the Foundation Coalition go to their web-site at **http://www.foundationcoalition.org**.

Methodology

In order to determine the success of the FC Program, a comparison had to be drawn between students belonging to the FC and students belonging to the Traditional Engineering Program. To maintain the integrity of the entire exercise, it was important to ensure that the students from the two comparison groups had similar backgrounds at the start of their engineering education. The Assessment and Evaluation Center of the FC at Texas A&M University-Kingsville identified a set of students in the Traditional Engineering Program with a background similar to that of the students enrolled in the FC. Once this had been done, the center also gathered relevant data necessary in comparing the two groups. This constituted the first part of the benchmarking exercise.

The second part of the benchmarking exercise involved comparing the performance of the students from each group after attending an entire school year. This data pertained to the students from the years 1995 through 1997. Statistical methods such as Chi-Square Test, t-test, ANOVA and Means were used to compare the performance of the two groups. The analysis data was carried out in two phases. Phase I involved establishing that the two groups were the same at the start of their engineering education. Phase II involved verifying if there was a difference in the performance of the two groups after a given time interval. It should be understood that there would be some merit to the benchmarking exercise if and only if the Null Hypothesis could not be rejected for all of the key factors during Phase I of the analysis.

Phase I

During the first phase of analysis, students belonging to the two groups were compared on the basis of the following factors: Gender, Ethnicity, SAT/ACT Scores, Rank/Percentile in High School, and High School GPA (HSGPA). The analysis was performed using the following statistical methods; Chi-Square Test and Fisher's Exact Test for non-numeric data (Gender, Ethnicity); t-Test, ANOVA and Means for numeric data (SAT/ACT, Rank/Percentile and HSGPA).

All the data was analyzed using a confidence interval of 95 percent. The proposed Null Hypothesis was: There were no significant differences between the two groups. The Alternate Hypothesis would of course state that there were differences between the two groups. The objective of Phase I was to not reject the Null Hypothesis.

The criterion for not rejecting or rejecting the Null Hypothesis is given below:

- If Prob. $|t| > 0.05$, not reject Null Hypothesis
- If Prob. $|t| < 0.05$, reject Null Hypothesis

The outcome of the Phase I of the analysis for the years 1995 through 1997 is shown in Tables 1, 2 and 3 respectively. As demonstrated in each of these tables, the Null Hypothesis was not rejected in each case. This would indicate that all the comparisons made between the two groups during Phase II of the analysis would be valid.

Table 1. Results from Phase I of Analysis (1995)

FACTOR	FC MEAN	TRAD. MEAN	PROB. |t|	DIFFERENCE
ETHNICITY	NA	NA	0.1733	Not Significant
GENDER	NA	NA	0.2081	Not Significant
SAT	960.455	965.652	0.8709	Not Significant
HSGPA	89.656	88.382	0.5509	Not Significant
RANK/PERC	0.784	0.773	0.8369	Not Significant

Table 2. Results from Phase I of Analysis (1996)

FACTOR	FC MEAN	TRAD. MEAN	PROB. |t|	DIFFERENCE
ETHNICITY	NA	NA	0.8689	Not Significant
GENDER	NA	NA	0.6749	Not Significant
SAT	1082	1063	0.6229	Not Significant
HSGPA	88.861	91.244	0.1866	Not Significant
RANK/PERC	0.740	0.785	0.3740	Not Significant

Table 3. Results from Phase I of Analysis (1997)

FACTOR	FC MEAN	TRAD. MEAN	PROB. |t|	DIFFERENCE
ETHNICITY	NA	NA	0.1749	Not Significant
GENDER	NA	NA	0.7644	Not Significant
SAT	1098.260	1081.030	0.5912	Not Significant
HSGPA	89.977	88.591	0.3521	Not Significant
RANK/PERC	0.814	0.736	0.1314	Not Significant

Phase II

Phase II of the analysis involved comparing the performance of students from the two groups on the basis of the following factors: Cumulative GPA (CGPA), Retention, Earned Hours in Math, Science and Engineering. The analysis was carried out using these standard statistical tests; t-Test, ANOVA and Means.

All the data was analyzed using a confidence interval of 95 percent. The proposed Null Hypothesis was: There were no differences between the two groups. The Alternate Hypothesis would state otherwise. The objective of Phase II was to reject the Null Hypothesis on the basis of as many factors as was possible, thereby establishing that there was a difference in the performance of the two comparison groups.

The criterion for not rejecting or rejecting the Null Hypothesis is given below:

- If Prob. |t| > 0.05, not reject Null Hypothesis
- If Prob. |t| < 0.05, reject Null Hypothesis

The outcome of the Phase II of the analysis for the years 1995 through 1997 is shown in Tables 4, 5 and 6 respectively.

These tables demonstrated that there was a significant difference between the two groups on the basis of Earned Hours in Engineering (1995), Earned Hours in Science and Retention (1996), Earned Hours in Science and Earned Hours in Engineering (1997), with the difference always favoring the FC. It is interesting to note that in 1995 the Traditional Mean for Earned Hours in Engineering was very small (0.6) but increased substantially in 1996 and 1997. This was many due to the lessons learned from the FC in 1995 that were carried over into the Traditional Program in 1996 and 1997. Furthermore, the difference between the two groups on the basis of the other factors such as CGPA, Retention and Earned Hours in Math, although not significant, is believed to be generally in favor of the FC, based on our own perceptions. The evidence to confirm this conclusion is incomplete and can not be proven until more data is collected. These results would certainly support the conclusion that the FC has been more successful in retaining student interest in engineering, while at the same time ensuring that the students make quicker progress towards the degree without compromising their grade point average.

These results have also helped to establish the fact that there was a difference in the performance of the students belonging to the FC and those belonging to the Traditional Engineering Program.

Table 4 - Results from Phase II of Analysis (1995)

FACTOR	FC MEAN	TRAD. MEAN	PROB. |t|	DIFFERENCE
CGPA	2.5185	2.6207	0.6773	Not Significant
RET_COE	0.6818	0.5217	0.2837	Not Significant
MATH EHRS	4.3333	3.6000	0.2568	Not Significant
SCI EHRS	7.1429	5.6000	0.2928	Not Significant
ENG. EHRS	**4.5714**	**0.6000**	**0.0001**	Significant

Table 5 - Results from Phase II of Analysis (1996)

FACTOR	FC MEAN	TRAD. MEAN	PROB. |t|	DIFFERENCE
CGPA	2.5107	2.2238	0.2268	Not Significant
RET_COE	**0.9167**	**0.6000**	**0.0093**	**Significant**
MATH EHRS	5.7500	4.4400	0.1830	Not Significant
SCI EHRS	**9.6250**	**4.7917**	**0.0003**	**Significant**
ENG EHRS	5.9583	4.6800	0.0606	Not Significant

Table 6 - Results from Phase II of Analysis (1997)

FACTOR	FC MEAN	TRAD. MEAN	PROB. |t|	DIFFERENCE
CGPA	2.0173	1.9332	0.7769	Not Significant
RET_COE	0.8261	0.7931	0.7698	Not Significant
MATH EHRS	4.3044	4.1379	0.7452	Not Significant
SCI EHRS	**9.7826**	**6.6207**	**0.0270**	**Significant**
ENG. EHRS	**7.6957**	**6.2069**	**0.0347**	**Significant**

Benchmarking

The presence of a gap in the performance provided the opportunity to benchmark the student performance in the Traditional Program against that of the FC. The purpose of this benchmarking exercise was to identify the reasons for the presence of this gap. By identifying these reasons, it was thought that changes could be made in the Traditional Program to help improve the performance and retention of these students.

This led to a thorough investigation and subsequent evaluation of the teaching techniques employed in educating the two groups. After thorough observation and comparison of program strategies, it was found that the difference in student performance could be attributed to the relative emphasis within the FC of the six point program consisting of:

- Curriculum Integration
- Technology Enabled Learning
- Teaming
- Tutoring
- Innovative Design Projects
- Assessment and Evaluation

While it could not be said that the six point program was completely absent from the Traditional Program, the emphasis of the Traditional Program on some or all of these aspects was weak. On the other hand, from these observations, emphasis within the FC of these points was a priority. A comparison of the FC and the Traditional Engineering Program was made. The preliminary comparison was made by highlighting the teaching techniques employed in educating the two groups. The second, more definitive comparison was made by assigning weights established by the FC members to the two groups on the basis of their emphasis on the six critical factors. The weighted comparisons are shown in Table 7. Depending on the weights assigned, the emphasis was further classified as being weak, moderate and strong.

Table 7 - Emphasis of the FC and the Traditional Engineering Program of Key Strategies

Factor	FC Emphasis	Weight	Trad. Eng. Emphasis	Weight
Curriculum Integration	Strong	9	Moderate	4
Technology Enabled Learning	Strong	8	Moderate	6
Teaming	Strong	9	Moderate	5
Tutoring	Strong	9	Weak	3
Innovative Design Projects	Strong	8	Moderate	6
Assessment & Evaluation	Strong	8	Weak	2
		Total = 51		Total = 26
Rating Scale: Strong: 8-10 Moderate: 4-7 Weak: 1-3				

Conclusions and Recommendations

As noted in Table 7, emphasis of the FC on the six critical strategies was strong. On the other hand, emphasis of the Traditional Program of these six strategies ranged from moderate to weak. It can also be recognized that there was considerable difference between the two groups based on the program's emphasis on Curriculum Integration, Tutoring and Assessment and Evaluation. The difference in emphasis on these factors, particularly Curriculum Integration, Tutoring and Assessment and Evaluation has helped the FC to assist and educate students more effectively. Therefore, increased emphasis of these strategies within the Traditional Program should certainly help to bridge the gap in performance.

The benchmarking exercise helped to fulfill two objectives. One objective was to support the recommendations, based on observations, to reduce the gap in performance. The other more important objective (although it could not be proven to be statistically significant due to a small sample size that ranged from 40-50) was to help improve retention in the engineering program, in our opinion. Additional research in this area should provide more answers to some of the questions facing the academic world, particularly in the field of engineering enrollment and retention.

This entire exercise was an example of internal benchmarking wherein two groups from within the same university and same department were compared to each other. The scope of such a benchmarking exercise can be increased by including more partners, preferably from different universities across the country. This would provide an ideal opportunity to analyze various factors affecting enrollment and retention of students in engineering programs. The advantage of a cross-institutional benchmarking exercise would lie in the fact that it would provide the opportunity to identify factors that commonly affect enrollment and retention in all the universities involved, and not just factors that are specific to a particular institution.

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