Longitudinal Analysis of Retention within Engineering

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Abstract
Reform across subject areas through curricular integration has overarching goals of achieving academic success and retaining engineering students. In an attempt to reform engineering education, seven institutions became part of the Foundation Coalition (FC) sponsored by the National Science Foundation. One method utilized by the FC member schools was to offer an integrated freshman or first-year program. Embedded within this innovative curriculum reform were seven student learning outcomes that were established in the FC's strategic plan and were implemented and measured across selected subject areas. The student learning outcomes were emphasized for high academic success, student retention, and professionalism. The learning outcomes were so important that the Foundation Coalition now uses three of the four as their core competencies. A core competency is defined by the Foundation Coalition to be "the abilities that we must develop, continuously improve and use in order to realize the overall mission and vision of the Coalition." (Foundation Coalition Strategic Plan Years 6-10) As a result of these strategies, retention for those students who participated in the FC programs has been consistently higher than the retention of those students in the more traditional engineering program. This report focuses on two very different participating member institutions and four of the student learning outcomes. The two universities, Arizona State University (ASU)-a flagship public university-and Rose-Hulman Institute of Technology (RHIT)-a small private engineering and science college-are two of the seven institutions that comprise the Foundation Coalition.

The Study
The purpose of this study is to provide, for anyone interested in improving student retention in engineering, an examination of data from contrasting institutions that implemented one of the FC Programs. As a result, it is possible to draw parallels between the two universities. Although the intricacies of curriculum design were different, the overall concept of the FC Program and assessment and evaluation methodology were common to both institutions in our study. The data from this research indicated that a program such as the FC can be implemented at different types of institutions with diverse student populations yet yield similar results. This report is from year five (5) of a 10-year plan to observe the quality of the FC program through analysis of student learning outcomes (also referred to as core competencies) and retention.

Background
The FC program is a self-selection program and is publicized through Freshman Orientation as well as in a mailing to entering freshmen who have indicated engineering as their chosen major. The courses selected for the curriculum are somewhat different for ASU and RHIT, but the

design is basically the same. At ASU, all FC students were engineering students who are required to take four specific core courses as a package, with no exceptions. These four courses now include: Introduction to Engineering Design, Calculus with Analytic Geometry, Physics, and First-Year English Composition.

RHIT had its beginnings with the first-year integrated curriculum during the 1990-91 academic year, however, RHIT's initial participation in the FC occurred during the 1993-94 academic year. At RHIT, the design of the FC curriculum is based on the tradition that the typical RHIT student takes 16-18 credit hours per quarter. Therefore, the FC course load consists of 12 credit hours per quarter encompassing nine one-hour sessions and three three-hour laboratory periods. In addition, FC students take an elective each quarter in humanities, social science, physical science, or life science. Also, RHIT FC included students in engineering and the sciences.

Based on the profile of the students in the FC group, a matched comparison group of freshmen students (called the non-FC group) was chosen at each campus. ASU selected its matched comparison group by sorting through the list of incoming freshmen students and selecting those who were: (1) enrolled as professional engineering students in one of the degree programs in the College; (2) taking at least the same course load as were the FC students (i.e., 13 hours or more); and (3) enrolled in at least three of the same courses in which the FC students were enrolled. Additional categories included high school GPA, SAT and ACT scores, and ethnicity. RHIT selected its matched comparison group based on a predicted index formula that included GPA, SAT scores, high school rank percentile, Force Concept Inventory (Hestenes, Wells, and Swackhamer, 1992), and Mechanics Baseline Test (Hestenes and Wells, 1992) scores. RHIT selects its matched comparison group for FC students during the Fall of the succeeding year after completion of the FC program. The two groups are then tracked on cognitive and attitudinal data, GPAs, and retention through graduation. ASU selects its comparison group after the 21st day of enrollment when drop/add is no longer a student-selected option.

Methods

ASU and RHIT shared common measurement instruments to facilitate a more cohesive analysis of student retention and performance data. However, the evaluation of these data incorporated quasi-experimental design and a multi method approach. During the 1994-95 academic year, the FC program provided an integrated curricular program to engineering freshmen for which the Assessment and Evaluation Team (A&E Team) began to collect data. The A&E Team is a national team made up of representatives from each of the participating institutions. The Team was charged to assess the FC program over a 5-year period by comparing FC students with a matched comparison group (non-FC students) using student outcomes, retention, GPA's and attitudes about engineering. The FC programs at both institutions were examined to capture short and long term effects, measured by cognitive and attitudinal data. Methods of assessment included: survey research, document review, and collection and analysis of student data.

Students completed surveys designed by the A&E Team that were administered periodically during the year to assess student attitudes about engineering. In addition, we administered the Force Concept Inventory (FCI) and the Mechanics Baseline Test (MBT). The purpose of the FCI is to help instructors discover and evaluate their students' commonsense beliefs regarding physics, identify serious problems regarding students' commonsense misconceptions that can effect their performance in introductory physics, and function as a probe of belief systems rather

than a test of intelligence. The MBT can be used to assess the students' abilities to apply the fundamentals of mathematics and science to solve problems in engineering and assesses the learners' understandings of basic concepts in mechanics, which are taught in introductory Physics. Both tests are multiple choice and were scored on a percent correct basis. Hestenes recommends that both tests be used with one another for optimal use of data results.

Results

The Coalition requires participating campuses to administer a standardized survey to exiting FC freshmen each year to acquire learning outcomes data. The FC student learning outcomes include teaming, technology, integration, and life-long learning. ASU measured these outcomes by administering two surveys. The first survey was an FC Exit survey designed by the A&E Team, and the second was a non-FC survey adopted from the FC Exit survey and approved by the Engineering and Applied Sciences College administration. RHIT measured the core competencies via the FC exit survey which was administered only to students who completed the FC program while an additional survey, referred to as the Sophomore Survey, was administered to both FC and the non-FC matched comparison groups. All surveys had a five-point Likert scale with 5 - Strongly Agree, 3 - Neutral and 1 - Strongly Disagree.

ASU ran non-parametric tests for special groups to examine differences between groups (i.e., gender and ethnicity) within the FC program, due to small sample sizes. RHIT ran the SPSS GLM Multivariate analysis to identify means and mean differences in addition to an independent two-tailed test of the means with a significance level of .05.

The data analysis revealed that the FC program for both institutions continued to meet student learning outcomes. In Year 5, the FC program was more effective in the utilization of technology at both institutions. More specific analysis of the data revealed that FC students at ASU felt more effective in curricular integration and the promotion of life-long learning than the comparison group, and RHIT FC students felt more effective in teaming than the matched comparison group. See Table 1 for the ASU results and Table 2 for the RHIT results.

Table 1
Four Student Learning Outcomes
Year 5 FC and non-FC Comparison
ASU

Special Groupings 4 Student Learning Outcomes	**FC (n = 50)**	**Non-FC (n = 25)**	**.05 Significance *p* value**
Technology	Mean = 3.80 SD = 0.3639	Mean = 3.40 SD = 0.6441	.0088
Curriculum Integration	Mean = 3.81 SD = 0.4020	Mean = 3.33 SD = 0.5538	.0001
Life Long Learning	Mean = 3.15 SD = 0.3884	Mean = 2.77 SD = 0.2926	.00001
Teaming	Mean = 3.82 SD = 0.4737	Mean = 3.69 SD = 0.6661	no significance

Table 2
Four Student Learning Outcomes
Year 5 FC and non-FC Program Comparison
RHIT

Special Groupings 4 Student Learning Outcomes	**FC (n =48)**	**Non-FC (n = 51)**	**.05 Significance *p* value**
Technology	Mean = 3.68 SD = 1.01	Mean = 3.39 SD = 1.08	.006
Curriculum Integration	Mean = 3.87 SD = 0.76	Mean = 3.70 SD = 0.96	.063
Life Long Learning	Mean = 3.31 SD = 1.14	Mean = 3.27 SD = 1.10	.716 (no significance)
Teaming	Mean = 3.67 SD = 1.06	Mean = 3.36 SD = 1.10	.005

When the ASU attitudinal and cognitive data were analyzed based on gender, data from both institutions revealed differences between FC groups. First, although not statistically significant, on average, male responses were more positive than female responses regarding teaming, the utilization of technology, integration of concepts, and life long learning. Second, two cognitive measures, the Force Concept Inventory (FCI) and the Mechanics Baseline Test (MBT), revealed gender differences as well. However, unlike the attitudinal measures, these cognitive differences were statistically significant. Both the pre- and post-FCI and MBT analysis indicated significant gender differences favoring the males.

Considering that RHIT admitted its first female cohort as full-time students in 1995, it is interesting to note that the attitudinal and cognitive data were very similar to that revealed in the data from ASU. Additionally, female students reported studying more hours than males and that the material in the FC program was presented too fast.

Retention

Longitudinal Retention Data for ASU:

The FC program retained more students, on average, over a four-year period (63%) than the non-FC group (56%). Although the FC program retained 82 percent of its students during Year 5 of the program, retention rates for years three and four brought the four-year overall average down. Additionally, the FC program retained more under-represented minorities (61%) than the non-FC group (58%) over the same period. However, the female retention rate was not as noteworthy. The overall female FC retention rate in the four-year period was 61 percent in comparison to 68 percent in the non-FC group. Although the FC program retained 92 percent of all females in Year 5, years three and four brought the overall average down. (See Table 3 for results).

Table 3
ASU Four-year Retention Analysis
FC and non-FC Comparison

Program	Total (n)	Fall 1998	Male	Female	White & Asian	African American	Hispanic	Native American
Total FC students	219	137 63%	111 63%	26 61%	110 63%	6 60%	18 62%	3 69%
Total Non-FC Students	183	103 56%	82 54%	21 68%	84 56%	2 50%	12 57%	4 67%

Longitudinal analysis of the data has shown that the FC program has continued to improve retention and student learning outcomes over the last four years. In fact, in Year 5 (1997/98), the FC program at ASU experienced the best retention rate for women and minority students since its inception and retained more of every group of interest than the comparison group of students as shown in Table 4.

Table 4
FC Year 5
Freshman Female and Minority Retention
College of Engineering at ASU

	Fall Enrollment 1997			Retained at the End of Spring 1998		
	Enrollment	Female	Minority	Enrollment	Female	Minority
ASU FC	78	15% (12)	23% (18)	82% (64)	92% (11)	77% (14)
ASU Non-FC	32	16% (5)	31% (10)	66% (21)	80% (4)	40% (4)

Number in parenthesis represents the number of students

Longitudinal Retention Data for RHIT:
Longitudinal retention of integrated-curriculum students at RHIT has been tracked since 1990 and their retention in comparison to non-FC students has resulted in a 5 to 20 percent difference in favor of the FC students. Although FC student retention has been greater than the retention of the matched comparison group, the difference has not been statistically significant. See Table 6. It is quite possible that this lack of significant difference between RHIT's FC and the non-FC comparison group of students is due to the length of time that faculty members utilized the FC concepts. The use of these concepts began with the inception of the integrated curriculum in 1990, and many faculty members who were FC instructors at some point over the past nine years have had the opportunity to incorporate into their instruction concepts that are consistent with the FC Program pedagogy.

Table 6
RHIT FC and Non-FC Retention Comparison 1994 - 1998

Group	Enrolled	Graduated < = 4 years	Graduated/Continuing Fall 1998
1994 FC Cohort	59	82.1% (46)	91.5% (54)
1994 Comparison Group	59	69.5% (41)	88.1% (52)
1995 FC Cohort	85	0.0% (0)	83.5% (71)
1995 Comparison Group	85	2.4% (2)	84.7% (72)
1996 FC Cohort	87	-------	93.1% (81)
1996 Comparison Group	87	-------	92.0% (80)
1997 FC Cohort	95	-------	88.4% (84)
1997 Comparison Group	----	-------	-------

Conclusion

The FC program has successfully raised student retention in the field of engineering when these rates are compared to national engineering retention rates. For example, less than 50 percent of engineering freshman persist to earn an undergraduate degree and most of this occurs during the first year (Besterfield-Sacre et al., 1997). Additionally, we typically find low numbers of female and minority graduates despite the thrust for increased recruitment for under-represented students. However, the FC continues to increase retention rates for both groups of interest.

After careful analysis of the multiple sources of data, it became evident that the perceptions and attitudes of engineering students are related to retention and differences across gender cohorts. It became obvious that the population of females, more neutral or negative towards program objectives and engineering in general, were less likely to persist in engineering.

The formative evaluation feedback has inspired and promoted program modification. As a result of the feedback, faculty and staff examined gender differences and determined strategic curricular and non-curricular actions to diminish learning and attitudinal discrepancies. The FC program faculty and A&E Team have incorporated multiple methods of measuring student achievement and have developed two original, discipline-based assessment measures. They are continuing to explore and use alternative assessment with formats other than multiple-choice tests (i.e., through the use of portfolios and journals), and are assessing competence in the four student outcomes: teaming, technology, curricular integration, and life long learning, through projects, self assessments, and observation. Additionally, the freshman program is continuing to promote active classroom learning, collaboration, and inquiry-based activities which encourage the participation of females and under-represented minorities (Hamilton, 1998; Entwisle et al., 1994; Resnick & Resnick, 1992)

The FC program, promoting team learning, course integration, and the utilization of technology, created a learning community and facilitated student retention. The assessment and evaluation feedback revealed that the combination of methods has enabled the FC program to retain more students (e.g., females and under-represented students) in Year 5 than in any prior year. The FC faculty and A&E team have worked collaboratively to determine and implement relevant strategies to minimize learning and attitudinal discrepancies in an effort to improve student satisfaction, outcomes, and retention.

References

Besterfield-Sacre, M.E., Atman, C. J., and Shuman, L.T. (1997). Characteristics of freshman engineering students: Models for determining student attrition and success in engineering. *Journal of Engineering Education*, 86(*2)*, 139-149.

Entwisle, D. R., Alexander, K.L., & Olson, L. S. (1994). The gender gap in math: Its possible origin in neighborhood effects. *American Sociological Review*, 59, 822-838.

Hamilton, L. S., (1998). Gender differences on High School Science Achievement tests: Do format and content matter? *Educational Evaluation and Policy Analysis*, 20(*3*), 179-195.

Hestenes, D. and M. Wells. (1992). A Mechanics Baseline Test. *The Physics Teacher*, 30, 159-166.

Hestenes, D., M. Wells, and G. Swackhamer. (1992). Force Concept Inventory. *The Physics Teacher*, 30, 141 158.

National Action Council for Minorities in Engineering (NACME) Research Letter, Vol. 7, No. 1, May 1997.

Resnick, L. B., & Resnick, D. P. (1992). Assessing the thinking curriculum: New tools for educational reform. In B. R. Gifford and M. C. O'Connor (Eds.) Changing assessments: Alternative views of aptitude, achievement, and instruction, 35-75. Boston: Kluwer.