An Assessment and Evaluation of an Integrated Engineering Curriculum

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Abstract

The objective of this paper is to report a comparative analysis of student performance in a Traditional Engineering environment with Foundation Coalition (FC) students over a six year period of time at Texas A&M University–Kingsville (TAMUK). The FC is an engineering coalition funded by the National Science Foundation (NSF). The purpose of this program is to provide a means of improving current engineering programs in order to produce quality students that can meet the changing and demanding needs of their future employers. This analysis makes use of data provided by the Assessment and Evaluation (A/E) team at TAMUK. A commitment was made by TAMUK, along with six other FC partner institutions, to thoroughly assess and evaluate the work of students to provide a foundation that would ensure student development and life-long learning in engineering education.

I. Introduction

This work makes use of data provided in the course of developing Assessment/Evaluation (A/E) results for the Foundation Coalition curriculum development research project at Texas A&M University-Kingsville (TAMUK). It is the result of a commitment made by TAMUK, together with six other Foundation Coalition (FC) partner institutions, to thoroughly assess and evaluate their work in providing a foundation that will ensure student development and life-long learning in engineering education[1]. The FC is an engineering coalition funded by the National Science Foundation (NSF). Coalition partners are: Arizona State University, Maricopa Community College District, Rose-Hulman Institute of Technology, Texas A&M University, Texas Women's University, and The University of Alabama-Tuscaloosa and TAMUK.

Assessment activities are being performed across university campuses to develop their own assessment instruments. These assessment processes have typically been implemented in a relatively short time within engineering programs due to the new ABET criteria 2000. The effects of these assessment programs have lead to program and/or curriculum changes altering conventional learning and teaching processes[2]. The prediction of student academic success in an engineering curriculum is a predicament at any university[3]. Student historical performance data has been used to train a neural network to predict the level of success (GPA) of students in engineering at TAMUK. The data was provided by the A/E for FC project at TAMUK[4]. The analysis found that neural network can be used to predict student academic success in terms of their GPA in the majority of the cases considered. This neural network system shows promise as a predictive modeling tool that can be used for assessment and evaluation purposes. It can help faculty advisors by; (a) identifying and monitoring potentially at risk students, and (b) improve the retention and academic performance of engineering students at TAMUK.

Another area of analysis regarding the assessment of students involves their ever-changing attitudes. Prior research has shown that attitudes of freshman engineering students change over the course of their first academic year. Therefore, assessment of both the attitudes that students bring into the university and the attitudinal changes that occur over the course of the year can provide an effective means to evaluate freshman-engineering programs[5].

II. Foundation Coalition at TAMUK

The FC Engineering Program at TAMUK offers unique opportunities for freshman and sophomore students. Participants develop the ability to work in teams, to use technology for the purposes of analysis, design and communication, and to use an engineering problem-solving methodology solving real-world problems. Students also learn to integrate concepts such as mathematics, science and engineering to design and test prototypes.

The FC Program at TAMUK provided an integrated curricular program to engineering freshmen during the 1994-98 academic years. The FC was publicized through recruitment, freshman orientation, university visitation and in mailings to entering freshmen who have indicated engineering as their chosen major. The College of Engineering and FC entering freshmen are required to have a minimum composite score of 21 on the ACT or 970 on the SAT. In certain situations, students not having the minimum scores for admission into the college may complete preparatory course work in the College I program as a pre-engineering major. The following year, 1995-96, the FC at TAMUK introduced the sophomore curriculum for first time. The following Assessment and Evaluation methodologies were introduced to measure the students' performance and attitudes with the goal to achieve the following[6]:

- Increased appreciation and motivation for life-long learning
- Increased ability to be an effective team member
- Increased oral, written, and graphical communication skills
- Improved ability to apply the fundamentals of mathematics and the sciences
- Increased capability to integrate knowledge form different disciplines
- Increased flexibility and competence in using modern technology

Another goal of the College of Engineering at TAMUK was to improve student retention in their engineering programs. The inability of universities to retain students in engineering programs has been a source of concern for many institutions. As noted earlier, a student's perception plays a key role for freshman in their desire to remain in a given engineering program. A number of models can be used to explore the link between a student's perception of the importance of knowledge and their success in engineering. For example, at TAMUK the Force Concept Inventory (see Figure 1), Mechanics Baseline Test and the Mathematical Background Test, to name a few, have been used by the FC for this purpose. Using surveys to poll students' attitudes toward engineering to help understand students' needs, then adapting the six-point program outlined by the NSF where needed[7]:

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

The College of Engineering institutionalized the FC into a base set of core courses in the fall and spring of the freshman year.

Table 1: FC Course Schedule

Freshman Curriculum	*Fall Semester – 15 Hours*	*Spring Semester – 17 Hours*
	Analytical Geometry – 3	Calculus I - 3
	Chemistry – 4	Chemistry II - 4
	English – 3	English - 3
	Engineering as a Career – 2	Physics I – 4 *
	Computer Based Graphics and Design I – 3	Computer Based Graphics and Design II – 3
Sophomore Curriculum	*Fall Semester – 17 Hours*	*Spring Semester – 17 Hours*
	Calculus II – 3	Differential Equations - 3
	Thermodynamics – 3	Electrical Systems I - 3
	Mechanics I (Statics and Mechanics) – 3	Mechanics II (Dynamics) – 3
	Physics II – 4 *	Core Courses – 8
	Business Communications – 3	
	EDKN, ROTC, Band - 1 **	

* Integrated Years 2-5, not Year 6
** Not Integrated

Traditional engineering curriculum covers various aspects of sciences and mathematics in separate courses from freshman year to junior year. The drawback of the traditional curriculum is that the students do not see how the concepts learned in engineering, mathematics and science courses apply to engineering problem solving till they reach senior level. An integrated engineering curriculum is designed to circumvent these drawbacks. In the integrated engineering curriculum developed at TAMUK, science and mathematics courses are closely tied to engineering courses.

III. Assessment & Evaluation Purpose and Design

The goals of the A/E Program are to gather information that serves to validate progress toward attainment of program objectives and to improve the overall effectiveness of the project by providing ongoing assessment. Qualitative methods such as focus groups, journals, and attitudinal surveys have been used throughout the existence of the project at TAMUK. Quantitative data related to student retention and performance between comparison groups has also served to assess the effectiveness of the program. The assessment staff actively seeks the involvement of faculty and administration in the planning, creation, interpretation and dissemination of FC assessment processes and findings. TAMUK is working to implement the best assessment and evaluation practices that can be adapted for classroom use. The information should serve to improve student learning with corrective feedback upon which they can improve their performance. The FC has maintained a comprehensive record of the history and performance of all of its students. The A/E Center gathers this data. The basis for collecting data used the following instruments:

- Freshman Assessment Tests and Surveys Results
- Assessment Tests
- Mechanics Baseline Test
- Force Concept Inventory
- California Critical Thinking Skills Test
- California Critical Thinking Disposition Inventory
- Assessment Surveys
- General Survey
- Communication Survey
- Teaming Survey
- Life Long Learning Survey
- Student Goals Survey
- Student Survey of Faculty Members
- Chemistry Bridge Survey
- Personal Progress Survey
- Exit Survey

The A/E Program at TAMUK had three main purposes:

1) To gather information for the evaluation of student learning, recruitment and retention of under-represented populations under the Coalition's programs
2) To gather information to provide faculty and administration feedback concerning the success of instruction and curricular strategies related to FC
3) To facilitate the gathering of information about faculty climate in order to facilitate change and program institutionalization.

The program has developed and implemented a plan that includes formative and summative measures, many of which are based on common assessment and evaluation methodology and processes across the FC sister institutions.

The A/E Center has also identified students from the FC with similar backgrounds to their traditional engineering program counterparts. The students meeting these requirements were designated as the comparison group (non-FC group) for the FC cohorts. The comparison group of freshman students was defined by sorting:

- A list of incoming freshman students selecting those who were enrolled as engineering students in one of the degree programs in the College;
- Had similar High School GPA or Rank %, and ACT/SAT Scores
- Enrolled in at least two to three of the same courses in which FC students were enrolled;
- Taking at least the same course load as the FC students (e.g., 13 or more hours);

- Percent distribution of gender and minorities were looked at as well.

In order to identify key factors that would impact and aid students to be successful in an engineering program at TAMUK, the analysis from the collected data needed to be analyzed using these comparison groups (see Figures 2 and 3 for examples of the FC & Traditional comparison). The analysis used various techniques such as chi-square Test and Fisher's Exact Test for non-numeric data, t-Test, ANOVA and Means for numeric data, and chi-square Test and Pareto Analysis for survey data to identify statistical significance.

IV. Lessons Learned and Outcomes

A number of lessons were learned over the six-year period that the FC was implemented. The following is a discussion of some of these lessons along with outcomes, but is by no means all-inclusive.

Typically, the students are required to take all courses as outlined previously in Table I, excluding the 1998 fiscal year, when the FC program was open to anyone who wanted to attend. In this case students did not participate in all FC courses, either because they chose not to or they had already taken the courses. In other cases, students may not have been academically ready to take certain courses and therefore did poorly. As a result, some students had difficulty in the teaming and integration part of the program since they did not take all the FC classes lacking necessary information or activities. In other situations students participated in class but claimed they did not know about FC integrated projects and tests. These situations resulted in mixed outcomes in the analysis in comparing FC and traditional students. On the other hand, when students were required to take all the courses needed it became limiting in two key ways:

1) Some students already had course credits in English, Math, Chemistry or Physics whereby they need not take all the FC courses; changing the effectiveness of an integrated curriculum
2) Some may demonstrate academic weakness in one or two areas, thus affecting their success.

Many of the assessment activities, as listed previously, included too many instruments for collecting data. Even though some instruments were combined, modified or removed, there still needs to be an overall reduction to be more efficient. The data gathering process should be communicated to students in a way so they will realize the importance and perform at their best. The faculty needs tools that are more relative to their experience consequently providing more useful information. The assessment tools need to be fully incorporated into the education process in a way that the students and faculty can derive meaning and purpose from them.

In an attempt to retain more students, both the first and second year reduced the number of core courses to allow student to take classes outside of the FC. Students were allowed more flexibility in the latter years by taking 13-17 FC hours. The students reported that they enjoyed being more in control of their schedules. Pizza socials were held to encourage dialogue between faculty and students and to recruit new students. Figure 4 illustrates the comparison of retention over the six-year period comparing FC to Traditional students in the College of Engineering at

TAMUK. From 1995, students noted basically the same reason on the exit survey for staying in the FC:

- The access to the computers, design projects
- The quality of teachers
- The one to one relationship between teachers and their students
- The friends-and-family-like atmosphere
- Teamwork enabled students to feel more comfortable when reaching out for help.

Software was found to be more meaningful as the students understood the principals behind the software. Early in the degree plan, particularly Math and Physics courses, students felt that some of the technology and teaming was beneficial, but preferred more of a direct teaching approach to learn the basics. Other examples of technology used by students in the first year program included: MAPLE (used for design projects, integrated exams and calculus), Microsoft Excel (Physics project), Word (Formal reports), Netscape (research and accessing old test), and AutoCAD (image projection).

Design projects were introduced in the first and second year of the FC to integrate the science/math courses with technology and English. The faculty found that a project needed to go through a series of process steps to ensure that the teams were on target in meeting their deadlines and fully understanding what they needed to do. Otherwise students tended to typically wait until the last minute to pull their projects together. The faculty was initially dissatisfied with the teams' design and presentations on their projects. Consequently, they required students to perform trial runs and then go back and modify their calculations based on experiments in the MAPLE software. As a result, a more successful design was produced for a follow-up test. The first year design projects included three key design projects, while the second year included four projects.

Based on the analysis of GPA, comparing FC to traditional students, there were mixed results as illustrated in Figure 5 demonstrating no consistent measure. However, when FC student performance was tracked in upper division courses in math, science and engineering, a remarkable trend was found. The final grades of the Second Year Integrated Curricula students were compared with traditional students enrolled in the same course, same professor, and same semester. In 15 out of 17 courses, FC students significantly out performed traditional students.

The FC Program has enabled more students who enroll in core engineering courses to complete them and perform better than their traditional counterparts. Gatekeeper courses such as Chem I and II, Physics I and II, and Calculus I are often dropped or failed by many students whereby they must take them two or three time as observed on their transcripts. Through the use of teaming, technology, integration, and ongoing assessment students are retained at a higher level in Foundation courses yielding a progress through the engineering curricula at a more rapid rate when compared to traditional students (Figure 6 is an example of results from Year 6).

IV. Conclusions

The outcomes of the FC and the A/E efforts have been very positive. The analysis of the data that was gathered by the A/E group indicated that there was a gap in the performance of the students belonging to the two comparison groups in favor of the FC. Even though there are mixed results, the overall conclusions are that the FC provided its students with a better quality of education resulting in higher CGPA, quicker progression in their degree plans, and higher retention in the College of Engineering at TAMUK. On the basis of the outcomes of the work analyzed by the FC and the A/E teams at TAMUK, it can be concluded that the six-point program implemented was successful in providing the students with a quality education in engineering. Based on analysis reported by other FC sister institutions, good results can be duplicated by the same type of efforts at other universities. Other long-range program goals, such as life-long learning, will require more data collection and analysis from surveys as the students gain experience in their professional careers. Perhaps the most positive impact that assessment has had on the curricula has been the cooperative atmosphere between faculty and students needed to focus their attention on FC program goals and objectives.

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Gary Weckman is an Associate Professor in the Mechanical & Industrial Engineering Department at Texas A&M University-Kingsville. He received Ph.D. from the University of Cincinnati and is a registered Professional Industrial Engineer in the State of Texas. He has over 13 years of industrial experience including 10 years with an aircraft engine manufacturer. Dr. Weckman received his B.S. and M.E. degrees in Industrial Engineering at the University of Louisville. The majority of his industrial responsibilities involved developing and implementing various forecasting systems and techniques.

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Robert A. McLauchlan, P.E., is Professor and Chairman of the Mechanical Engineering and Industrial Engineering Department at Texas A&M University - Kingsville (TAMUK). A registered professional engineer in Texas, he has eleven years research and development experience with the Analysis and Applied Research Division of TRACOR,

Inc.; seven years of Summer Faculty Research Program experience with the U.S. Navy, Air Force, and NASA; and twenty one and a half years teaching experience at Texas Tech University and at TAMUK. He has also been the PI/Participating Institution Coordinator for the NSF Foundation Coalition at TAMUK. His professional and research interests are in the areas of dynamics and control of systems, devices, and structures; intelligent controls and robotic/learning systems using neural networks, fuzzy logic, and evolutionary systems; design and optimization of systems and processes. He is also working in the areas of process improvement and process innovation as applied to engineering curriculum change. Dr. McLauchlan received the B.S. and Ph.D. degrees from the University of Texas at Austin.

JENNIFER CROSBY
Jennifer Crosby became the full time Assessment & Evaluation Coordinator in 1999 for the Foundation Coalition at TAMUK. Her responsibilities included the development of a database system for tracking key data analysis, and the development of a web-site for both the Foundation Coalition and ABET. She was a member of the FC A&E team at the national level and completed a comparative analysis for the TAMUK Year 1-6 reports and for the National FC Year 1-6 reports. Jennifer is currently working for the Office of Institutional Research at TAMUK.

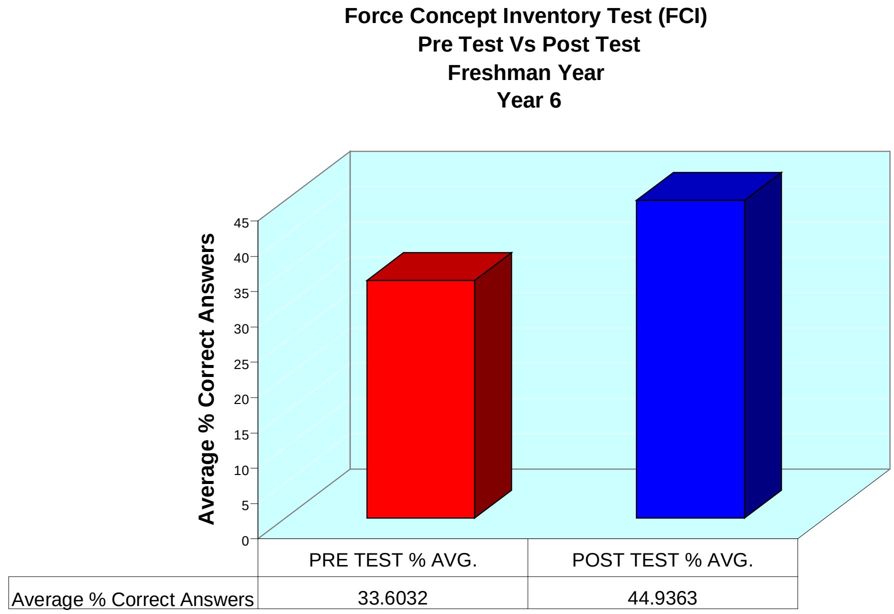


Figure 1: Example of FCI Results at TAMUK

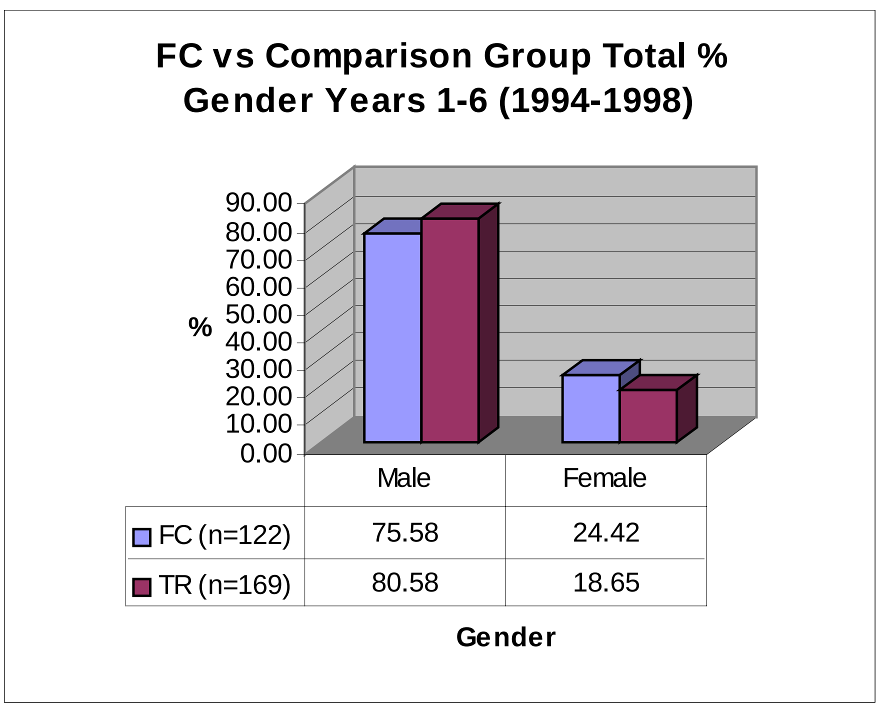
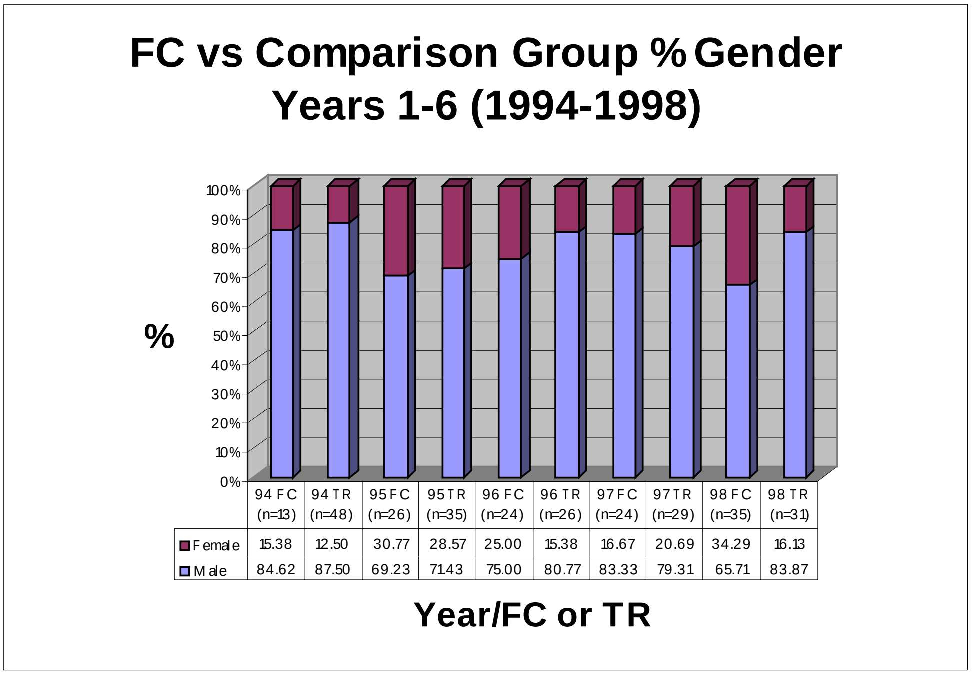
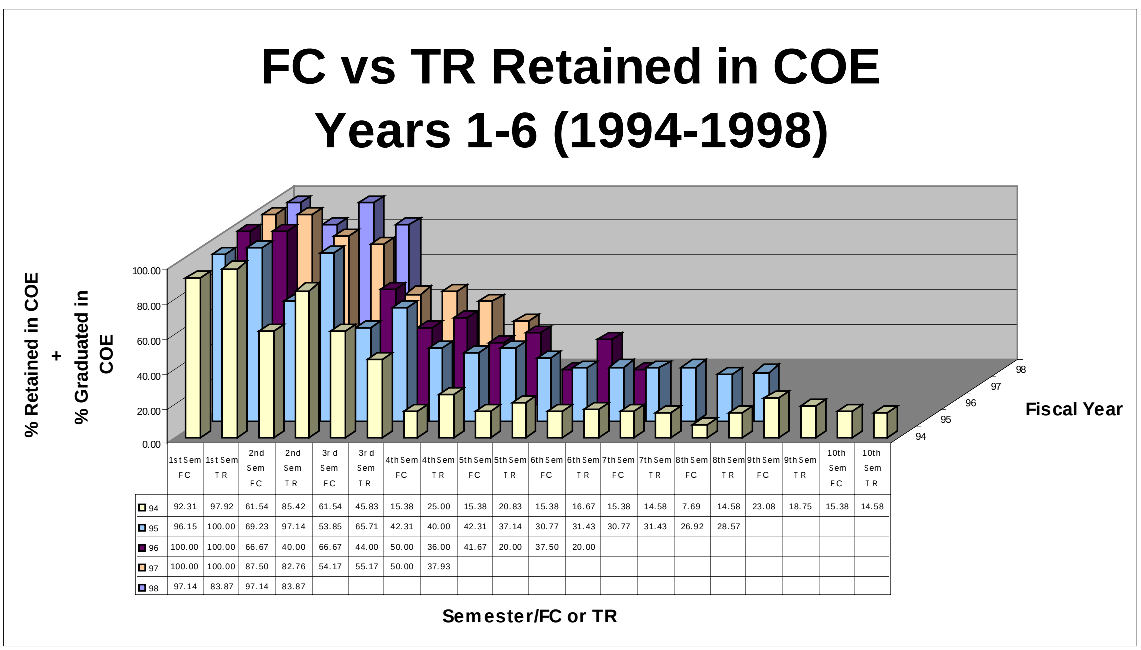


Figure 2: FC Comparison - Gender



	94 FC (n=13)	94 TR (n=48)	95 FC (n=26)	95 TR (n=35)	96 FC (n=24)	96 TR (n=26)	97 FC (n=24)	97 TR (n=29)	98 FC (n=35)	98 TR (n=31)
Female	15.38	12.50	30.77	28.57	25.00	15.38	16.67	20.69	34.29	16.13
Male	84.62	87.50	69.23	71.43	75.00	80.77	83.33	79.31	65.71	83.87

Figure 3: FC Comparison - Gender



	1st Sem FC	1st Sem TR	2nd Sem FC	2nd Sem TR	3rd Sem FC	3rd Sem TR	4th Sem FC	4th Sem TR	5th Sem FC	5th Sem TR	6th Sem FC	6th Sem TR	7th Sem FC	7th Sem TR	8th Sem FC	8th Sem TR	9th Sem FC	9th Sem TR	10th Sem FC	10th Sem TR
94	92.31	97.92	61.54	85.42	61.54	45.83	15.38	25.00	15.38	20.83	15.38	16.67	15.38	14.58	7.69	14.58	23.08	18.75	15.38	14.58
95	96.15	100.00	69.23	97.14	53.85	65.71	42.31	40.00	42.31	37.14	30.77	31.43	30.77	31.43	26.92	28.57				
96	100.00	100.00	66.67	40.00	66.67	44.00	50.00	36.00	41.67	20.00	37.50	20.00								
97	100.00	100.00	87.50	82.76	54.17	55.17	50.00	37.93												
98	97.14	83.87	97.14	83.87																

Figure 4: FC Retention

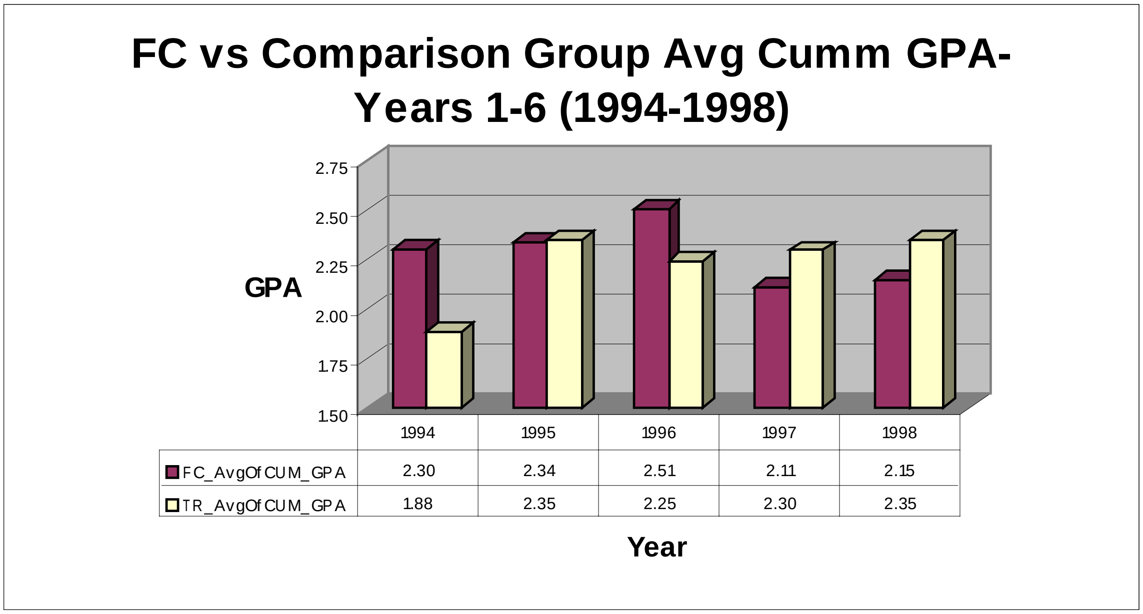


Figure 5: FC Comparison - GPA

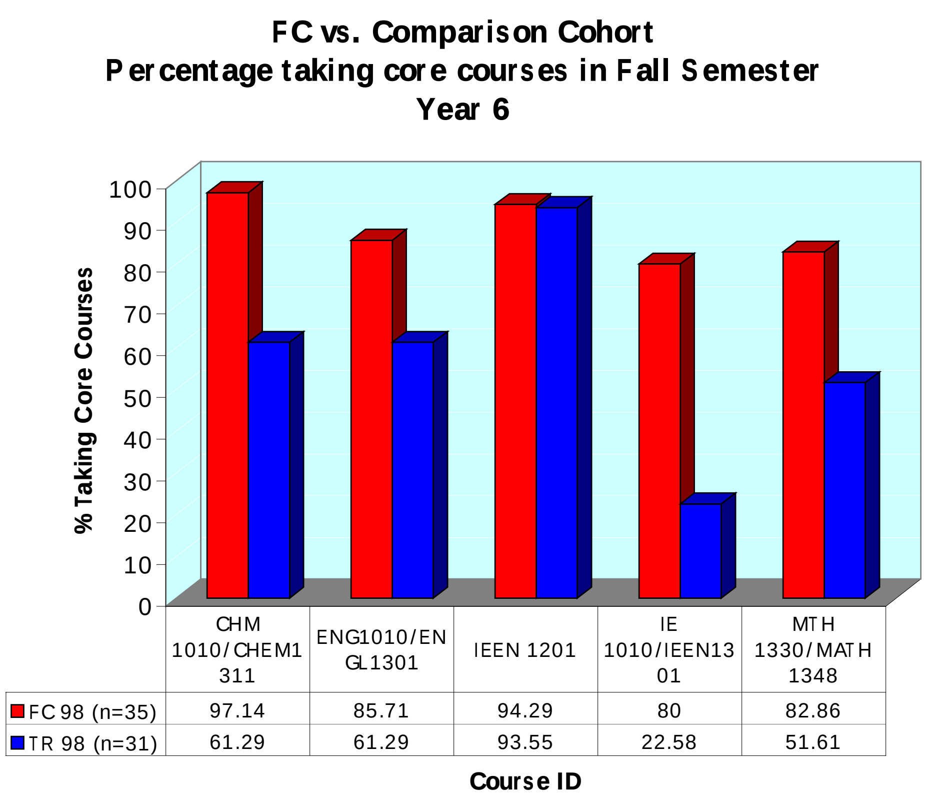


Figure 6: FC Comparison – Engineering Curriculum