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SUCCEED-Sponsored Freshman Year Engineering Curriculum Improvements at NC State: A Longitudinal Study of Retention

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Abstract

NC State's involvement in the NSF-sponsored SUCCEED Coalition has led to a number of changes to the freshman year of the engineering curriculum as reported previously (e.g., ASEE 1999, Porter, et al.). An explicit objective of these changes was to retain in engineering those students who were qualified and interested in engineering, but were leaving engineering for other reasons. While a number of isolated innovations have been studied and have demonstrated positive benefit, this study looks at each freshman cohort from 1987 through 1998 to evaluate changes in retention in engineering during that period. Eleven cohorts were studied; five (1987-1991) experienced no influence from SUCCEED-sponsored innovations, three (1992-1994) had subsets of the cohort involved in various pilot programs, and four (1995-1998) were more thoroughly affected by SUCCEED-sponsored curriculum changes. Aligned with these cohort groupings, the data indicate three different patterns of attrition. The pre-implementation cohorts are characterized by rapid attrition to a retention of 60-65% by the first semester of the sophomore year, and remaining relatively unchanged beyond that point. The transition cohort data show that the steep rate of attrition of the pre-implementation cohorts was mitigated. Continued attrition through the sophomore year, however, resulted in a transition cohort retention rate that was not significantly different from that of the pre-implementation cohorts. The post-implementation data indicate both a slower rate of attrition and a significantly improved retention rate—with 75% of the 1995 cohort retained in the engineering curriculum after eight semesters and 85% of the 1996 cohort retained after six semesters. If the observed trend in engineering retention continues, NC State might be close to the maximum expected retention, after removing uninterested and unqualified students from the population.

I. Introduction

The NSF funded **SUCCEED** Engineering Education Coalition is a collaboration of eight Colleges of Engineering in the southeastern U.S.[1] with a shared mission of creating sustainable engineering education reform on each of our campuses. **SUCCEED** has a vision of a curriculum that will educate our students for success throughout their career by nurturing technical confidence, developing a skill base for success, and instilling a positive attitude in its graduates. While these schools are all publicly funded, there is great diversity in their size, mission, student body, experience, and academic strengths. This diverse "educational research laboratory" has

[1] Clemson University, Florida A&M University-Florida State University, Georgia Institute of Technology, North Carolina A&T State University, North Carolina State University, University of Florida, University of North Carolina at Charlotte, Virginia Polytechnic Institute and State University

been essential to ensuring that the products and processes developed are robust and widely applicable.

As formulated over 8 years ago, the **SUCCEED** curriculum model is based on the desired attributes of graduates. These graduates should be technically competent, critical and creative thinkers, life-long learners, effective communicators, team players, and globally aware. They should understand process and systems design and integration, display high ethical standards, and appreciate the social context of engineering and industry business practices. The curriculum model proposes to achieve these qualities in its graduates through specific changes in the curriculum content and structure and, importantly, the implementation of processes by which the curriculum is delivered and managed. The key change elements in the curriculum content and structure are subject integration (knowledge structure and information processing), early and multidisciplinary design, explicit success skill development, and exposure to professional practice. The curriculum model also incorporates processes and systems to enhance student learning through the use of technology-based delivery systems (e.g., multimedia, electronic delivery, electronic advising and mentoring), the development of faculty (e.g., teaching/learning style awareness, student performance evaluation, self-evaluation), the establishment of a learning support system (e.g., student mentoring, pre-season programs), and the institution of a continuous improvement culture (e.g., outcomes assessment tools, continuous curriculum renewal).

The retention of engineering students, as measured by those students who have enrolled in engineering at some time and graduate with an engineering degree, is a widely tracked performance measure. Such issues as the cost of education, gender and ethnicity success, perceived institutional ranking, and the efficacy of institutional admission and advising systems are related to retention. Although high retention does not necessarily imply educational success, it is generally believed that early identification of a suitable degree program by students and subsequent persistence to graduation and employment in the field should be viewed as success. Retention of engineering students is an integral performance measure in that decisions to not remain in engineering are influenced by an integrated set of experiences. Thus, there are often many factors contributing to retention data change. Similarly, it is difficult to take a specific change in the curriculum that has shown a positive impact on retention and confidently predict success in another educational context. Nevertheless, the **SUCCEED** Colleges of Engineering have dramatically increased the enrollment and graduation rates of their minority and women students when compared to national data. The **SUCCEED**-initiated programs that facilitated the transition of students to University life during their first year on campus and expanded design and practice experiences are believed to be partially responsible for this improved student success.

II. The NC State Freshman Engineering Curriculum—Past and Present

During the past six years, the College of Engineering at North Carolina State University has offered several experimental courses designed for first year student in engineering. Each of these courses were developed through SUCCEED. They include: IMPEC, an integrated approach to mathematics, physics, engineering, and chemistry;[1,2,3] E123, a mechanical dissection course that has also been linked with a first year writing and composition course;[4,5] and ECE292D, a hands-on team-based design course offered to both freshman and upper class students.[6,7] All were offered as an alternative to a introductory course (E100) that had little academic content, no engi-

neering problem solving, and consisted of a large lecture room format with information dissemination as its major goal. Although each of the alternate courses was excellent and well received by the students, none could be easily scaled up to accommodate the 1100+ freshmen engineering students. Beginning in 1996, a new version of freshmen engineering was offered that incorporated many of the elements of the alternative courses.[8]

The original freshman-engineering orientation course, E100, in place since the mid-eighties, met for one hour per week in a large (150-200 students) lecture format. The content included matriculation procedures, advising strategies, academic integrity, study skills, elective selection, and all the "rules of the road" necessary for success. No academic credit was given for this course, thus little if any outside work was assigned. However, students were required to attend several departmental information sessions throughout the semester to learn more about the various academic disciplines.

NC State's motivation for changing the freshman orientation course stems from a desire to introduce engineering problem solving and teamwork early in the curriculum as a way to stimulate interest in engineering disciplinary thinking. Generally, our students' interest in engineering is high when they enter the university but decreases during the first year. By presenting connections to engineering disciplinary thinking early, students should be better able to understand the relevancy and necessity for related basic science courses and what it means to be an engineer. It was expected that an enhanced understanding of and interest in engineering would lead to improved decision making about curriculum choices, higher matriculation rates, increased retention, and ultimately a higher graduation rate.

In spite of the success of the experimental courses, space, equipment, and/or cost limitations made it difficult to scale up any one of them to the 1100+ incoming freshman. Instead, a new version of freshman engineering was developed that incorporates many of the elements of these experimental courses. The new course, E497F, stresses multidisciplinary engineering problem solving and design, active learning, integration with other first year courses, teamwork, critical thinking, ethics, safety, and written and oral communication. The structure of the course includes weekly team-based, problem-solving laboratories, along with biweekly lectures that alternate with the biweekly introduction to the computing environment laboratories.

The content of the new Introduction to Engineering Problem Solving course, selection of topics, assignments, and teaching methodologies have all been directly influenced by the successes in the experimental courses. A combination of traditional lecturing and alternative instructional methods including cooperative learning and activity-based class sessions were an integral part of the success in IMPEC and have been integrated into the new course. The goals of providing motivation and context for the fundamental material taught in the first-year mathematics and science courses, a realistic and positive orientation to the engineering profession, and the training in problem solving were also brought into the new course from IMPEC. ECE292D served as the model for the hands-on, team-based problem solving and design projects and E123 provided the model for integrating disciplinary writing and speaking.

During the Fall semesters of 1996 and 1997, the new Introduction to Engineering Problem Solving course was piloted to approximately 300 out of ~1000 incoming freshman. Since Fall 1998, the new course has been delivered to all the incoming freshmen, ~1100 students.

The *Introduction to Engineering* course is designed to introduce students to the field of engineering and the study of engineering. An objective is to integrate computer usage, teamwork, problem solving, and verbal/written language into a design project within the course in such a way that these skills become the foundation of a successful engineering career. An early understanding of these skills will assist students throughout their undergraduate experience and beyond. The course culminated with a Freshman Design Day at which each team of students presented their designs to the university community and participated in a competition to see whose design was best.

During Fall 2000, the *Introduction to Engineering* course was offered as a weekly fifty-minute interactive course in a computer-equipped classroom. In addition, a bi-weekly two-hour lecture session was paired with a section of E 115 *Introduction to Computing Environments.*

III. The SUCCEED Longitudinal Database

Longitudinal study can be used to show how cohorts performed through the NC State curricula of the past and present. A longitudinal database is under continuing development by the SUCCEED Coalition. The database contains data for all entering cohorts from 1987 to the present at SUCCEED member institutions. We believe this database is the only one of its kind, containing data from nine universities across five states placed in a common format.

Data are collected in a variety of formats from the nine SUCCEED institutions. A description of each institution's data definitions tempered with knowledge of the different academic policies allows merging of a common set of data in a consistent format. The SUCCEED longitudinal database has three components: 1) a demographic component, which contains unchanging data such as ethnicity, gender, matriculation date, matriculation major code, high school GPA, SAT scores, and ACT scores; 2) a term component, which contains data that change each term including term and cumulative GPA, major field of study, and course load; and 3) a graduation component, which contains records for each bachelor's degree awarded to each student in the database. A common identifier, the student's social security number, synchronizes records in each of the database modules. The SUCCEED longitudinal database only includes records for undergraduate, degree-seeking students. A more complete description of the SUCCEED longitudinal database is available elsewhere.[9]

The SUCCEED longitudinal database used in this study will continue to be augmented, making it possible to extend this longitudinal study. All SUCCEED schools have made a commitment to provide supplementary data each year continuing until five years after the end of the current SUCCEED Cooperative Agreement in 2002.

It is important to note that both in compiling and in reporting student records, it is common to make certain assumptions regarding population behavior. These assumptions will vary among institutions, researchers, and study conditions, and many decisions are somewhat arbitrary. For

example, should students who are attending the University for the first time yet have a large number of credits from Advanced Placement examination be considered in the same population with freshmen with no AP credit? Consequently, numbers reported from the SUCCEED longitudinal database may not be identical to numbers published elsewhere by North Carolina State University or others.

IV. NC State Engineering Cohort Performance 1987-1998

Using the SUCCEED Longitudinal Database, NC State students enrolled in any engineering discipline during any Fall or Spring semester since their matriculation were identified and counted. These counts for students in each cohort appear in the Enrolled column ("Enr.") of each cohort year in Table 1. The number of students graduating in a term is shown with each cohort as well—in the Graduated ("Gr.") column or each cohort. Enrollment figures for summer terms are not a useful measure of retention, because many continuing students do not attend during the summer term. For this reason, Summer term enrollment figures are not displayed. Summer terms are included in the table, however, to account for the graduations that occur during those terms.

The cohort year a student is identified with is defined according to the Integrated Postsecondary Education Data System (IPEDS) guidelines developed by the National Center for Education Statistics for classifying First-Time-In-College students. Each Fall cohort includes students who matriculate during the previous Summer and the following Spring. Terms are described by a 5-digit number—a 4-digit year followed by a 1-digit term (1=Spring, 3=Summer 1, 4=Summer 2, 6=Fall).

Please recall that, as described in the previous section, numbers reported from the SUCCEED longitudinal database may not be identical to numbers published elsewhere by North Carolina State University or others.

A review of Table 1 shows some interesting facts. Some may be surprised to see that two students from the 1987 cohort were enrolled in the Spring 1991 semester—or that a student from that cohort graduated as recently as Summer 1998 (recall that these are undergraduate students). Such anomalies are not unusual in small numbers in student records—there are an extraordinary number of pathways that will lead to an undergraduate degree. Such students are special cases, and warrant neither concern nor statistical adjustment. It is also possible to have a dip in the number of engineers enrolled from a particular cohort in one semester, only to see a rise in enrollment for that cohort in the following semester. This also presents no concern—co-ops, internships, study abroad, leaves of absence, and other factors can explain this behavior. This effect cannot be caused by the introduction of transfer students, because the transfer student population is not included in this study. The benefit of longitudinal study is that the effect of these factors is short-term.

Table 1. Enrollment and Graduation of First-Time-In-College Cohort Students

	Cohort Year																				
	1987		1988		1989		1990		1991		1992		1993		1994		1995		1996	1997	1998
Term	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Gr.	Enr.	Enr.	Enr.
19876	1213																				
19881	1179																				
19886	760		1230																		
19891	750		1190																		
19896	777		786		1241																
19901	769		779		1228																
19906	762	2	816		835		1275														
19911	732	108	834		809		1105														
19913		3																			
19914		11																			
19916	596	122	814	5	857		823		1212												
19921	464	257	790	103	856		790		1019												
19923		14		7		1															
19924		17		10		2															
19926	200	75	662	155	838	4	816		803		1051										
19931	129	54	509	273	814	134	854	3	789		1019										
19933		5		6		7															
19934		5		16		4		1													
19936	70	23	225	107	672	148	833	6	832		959		1117								
19941	43	19	118	67	506	280	812	152	810	3	905		1088								
19943		1		3		9		4		1											
19944		1		3		20		13		2											
19946	31	9	57	14	214	87	617	159	759	5	806		986		1189						
19951	22	5	43	16	132	64	459	268	723	151	751	2	915	1	1102						
19953		1		1		2		17		5											
19954		1		2		7		10		12											
19956	18	1	29	2	55	15	185	64	571	115	721	4	809		988		903				
19961	15	6	22	4	42	11	115	50	445	279	672	142	755	4	901		868				
19963		1				1		3		13		10									
19964		1		1		1		8		9		9		1							
19966	9	1	20	2	27	4	61	13	149	63	535	163	729	4	828		865		867		
19971	9	4	14	6	29	5	44	10	85	34	373	211	696	155	750	8	831		889		
19973				2						8		8		6							
19974								2		6		17		10		1					
19976	7	2	12	2	19	8	37	17	50	24	155	59	526	144	715	8	775	2	827	986	
19981	5	3	10	5	17	3	24	19	36	11	94	45	379	238	680	134	754	1	803	961	
19983		1				2						3		9		7					
19984						2		3		5		6		8		7		1			
19986	3		9		16		19		30		50		138		507		701		811	919	1029
19991	2		6		14		13		27		41		78		381		671		771	864	996

In graphing this data, the cohorts are normalized so they can be displayed on the same scale. First, the total number retained from the cohort is calculated as the sum of those enrolled in a semester and the cumulative number previously graduated. Those that graduate in the present semester are subtracted from the enrolled figure to avoid double-counting. Second, the number enrolled or previously graduated is then expressed as a percentage of the cohort size.

While this graph is complicated, it must be shown to illustrate two points. Since it is clear that there is no significant change in the retention after the 8th semester, we may redraw the graph with an expanded scale. More importantly, Figure 1 shows certain behavior characteristic of the 1987-1991 cohorts, a different behavior characteristic in the 1992-1994 cohorts, and a third type of behavior in the 1995-1998 cohorts.

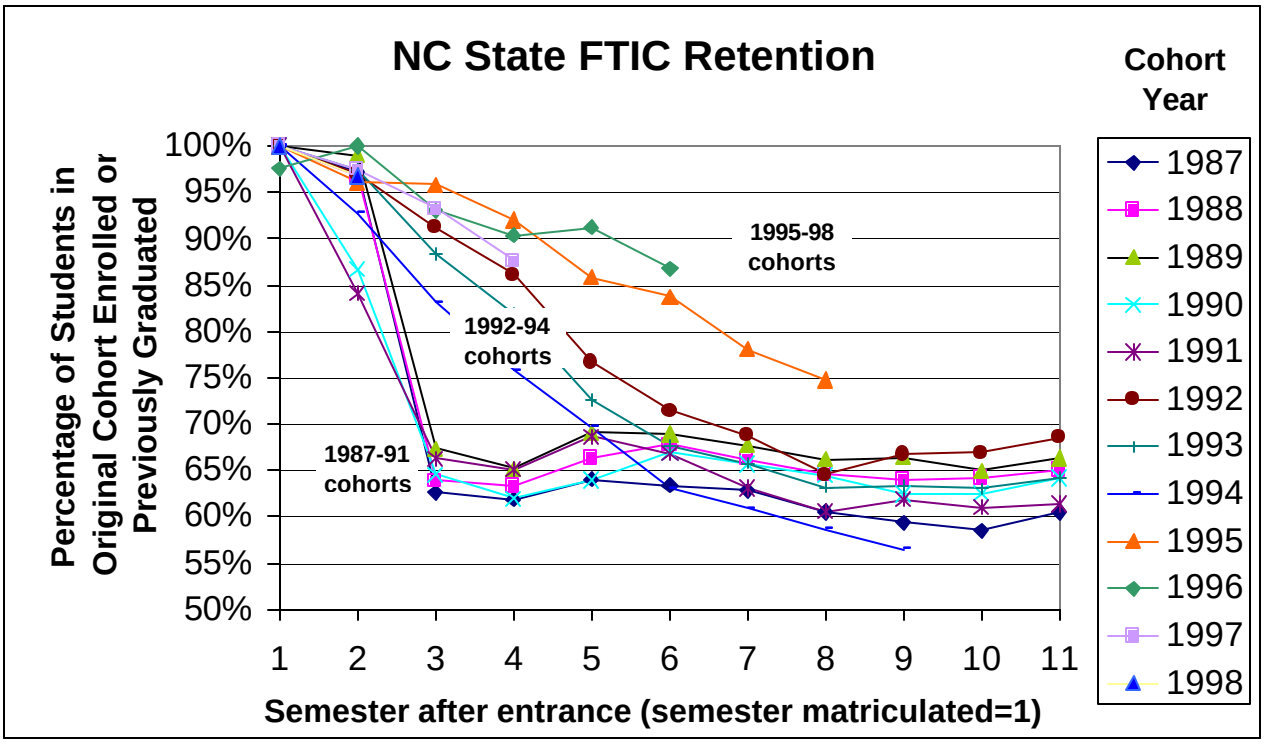

Figure 1. Retention of NC State First-Time-in-College Engineering Cohorts, 1987-1998.

Figure 2 shows the same data with an expanded scale and cohort groupings as discussed above. This less-complicated graph more clearly shows the distinct behavior of the cohort groupings.

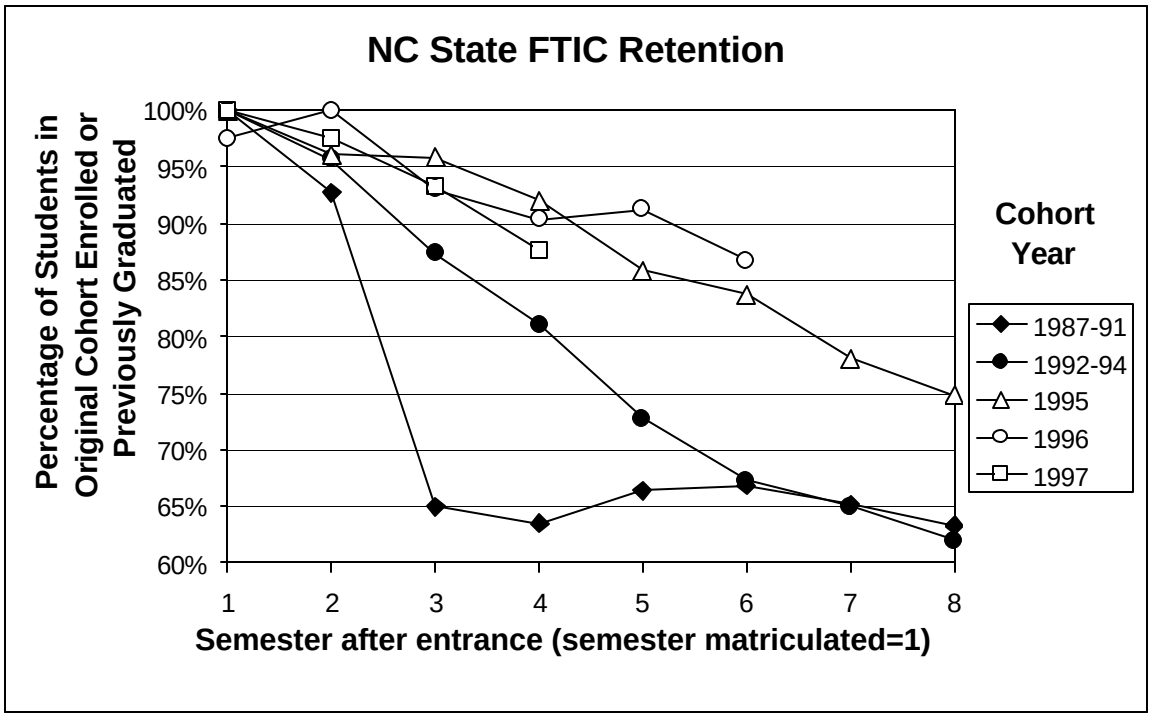

Figure 2. Retention of NC State Freshman Engineering Cohort Grouping, 1987-1998.

IV. Data analysis

Inspection of the 1987-1991 cohorts in Figure 2 indicates rapid attrition—35% do not return to engineering the sophomore year—followed by stable enrollment to graduation. The 1992-1994 cohorts, in contrast, have much slower attrition that lasts into the junior year, settling at the same level—65% retained to graduation. This is worse than the 1987-1991 cohorts—the ideal profile for a given level of retention would be very steep at the outset, while those who are either not interested or not qualified quickly move on to other pursuits. The 1992-1994 cohorts, however, kept students on track in engineering longer only to lose them to attrition anyway. Fortunately, the more recent data indicate that the 1992-1994 cohort behavior was a transition phase to a higher level of retention.

An analysis of the 1987-1991 cohorts indicates that they are not significantly different from one another, so it is appropriate that they have been grouped in Figure 2. Similarly, the 1992-1994 cohorts show no statistically significant differences. Analysis also shows that the 1992-1994 cohorts behavior is significantly different from that of the 1987-1991 cohorts. Most importantly, the 1995 cohort (indicating 75% retention) is significantly different from the 1992-1994 cohorts (retaining 62%). The 1996-1998 cohorts were not included in tests of significance, since a full range of data is not available. All reported levels of significance are derived from a Chi-squared test comparing expected values to observed values[10] with statistical significance defined by $p<0.05$.

VI. Conclusions and recommendations

The observed improvement in retention of engineering students at North Carolina State University has significant implications for engineering education. At NC State alone, this improvement will lead to the production of nearly 150 additional engineering graduates per year.

While many changes at NC State might have contributed to the noted improvements, including significant efforts to enhance faculty development (also sponsored by SUCCEED), we propose that the most significant contributing factor is the redesign of the freshman engineering curriculum. The time scale of the introduction of new educational practices early in the curriculum appears to coincide with the observed improvement in retention.

Further study of individual programs is ongoing. Such studies will help to isolate the specific measures that most contribute to student success and retention.

VII. Acknowledgements

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