

WORKING TO ACHIEVE A MORE GENDER NEUTRAL ENGINEERING CURRICULUM

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Individual career decisions are influenced by such things as ability and aptitude, family background, socio-economic status, culture and peer groups. The decision to pursue a degree and a career in engineering can be influenced by many factors. Certainly an ability in math and science is needed to pursue a degree in engineering, but why is it that students who are academically prepared to pursue an engineering degree choose not to? Why do first year engineering students transfer out of engineering with only limited, (or perhaps no) exposure to engineering? What role does the structure of the engineering curriculum play in retaining academically prepared female students?

There is evidence that the way science is taught at the undergraduate level can influence student retention, regardless of gender. Approximately 40% of first year students who have an interest in careers in science, mathematics and engineering change their plans before completing an undergraduate degree (Astin & Astin, 1993). What is the relationship between attrition and undergraduate pedagogy and curriculum?

This paper addresses the study of the curriculum revisions at Carnegie Mellon, and the impact of change on retaining female undergraduate students. The underlying assumption of this paper is that good pedagogy is good pedagogy and is a positive factor of success for all engineering students, but it can be viewed as especially relevant to the quality of the educational experience of female undergraduate engineering students. Perhaps the most effective way to improve retention of female and underrepresented minority students is to improve the quality of learning experience for all engineering students.

In 1990, the Carnegie Mellon College of Engineering implemented a significant curriculum change that is especially relevant in addressing issues related to the representation of women in undergraduate engineering studies. Much of the impetus for change centered on the preparation of incoming first year students, their interests, knowledge of engineering, career aspirations and retention of students within the engineering college.

The perception underlying the curriculum revision is that first year students are not equally prepared in math and science, knowledgeable about engineering, and often are unsure of their choice of major within engineering. Often they are looking to their first year experience to affirm their choice of profession and discipline.

In considering how to change the curriculum, the following factors most often cited as reasons female students choose engineering were also considered: knowledge of the subject, capability and interest in high school math and science, knowing an engineer, and support systems--most often family. (O'Donnell & Anderson 1978; Baum 1989; Fitzpatrick & Silverman 1989; Barber, Morgan & Darby 1990, Rosser, 1995, Tobias 1990)

Distinguishing characteristics of a curriculum that might contribute to female student achievement and success in engineering and science were also considered. Among these characteristics are a structure that places engineering students in early and regular contact with other engineering students and faculty, including female faculty, and flexibility that encourages and permits exploration and development of secondary or concurrent interests.

Revised Curriculum

In outlining the structure of the new curriculum, the college came to several conclusions. The first was to teach engineering early through required introductory courses. The profession of engineering is not well understood by many students, so it is unclear if student expectations of the field match the reality of being an engineer. Most of the students in beginning engineering courses are engineering majors who have had no previous exposure to the subject. Many students look to an entry-level course as a way to affirm their interest and to understand the nature of their prospective field. In traditional curriculum structures, first year students take math and science requirements and do not gain much exposure to engineering until much later in the undergraduate experience.

First year engineering students at Carnegie Mellon are required to take two out of a set of six first year engineering courses. These courses are intended to provide hands-on engineering experience, to provide a context for related courses in science and mathematics, to introduce the range of engineering practice and to introduce students to methods for engineering design and problem solving.

Features of the Carnegie Mellon first year required introductory engineering courses: to emphasize the "Big Picture", include a hands-on lab experience with an engaging project, exposing students to engineering design and problem solving. Faculty assigned to these courses are considered to be among the best teachers in the college. Female faculty regularly rotate through three of the six introductory engineering courses, thereby exposing female students to female faculty early in their careers.

In essence, the College of Engineering is taking ownership of all students who express interest in engineering at the time he or she enters the university. This is achieved by placing students in courses with engineering faculty and other engineering students (both first year and upper-class students.) A goal in the curriculum revision is to minimize required core and course load, especially in the first year, partially in response to student concern that the workload was uncomfortably heavy. The purpose here is to create a "student friendly" structure, not one that has less work per se, but rather one that has fewer topics to worry about at the same time.

A unique underlying philosophy is the specific technology taught is less important than teaching students how to learn, how to solve problems, and how to be leaders in industry and government. With this philosophy, eliminating some of the traditional engineering topics that normally are included in a four year undergraduate program becomes feasible. Carnegie Mellon is teaching students engineering, not necessarily teaching them to be engineers. In that vein, engineering education in the 21st century can be thought of in much the same way as liberal arts education is thought of today. Students use engineering as a platform from which they pursue a number of careers, including engineering.

Following the first year revisions, several departments have also instituted curriculum change. The curriculum in Electrical and Computer, Civil and Environmental and Mechanical Engineering have been altered to reduce the number of required courses and the length of required pre-requisite chains. In each case there are from five to eight totally free electives, in addition to the eight general education courses that are required of all engineering undergraduate students. A series of designated engineering minors that can be completed within the structure of the different degree programs were also introduced.

Assessment

Ongoing impact assessment is being conducted, contrasting the experiences and accomplishments of the 1994 class, the last to graduate under the old curriculum with the 1995 and 1996 classes, the first and

second classes to graduate in the new curriculum. Successive years of graduating seniors will be surveyed, and after five years alumni will also be asked to answer questions of the relevancy of their education. (It is noted that comparing attitudes and experiences over time is fraught with peril since external factors could cause any observed differences.)

The response rate for the three years of the senior surveys has remained fairly constant, averaging 26%. Women represent approximately 15% of the senior class over the three year period. The response rate of female seniors to the survey has been slightly higher than their representation in the class, 22%. The distribution of responses by senior women appears to reflect the distribution in the departments.

The study of curricula impacts includes the following: retention and graduation rates, surveys of graduating seniors, faculty and recruiters. Due to time and space considerations the first two are reported here.

At the time of the curriculum proposal it was hypothesized that exposure to disciplinary engineering courses in the freshman year would allow students to assess the suitability of engineering as a major earlier, so retention would likely decrease between the freshman and sophomore years, shifting a drop that normally occurs after the sophomore year.

However, what occurred with freshman to sophomore year retention was just the opposite. Since the introduction of the new freshman curriculum in the fall of 1991, the retention of engineering freshman to engineering sophomores remained level in that first year (about 80% for both the 1990 and 1991 cohort of entering students) but increased to 82.5% for the 1992 cohort, and leveled off to 86% for the 1993 and 1994 cohorts.

The cause of this surprising increase in freshman to sophomore retention may be that first year engineering students may be more likely to continue in engineering because they are integrated into the academic and social environment of the department and college, feel connected to the engineering faculty, connected to other engineering students and to the engineering program. Personal contact with faculty, immersion into engineering in the introductory courses and contact with their peers, (other engineering students), are all characteristics of effective retention models. (Astin 1984, Tinto 1975).

Surveys of Student Opinion

In the month before graduation, seniors were surveyed to report on their experience at Carnegie Mellon and their career preparations. Students were asked to rate the engineering curriculum and various aspects of their educational experience on a scale of 1 (poor) to 5 (excellent). Generally, student satisfaction with their education increased over the period from the old curriculum to the new, although only the changes in "understanding engineering by the end of the freshman year," "sufficient flexibility in the curriculum" and "instruction quality in engineering" were statistically significant at a 95% confidence level. It is interesting that the responses were surprisingly similar when analyzed by gender.



Characteristics	1994 Graduates: Old Curriculum		1995 Graduates: New Curriculum		1996 Graduates: New Curriculum	
	All	F	All	F	All	F
Rating of CIT Curriculum Overall	3.9	3.9	4.1	4.1	4.1	4.1
Rating of student's skills in oral communication	3.8	4.0	3.9	3.9	3.9	4.0
Rating of student's skills in written communication	3.9	4.0	3.9	3.9	3.9	3.9
Rating of student's skills in engineering problem solving	4.2	4.1	4.3	4.4	4.3	4.3
Rating of student's skills in the application of fundamental analysis	4.0	3.8	4.1	4.2	4.1	4.2
Preparation for continued learning	4.2	3.9	4.3	4.4	4.3	4.3
Preparation for teamwork	4.3	4.3	4.4	4.4	4.5	4.6
Understanding of engineering by the end of freshman year	2.2	1.8	3.1*	3.2*	3.1*	3.1*
Sufficient flexibility provided in curriculum for your educational objectives?	2.9	2.7	3.5*	3.6*	3.3*	3.1*
How well did mathematics and science courses prepare you for engineering courses	3.5	3.4	3.5	3.6	3.4	3.5
Rating of the instruction quality in engineering courses	3.8	3.7	4.1*	4.1*	4.0	4.1*
Rating of the instruction quality in non-engineering courses	3.6	3.7	3.5	3.5	3.6	3.9

*Indicates statistically significantly different means at a 95% confidence level.

Specific comments from some of our female seniors who graduated in 1994, prior to implementation of the new curriculum, and in 1995 and 1996, the first and second classes to begin and complete the new curriculum help to illustrate the impact of the new curriculum.

In response to questions about the best aspect of engineering education at Carnegie Mellon, some of the 1995 and 1996 female graduates mentioned the introductory courses.

"The intro classes were helpful in deciding a major."

"I love the introductory courses! The experience really gave me confidence in being able to choose a major that I'd be happy with and successful in."

One 1994 female graduate who entered Carnegie Mellon before the new curriculum commented: "I think the Introductory to Engineering courses are a very good idea."

Efforts to decrease the total number of classes in the first year were noted by a 1994 female graduate who commented: "The crunch of dealing with 5 classes as opposed to my friends at other schools who only take 4 classes" as one of the worst aspects of engineering education at Carnegie Mellon.

Lack of flexibility in choosing courses seemed to dominate comments by many 1994 and some 1995 and 1996 female graduates when identifying the worst aspects of their engineering education at Carnegie Mellon. The 1996 responses begin to note the increasing flexibility in some departmental curricula:

"The flexibility in the curriculum allowed me to pursue other areas of interest other than engineering."

"Time limitations on electives--would like to explore more areas but had to choose"

"At times Chemical Engineering curriculum seemed too structured and rigorous. Not enough freedom to choose what classes you will take."

And another, after sophomore year "I did not have any classes with people outside of my major. There is no flexibility in the chemical engineering curriculum, which is unfortunate."

"I got very little chance to choose my own classes and interests, . . . that once you choose a minor or option you have no choice"

"The rigidness of the engineering core. I didn't get enough opportunity to take other classes that I wanted to take."

"Did not have the time or flexibility to take other classes and pursue other interests."

But curriculum change has it's price as noted by one woman, "curriculum changes were too often."

The 1994 female graduates commented on lack of hands-on experience as the worst part of their engineering education at Carnegie Mellon. In contrast, many 1995 and 1996 female graduates commented on their positive feelings towards the hands-on experience and the opportunity to participate in undergraduate research:

Best was "the opportunity to do research and the opportunity to work in the department."

"Problem solving skills and team work were enforced and taught very well. Open-ended group projects were challenging and great preparation for real world problems."

"I could participate in a project as a freshman under one of my department's professors."

"The hands-on experience was great."

"Undergraduate research projects and labs" as the best aspect of the engineering experience, also, "Project classes, senior design classes, senior projects."

Summary

From student surveys we have found that our first year students remain enthusiastic about engineering. Of the students that entered the college of engineering over the past two years, on average over 92% stayed at Carnegie Mellon. Of these, 95% have remained in engineering.

Students also seem to rely on the introductory courses as a basis for choosing a major. The introductory courses have also allowed our students to become employable in a technical profession after their first year because they have some engineering as a result of the introductory courses.

The flexibility in the new curriculum makes students much more proactive in planning their academic choices. Because they're engaged in planning their curriculum, they seem to be much more interested in what they are taking. Interesting early assessment data of student course selection in the department that has had the most flexibility for the longest time (Electrical and Computer Engineering for six years) indicates that students are choosing more technical courses, rather than fewer, as was hypothesized at the time the curriculum was proposed.

One important factor in the long term success of the undergraduate curriculum revision is that advising in such a flexible program takes on even greater importance than it did under the old curriculum, and this

does place a greater burden on Carnegie Mellon's faculty and on the departments to step up to that responsibility. Flexibility means more choices, which have to be planned.

Assessment will be ongoing, especially as we evaluate the impact of change on the female students in the engineering college. Student satisfaction and retention has increased, we find that engineering students use their engineering background to pursue a variety of careers in other professions. Many engineering undergraduate students have specific career goals in mind, including careers in business, law or other professions. This curriculum accommodates the desire to achieve those goals, while providing an excellent education.

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