AC 2008-1194: THE IMPACT OF BIO-ENGINEERING: PART I: DO BIO-ENGINEERING STUDENTS DIFFER FROM OTHER ENGINEERING STUDENTS? PRELIMINARY RESULTS.

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The Impact of Bio-Engineering: Part I: Do Bio-Engineering Students Differ from Other Engineering Students? Preliminary Results.

Abstract

The under-representation of women in engineering is of particular concern nationally, both because there is a national need for more engineers, and because women's access to a lucrative and growing occupation is desirable. In research on recruitment into engineering, one of the explanations of women's under-representation in the undergraduate major is their preference for a profession that contributes to the social or societal good more clearly than engineering is traditionally perceived to do. Not only are they less likely to enroll in engineering for this reason, they also may leave the engineering major before completion because they do not see themselves making enough contribution to the societal good as they would in another profession. One field in engineering that has consistently attracted a disproportionately high percentage of women is bioengineering or biomedical engineering. While intuitively it seems that bioengineering and biomedical engineering are inherently female-friendly, little systematic research has demonstrated whether the women attracted to such programs differ in any way from women attracted to more traditional engineering disciplines, either in terms of who is recruited or how they experience the undergraduate program. The recent introduction of a bioengineering concentration at a mid-Atlantic public university provides us the opportunity to begin to fill this vacuum. At this university, on-going survey research enables us to compare the students enrolled in this new concentration to students in the more traditional engineering disciplines, perception of fit in engineering, engineering self-confidence, satisfaction with the program, expectations from completion of the degree (what kind of job they expect to attain), plans for future education and employment.

Compared to the rest of the students, the bioengineering students tend to be quite confident in many engineering-related competencies, but they are less confident in others, suggesting that the field may be attracting some students not traditionally in the field. Compared to the rest of the students, more of the bioengineering students expect to make a contribution to society and to have a job they like doing, and are less concerned with the security of the job or having time for outside interests. These findings are presented and discussed in terms of their insight into ways bioengineering might be effecting change in the culture of engineering.

As some have feared, more bioengineering than non-bioengineering students intend to finish a degree other than engineering, and less than a third expect to be working as an engineer ten years after the survey. Suggestions for continued research are discussed in the conclusions.

Introduction

The under-representation of women in engineering is of particular concern nationally, as the decreasing supply of qualified engineers perpetuates a national shortage as well as it reflects limited opportunities for women and minorities in a lucrative, developing and essential occupation[3,4]. In research on recruitment into engineering and attrition from it, one of the explanations of women's under-representation in the undergraduate major is their preference for a profession that contributes to the social or societal good more clearly than engineering is traditionally perceived to do[11]. Not only are they less likely to enroll in engineering for this reason, they also may leave the engineering major before completion because they do not see themselves making enough contribution to the societal good as they would in another profession.[11]. One field in engineering that has consistently attracted a disproportionately high

percentage of women is bioengineering or biomedical engineering; women's enrollment in such specializations has more than doubled in the last decade. In 1995, when nationally women were only 11.6% of the engineering college students, bioengineering/biomedical engineering and environmental health specializations within engineering had an average enrollment of 25% women. In 2005, when women's proportion of undergraduate engineering students was 17.2%, over 40% of the B.S. graduates in these fields were women[8]. Further, every undergraduate program that has over 25% women enrolled in engineering, has a bioengineering or biomedical specialization[1].

Anecdotal evidence by the Whitaker Foundation[2] suggests that women are attracted to BE/BME because of its potential to make a significant impact on people's lives and health. Indeed, the field seems characterized by the potential to break down the traditional gendered distinctions between "technical" and "social" which have maintained the traditionality masculine hegemony in engineering identities[5], hence making a deeper change in engineering beyond changing the gender balance in numbers. While intuitively it seems that bioengineering and biomedical engineering are inherently "female-friendly", little systematic research has demonstrated whether the students attracted to such programs differ in any way from students attracted to more traditional engineering disciplines, either in terms of the characteristics of students who are recruited, how they experience the undergraduate program, or what they expect from engineering upon completion of their studies. In fact, very little research systematically looks at the variation of students between engineering majors at all[6].

The characteristics of bioengineering/biomedical students have been studied by Schreuders and colleagues[10]. Using data from seven universities spanning the U.S., they focused on gender differences within biological and agricultural engineering students, finding few of significance. Men and women had similar academic preparation; interest levels in analyzing, building, and design activities; and interests in subspecialties of their field. However, differences between students in bioengineering/biomedical engineering and other engineering students were not studied.

The recent introduction of a bioengineering concentration in a mid-Atlantic public university's engineering program provided us the opportunity to consider differences between bioengineering and non-bioengineering students. At this university, ongoing survey research of the engineering students enabled us to compare the students enrolled in this new concentration to students in the more traditional engineering disciplines, on such characteristics as perception of fit in engineering, engineering self-confidence, satisfaction with the program, expectations from completion of the degree (what kind of job they expect to attain), plans for future education and employment. While the survey was not designed to probe the specific characteristics of the bioengineering program or students, there is enough relevant material to address some pertinent questions. While the number of students choosing this concentration is still small, there are enough to make preliminary comparisons to the students in more traditional programs, which is what we present.

Data and Sample

All engineering students at the university were surveyed in the spring of 2007, at the conclusion of the first year the bioengineering concentration was offered. Participation was voluntary, but class time in courses required of all majors was utilized for administering the surveys, in order to reach the largest number of students. Among other questions, students were asked how confident

they were of their fit to engineering, competency in engineering-related skills and subjects, expectations of staying with engineering as a major and a career, and expectations from the engineering degree.

At this university, it is not necessary to "declare" a concentration until graduation, when a certificate is issued for those fulfilling the requirements of the concentration. However, students self-identify as following this concentration in order to get proper advising and take the required curriculum sequence. The bioengineering concentration requires at least 18 semester hours of approved coursework, with a minimum of three semester hours above and beyond the required coursework for the student's major degree. At least one of the courses must be outside of the student's major and at least one must be in the chemical or biological sciences. It is designed to be a concentration for junior and senior students, although students may take appropriate courses, if they qualify, at an earlier stage, and may self-identify as concentrates even before they start the appropriate curriculum.

Fifteen of the 335 students surveyed in the spring identified themselves as having a bioengineering concentration. They form the "bioengineering" group in our analysis, and are compared to the rest of the students. Table 1 shows how the self-identified bioengineering students compare to the rest of the engineering students in terms of year in engineering, major, and gender. Approximately half of all engineering students are upper-level, while more than half of the bioengineering concentrates are upper-level, which may be explained by the fact that students do not have to declare the concentration upon entering as first-year students and often do not start taking classes to fulfill the concentration until the junior year.

TABLE 1

BIOENGINEERING CONCENTRATE BY GENDER, YEAR IN PROGRAM, AND MAJOR

	Bioengineering	Non-bioengineering
% Female	20.0	15.4
% upper-division (junior, senior)	73.3	46.2
% Chemical engineering majors	66.7	23.4
% Civil/Environmental engineering majors	0	27.2
% Electrical/Computing engineering majors	0	21.6
% Mechanical engineering majors	33.3	27.8
(n)	(15)	(320)

Note that there is a slightly higher proportion of women in bioengineering than in the rest of the engineering student body (though hardly overwhelming), the majority in the bioengineering

concentration are upper-division, and the students are drawn from Chemical and Mechanical engineering majors. Unfortunately, this small number of women currently identified as bioengineering concentrates is too small to do further analysis on the gender differences within bioengineering. Once the concentration has been running for several semesters, we hope to be able to combine samples to do further analysis.

Findings

Self-confidence and Perceived Fit to Engineering

Students were asked to rate how confident they were in a number of subjects related to engineering, using a scale of 1-5 (from 1 "not strongly confident" to 5 "strongly confident"). They were also asked the extent to which they agreed with several statements indicating their fit to engineering (from 1 "strongly disagree" to 5 "strongly agree"). The bioengineering students are among the most confident of the engineering students. Compared to non-concentrates, higher proportions of bioengineering concentrates are strongly confident in their abilities in math, calculus, chemistry, chemistry, computer science and biology (Table 2). Comparing the concentrates and non-concentrates, similar proportions strongly agree that they are well-suited for their major and their career. Somewhat lower proportions of bioengineering concentrates describe themselves as technically inclined or good at design, which suggests that the concentration may be tapping into alternate types of identities among the engineering students. It should be noted that while the differences appear large, not all reach statistical significance, perhaps because of the small number of bioengineering concentrates in the sample.

TABLE 2

ENGINEERING SELF-CONFIDENCE BY BIOENGINEERING CONCENTRATION

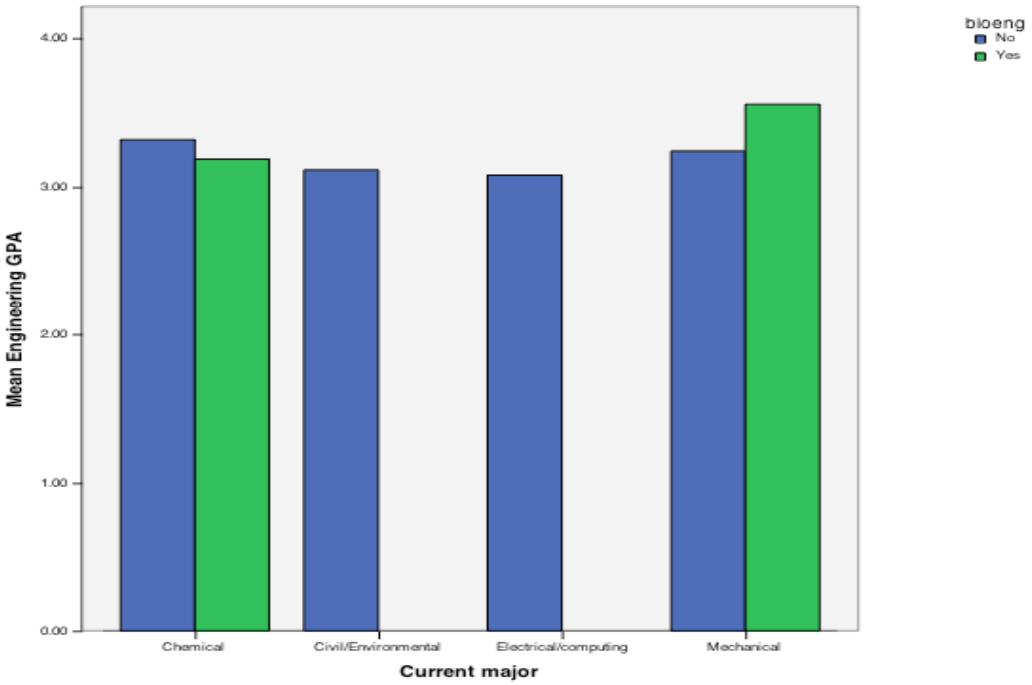
	Bioengineering	Non-bioengineering
Confident in math abilities (% strongly confident)	60.0	41.3
Confident in calculus abilities (% strongly confident)	53.3	29.4
Confident in chemistry abilities (% strongly confident)	26.7	17.1
Confident in physics abilities (% strongly confident)	26.7	26.5
Confident in computer abilities (% strongly confident)	26.7	19.7
Confident in biology abilities (% strongly confident)	26.7	6.8*
Mechanically inclined (% strongly agree)	33.3	30.0
Good at designing things (% strongly agree)	20.0	30.0*
Technically inclined (% strongly agree)	20.0	26.2
Well-suited for chosen major (% strongly agree)	33.3	30.0
Well-suited for chosen career (% strongly agree)	33.3	32.7

*Chi-square significant at $p<.05$.

GPA

Bioengineering concentrates report a higher grade point average in engineering courses than do non-concentrates (3.34 compared to 2.98). But if we break down the students into majors, we see that this is misleading (Figure 1). The main differences in GPA are between majors, rather than between bioengineering concentrates and others: the two majors which feed into the bioengineering concentration have higher GPAs on average than do the two majors which do not, which explains the difference between concentrates and non-concentrates in the total.

Figure 1 Engineering GPA by Major and Bioengineering Concentration



Expectations from Engineering Degree

Students were given a series of statements completing the sentence "A degree in Engineering will allow me to…get a well-paying job, choose to live in any geographic location I want, get a job I like doing, be respected by others, get a job where I can use my talents, get a secure job throughout my adult life, get a challenging job, have time to devote to interests outside my job, get a job where I will associate with interesting people, be an important contributor to society." For each of the competing statements, students could answer on a scale of 1 to 5, with 1=strongly disagree and 5=strongly agree.

A majority of students agreed that a degree in Engineering would enable them to get a well-paying job, whether or not they were bioengineering concentrates or not. Higher proportions of the bioengineer concentrates mentioned that they would be able to get a job they liked doing and be an important contributor to society. The latter is the one we expected to see emphasized by bioengineers, and indeed 40% of the bioengineering students strongly agreed with this expectation, compared to a third of the non-bioengineers. Over a third of the non-bioengineering students strongly agreed that they would be able to get a secure job through their adult life, compared to only about 20% of the bioengineering students, suggesting that this is a greater

motivator for the non-bioengineering students. More non-bioengineering than bioengineering students strongly agreed that they expected to have a job where they would associate with interesting people, but this was not one of the more prominent expectations of any of the students. Again, while the differences point clearly in these directions, they do not reach statistical significance.

TABLE 3

EXPECTATIONS ABOUT WHAT THE ENGINEERING DEGREE ENABLES

(% strongly agree)

	Bioengineering	Non-bioengineering
Get a well-paying job	60.0	55.5
Get a job I like doing	46.7	35.8
Be an important contributor to society	40.0	31.3
Get a challenging job	40.0	39.2
Be respected by others	33.3	34.5
Get a job where I can use my talents	33.3	36.2
Choose to live in any geographic location	26.7	26.2
Get a secure job	20.0	36.0
Get a job associating with interesting people	13.3	20.8
Have time for outside interests	6.7	15.6

Future in Engineering

One of the concerns among engineers about bioengineering and biomedical engineering is that undergraduate students in these fields are not committed to engineering, but rather are using these studies as a stepping stone to medical school or graduate school in another biological field. Our data lend some credence to these concerns (Table 4). Asked "how likely do you think you are to change majors before you graduate?", the students remain committed to their undergraduate major to the same degree as non-bioengineering students, but a much smaller proportion expect to be working as engineers 10 years from now.

Students were asked what was the highest degree they expected to attain, and what was the highest degree in engineering that they expected to attain. If the highest degree they expected to attain was higher than the highest degree in engineering that they expected to attain, they were classified as "intending to get higher non-engineering degree than engineering degree." A quarter of the bioengineering students fell into this category, compared to 12.5% of the non-bioengineering students. This suggests that a higher proportion of bioengineering students are intending to leave engineering for another field, such as medicine, although 75% intend to stay in engineering through their highest degree.

Juniors and seniors were asked what their plans were following graduation. Forty-one percent of the bioengineering concentrates expected to continue to engineering graduate school, compared to 60% of the non-bioengineering concentrates; 10 % of the bioengineering concentrates expected to go to graduate school in another field, compared to 6.4% of the non-bioengineering concentrates. The differences are in the expected direction, suggesting that some of these bioengineering students may be intending to move out of engineering; the differences, however, are not large, and most are not statistically significant, so bioengineering does not seem to be primarily a stepping-stone out of engineering.

TABLE 4

PLANS FOR A FUTURE IN ENGINEERING BY BIOENGINEERING CONCENTRATE

	Bioengineering	Non-bioengineering
Likelihood of switching to a different undergraduate major (% very unlikely)	63.6	67.3
Likelihood of working as an engineer 10 years from now (% very likely)	30.8	63.7*
% expecting to continue to engineering graduate school	41.2	60.0
% expecting to continue to graduate school in another field	10.0	6.4
% intending to get higher non-engineering degree than engineering degree	25.0	12.5

*T-test significant at $p<.05$.

Discussion

It is too soon to tell whether bioengineering is attracting more women or not at this particular university, though the slightly higher proportion of women in the concentrate than among non-bioengineers gives some indication that this may be the case. Another sign is the increase in women enrolling in mechanical engineering this year: in previous years, usually there were only two or three women in the entire incoming ME class, accounting for 5-14% of all mechanical engineers; this year there were eight incoming mechanical engineering women out of 39 (20%), many of whom informally indicated an interest in bioengineering.

Perhaps more significant than numbers, however, are the subtle indications of a shift in culture, toward a group of engineering students impassioned by their vocation and motivated to contribute to society through engineering. Part of what is exciting about bioengineering is that it seems to be a step in the direction of changing the traditionally masculine culture of engineering, introducing more emphasis on doing good in society and self-actualizing ("getting a job I like doing") rather than putting an emphasis on making money and job security (extrinsic rewards). This shift in culture itself is a step toward attracting more women into engineering[7,9]. Even larger differences might be found where established and traditional engineering programs are refreshed

by bioengineering components. Indeed, bioengineering is introduced into engineering programs in many different forms. The subject of this paper is a concentration not a major. Questions are raised because of this, that future research should address. We do not know whether the dynamics would be the same in a stand-alone major, or a double-major; whether biomedical engineering differs from bioengineering; or whether there is a difference based on which department houses the bioengineering component in terms of the types of students attracted and the impact on the interpersonal climate; or whether the size of the bioengineering/biomedical engineering program relative to the rest of the engineering programs matters.

The small numbers in the current analysis point in directions that would do well with validation, whether from amassing multiple years of information from this university and/or from comparative studies elsewhere. Larger numbers will enable us to focus on differences between women in bioengineering and elsewhere as well as do more detailed comparisons between students committed to bioengineering as opposed to others. Such studies would give valuable lessons in how to grow engineering to be a more inclusive, diverse profession, which most will agree is a worthwhile endeavor.

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