Exploring the Appeal of Customizable Computing Programs to Undergraduate Women

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Abstract

Engineering programs commonly offer students few opportunities to choose their own courses as compared to their non-engineering campus peers. A previous exploratory study found positive correlations between the extent to which engineering degree programs afford students with course choice opportunities (such as free electives, technical electives, etc.) and the percentage of their bachelor's degrees earned by women. The results pointed to the need for additional research to ascertain whether undergraduate engineering programs can attract and graduate more women by providing more customizable degree program options. Similar to engineering, many undergraduate computing programs offer minimal course choice opportunities, thus constraining students in their ability to realize a broad and balanced education. And, a shortage of women is prevalent in undergraduate computing programs. This study delineated the course choice opportunities and balance of required technical and non-technical coursework in 37 computer science and computer engineering programs spanning 25 U.S. News & World Report top-ranked U.S. engineering colleges and looked for correlations between curricular choice, curricular balance and the percentage of bachelor's degrees earned by women. A positive correlation was found between the computing programs' curricular customizability and their percentage of bachelor's degrees earned by women; a positive correlation was also found between the extent to which the computing programs afforded students opportunities for technical—non-technical curricular balance and their percentage of bachelor's degrees earned by women. These preliminary results suggest that providing more flexible, customizable computing program options and/or opportunities to pursue a broad, balanced education may be a means of attracting more women to undergraduate computing programs.

Introduction

Many undergraduate engineering[1,2,3] and computing programs[4] offer students minimal freedom to choose their own courses and constrain students in their ability to realize a broad and balanced education. In a study spanning 62 computer science and computer engineering programs, computing students were afforded a median of 3% of their degree program as free electives, and choices in 49% of their total course selections. In contrast, chemistry, math, and physics programs at the same universities provided students with a median of 17% free electives and choice in 67% of their course selections.[4] The computer science and engineering programs required a median of 74% technical coursework (engineering, math and natural science) and 23% non-technical coursework, and—despite the broad, interdisciplinary nature of computing[5]—students in those programs had less opportunity to pursue curricular balance than their natural science and math peers.[4]

Does this matter? Beyond Self Determination Theory's emphasis on the basic human need for autonomy, facilitated through choice,[6,7] one preliminary study was suggestive of a potential correlation between the customizability of engineering programs' coursework and their percentage female enrollments and bachelor's degrees awarded to women.[1] In that study, percentages of total degree credit hours comprised of free electives and course choices were delineated for 84 highly-regarded (in terms of US News & World report rankings) engineering programs. Significant correlations were found between curricular choice and percentage female enrollments and

bachelor's degrees awarded to women; the greatest correlations were found for mechanical engineering (a discipline with a low percentage of women enrolled[8]). The results pointed to the need for additional research to ascertain whether undergraduate engineering programs can attract and graduate more women by providing more customizable degree program options.

In a multi-institution study that queried students about the primary factor that influenced their decision to leave engineering, 8% of student respondents indicated that they found the curriculum too narrow; one female student reflected, "The curriculum was extremely narrow…there was little to no room for any humanities…or any other type of class. I feel that this is a major failing of the engineering program."[9]

The same question about the potential impact of curricular choice applies to computing, which—like engineering—suffers from gender diversity that is not representative of the population at large, nor the over 50% of bachelor's degrees earned by women in the U.S. each year.[10] In 2014, just 14% of computer science and 12% of computer engineering bachelor's degrees were earned by women.[8] For comparison, across all disciplines, women earned 20% of engineering bachelor's degrees during the same year (range 12-48% by discipline)[8], versus 20% in physics, 42% in math and statistics, 49% in chemistry and 59% in the biological sciences.[11]

Flexible and balanced degree programs in computer science and engineering exist, are well-supported by the outcomes-based CAC and EAC accreditation approach,[12,13] and may appeal to a broader sector of students, facilitate in-migration and on-time graduation, and reflect evolving societal needs.

The present study aims to further this work by asking: *do customizable, balanced (in terms of technical and non-technical coursework) undergraduate computing programs have a differentially higher percentage of their bachelor's degrees earned by women?*

Methods

A sampling of 37 computing programs were delineated for this study using online university catalogs; this sampling was taken from a larger dataset that included the computer science and computer engineering degree programs at the 2013 U.S. News & World Report's top 22 engineering colleges at doctoral-granting institutions and the top 24 engineering schools at non-doctoral granting institutions. The engineering rankings were based solely on peer assessment surveys (US News & World Report, 2013). Thirty-five of the universities offered computer science and/or computer engineering programs. The curricular choice and technical—non-technical balance of computing programs from these 35 universities were presented by the authors in a previous paper.[2] A subset of these computing programs were included in the present analysis; to filter for larger degree programs that would be less prone to annual fluctuations in percentage female enrollments, the computing programs with more than 20 graduates in 2014 were included (n=37). These programs spanned 25 universities, including 18 doctoral-granting institutions and seven non-doctoral institutions. Data for bachelor's degrees awarded to women were gathered for each program from the American Society for Engineering Education online college profiles (ASEE, 2014).

The 37 computer science and engineering degree programs included 17 computer science, 14 computer engineering, 3 software engineering, and 3 computer science and engineering programs, each of which was a bachelor's of science program. Sixteen of the programs were EAC-accredited, eight were CAC-accredited, three were both EAC- and CAC-accredited, and 10 of the programs were not accredited.

Based on the number of bachelor's degrees awarded nationwide by discipline for the 2013-2014 academic year, the examined sampling of computing programs characterized the experience of 19% of computer science graduates (for programs inside engineering colleges) and 20% of computer engineering graduates.[8]

As of October 2016, this sampling represented 6% of the total number of four-year ABET-accredited programs in computer science and 6% of accredited computer engineering programs. Although the coursework data for this study was based on the 2013-2014 academic year, these 2016 percentages provide a reference point for the scope of the study since retroactive counts were not available on ABET's site. Because ABET uses an outcomes-based approach and does not require specific courses, it neither favors nor hinders different engineering disciplines in terms of the amount of choice in coursework they provide students.

Curricular Choice

Curricular choice was delineated for each degree program using data for two metrics that were gathered from the 2013-2014 online university catalog: 1) "percent free electives," the percentage of total degree credit hours that were free electives with no restrictions placed on course selections and 2) "percent total choice," the percentage of total degree credit hours that offered students a choice in the course they could take—including free electives, technical electives, humanities electives, etc., or picking a class from a menu or list of options.

Curricular Balance

Data for three curricular balance metrics were also gathered from the university catalog for each degree program: 1) the total percentage of the degree program that consisted of required technical coursework ("technical"), 2) the percentage of required non-technical coursework ("non-technical"), and 3) the total possible percentage of non-technical coursework ("possible non-technical"; required non-technical coursework plus free electives). Technical was defined as coursework in engineering, computing, math and natural science; non-technical was defined as coursework outside of engineering, computing, math and natural science.

Statistical Analyses, Software, and Data Presentation

The data were ordinal in nature; therefore, median (M) values are reported and non-parametric statistical analyses were used. Mann-Whitney U tests were used to detect differences between two independent groups. The Spearman's rho correlation statistical test was used to test for coefficients of association between curricular choice/balance metrics and the percentage of bachelor's degrees earned by women. Statistical analyses were performed using MVPstats; α=0.05.

Box-and-whisker plots are used to present the data, displaying the median (the center of the box), the first quartile (lower extent of the box), third quartile (upper extent of the box), and maximum (upper extent of whisker) and minimum (lower extent of whisker). In some cases, statistical outliers extend beyond the whiskers.

Results and Discussion

Curricular Choice

The free elective and total choice percentages for the 37 studied computing programs are presented in Figure 1.

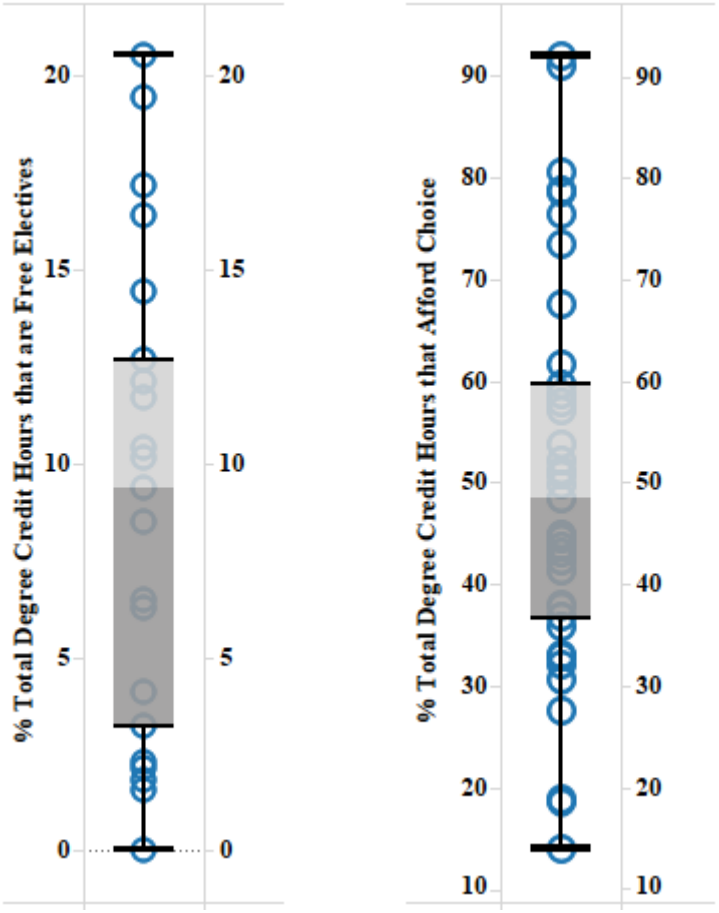

Figure 1: Percent free electives and percent total choice for 37 undergraduate computer science and computer engineering programs.

At the median, the programs allotted 10% free electives (range 0-21%) and 48% total choice (range 14-92%). The computer science programs allotted more free electives (M=10%) than the computer engineering programs (M=0%) (Mann-Whitney U p=0.006); analogous divergences were detected between the two computing program types for total choice ($M_{comp\ sci}$=60%, $M_{comp\ eng}$=36%; Mann-Whitney U p=0.000).

Curricular Balance

The required technical, required non-technical and possible non-technical coursework percentages for the 37 studied computing programs are presented in Figure 2.

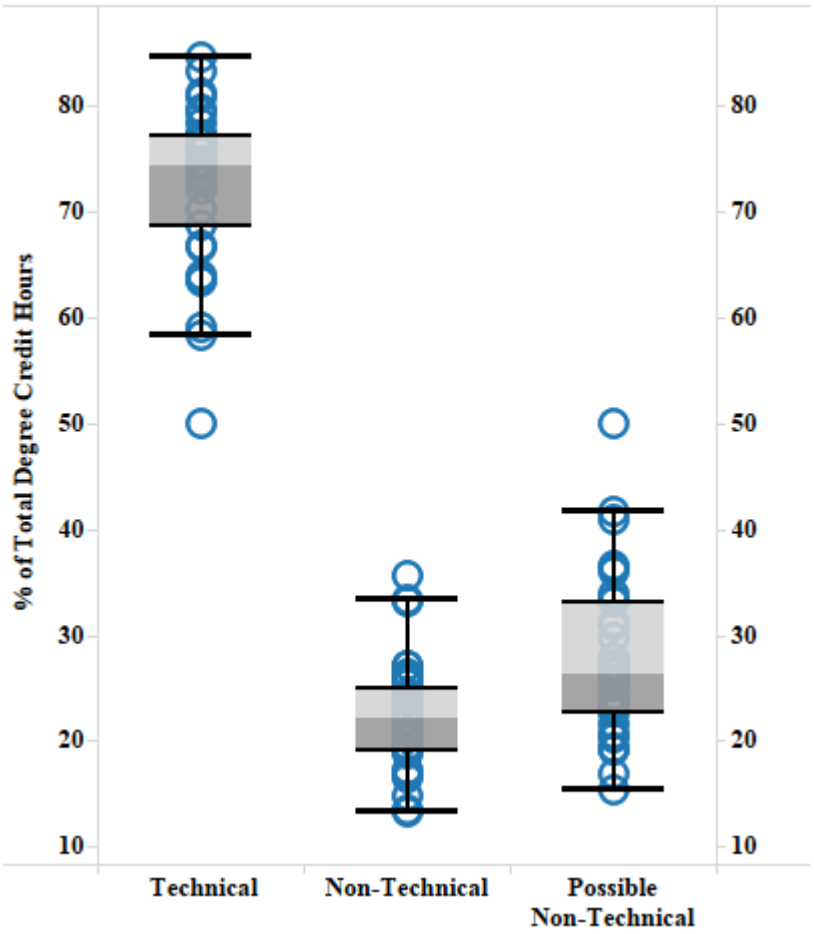

Figure 2: Percent required technical, required non-technical, and possible non-technical coursework for 37 undergraduate computer science and computer engineering programs.

At the median, the programs required 75% technical coursework (range 50-85%) and 22% non-technical coursework (range 13-36%); by "spending" free electives, it was possible to take up to 26% non-technical coursework (range 15-50%).

The computer engineering programs required more technical coursework (M=76%) than the computer science programs (M=70%) (Mann-Whitney U p=0.004); however, no difference was detected in the percentages of required non-technical coursework between the two engineering program types (Mann-Whitney U p=0.258).

Bachelor's Degrees Earned by Women

The 37 studied computing programs varied considerably (0-34%) in their percentages of bachelor's degrees earned by women (Table 1, Figure 3). Women earned higher percentages of computer

science degrees (M=20%) than computer engineering degrees (M=10%) (Mann-Whitney U p=0.007).

Table 1: 2013-2014 percentage of bachelor's degrees earned by women for 37 computing programs.

	All (n=37)	Computer Engineering (n=14)	Computer Science (n=17)
% bachelor's degrees earned by women, median (range)	14 (0-34)	10 (4-25)	20 (4-30)

Note: Software engineering (n=3) and computer science and engineering (n=3) programs are included in the "All" category but not presented in individual columns due to small sample sizes.

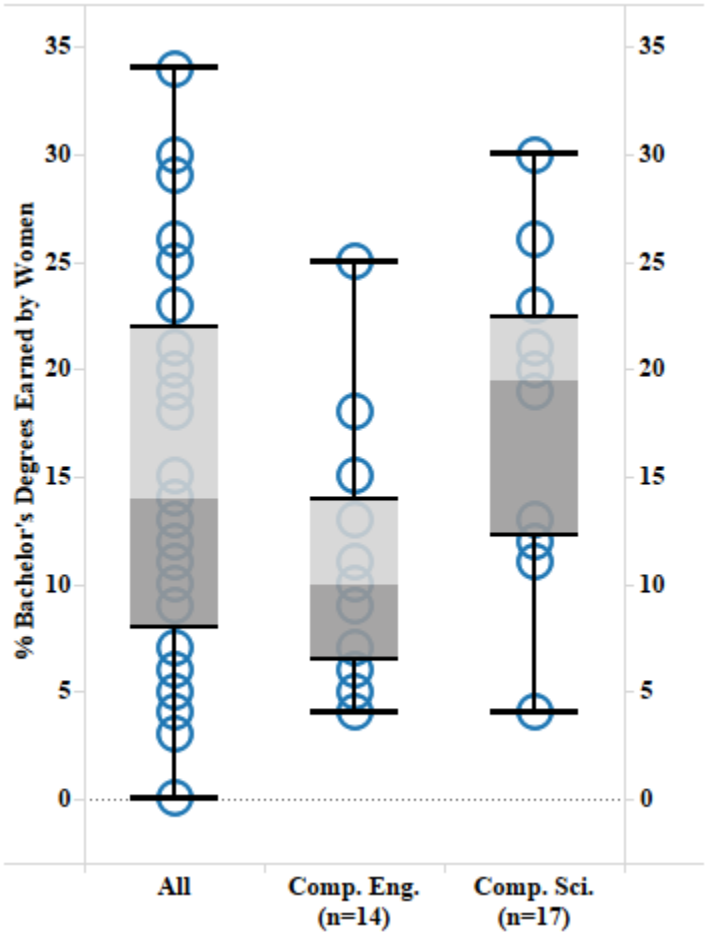

Figure 3: 2013-2014 percentage bachelor's degrees earned by women for 37 computing programs.

Curricular Choice, Balance and Degrees Earned by Women

Results of the Spearman's rho correlation tests (between curricular choice/balance metrics and the percentage of bachelor's degrees earned by women) are presented in Table 2. A significant positive correlation was found between the computing programs' total choice and their percentages of bachelor's degrees earned by women (p=0.002). A significant positive correlation was also found between possible non-technical coursework (i.e. the extent to which the computing programs afforded students opportunities for technical—non-technical curricular balance) and their percentages of bachelor's degrees earned by women (p=0.025). Significant correlations were not detected between the other three studied metrics and the percentage of bachelor's degrees earned by women.

Table 2: Spearman's rho correlation coefficients for 37 computing programs.

Computing Programs	% bachelor's degrees earned women M=13%
Free Electives M=2%	$.294^{0.077}$
Total Choice M=48%	$.494^{\mathbf{0.002}}$
Technical M =74%	$-0.287^{0.085}$
Non-Technical M=22%	$0.126^{0.459}$
Possible Non-Technical M=27%	$0.369^{\mathbf{0.025}}$

Note: Superscripts indicate p-values. Shaded cells and bold font indicate statistical significance.

Summary and Conclusions

Results from this study were preliminary and mixed. Innumerable confounding factors that impact a student's college experience, such as institution type, class size, student/faculty ratio, overall percentage female enrollment, etc., were not considered in this study. The positive correlations found between 1) the computing programs' curricular customizability and their percentage of bachelor's degrees earned by women, and 2) the extent to which the computing programs afforded students opportunities for technical—non-technical curricular balance and their percentage of bachelor's degrees earned by women are intriguing. These preliminary results beg this question: *might providing more flexible, customizable computing program options and/or opportunities to pursue a more broad, balanced education be a means of attracting more women to undergraduate computing programs?* Might these sort of curricular changes help attract a larger percentage of the nation's women to participate in the pervasive applications of computing that penetrate every facet of our economy and society? Might broader participation of women change the *nature* of the role of computing in our lives? The results from this preliminary study suggest the need for more qualitative and quantitative research to probe these broadening participation questions.

Acknowledgement

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