Increasing Women's Participation in Undergraduate Computing and Engineering with Systemic Change

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Introduction

The Extension Services for Undergraduate Programs (ES-UP) is a reform program of the National Center for Women & Information Technology (NCWIT) for increasing women recipients of bachelor's in computing. ES-UP uses a consultant-based approach to promote evidence-based practices for improving the experience of the major for all students, rather than expecting women to conform to existing, disadvantageous conditions [1]. Computing and Engineering departments ("Clients") who participated in the program were encouraged to adopt recruitment and retention strategies that bring the greatest return on investment in the shortest time with the smallest resource commitment, and which could be integrated into existing programs and practices. Increasing participation in undergraduate computing and engineering programs requires a multi-pronged, systemic approach including targeted recruitment, inclusive pedagogy, meaningful assignments and curriculum, academic and social support for students, high-level institutional support and appropriate policies, and ongoing assessment of progress [2], [3]. These components of the system experienced by students are represented in the NCWIT ES-UP Systemic Change model (see Figure 1).

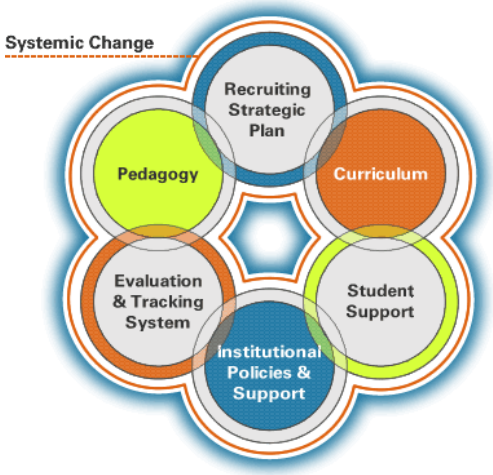

Figure 1: Systemic Change in Undergraduate Computing & Engineering

The NSF grant in division EHR/DRL was a five-year collaborative project between five institutions to serve the disciplines with the lowest representation of women: computer science, computer engineering, electrical engineering, and mechanical engineering. The collaborating institutions were:

1. The National Center for Women & Information Technology (NCWIT), housed at the lead institution, the University of Colorado at Boulder
2. ENGAGE (EngageEngineering.org), located at Stevens Institute of Technology
3. The University of Texas at Austin
4. The University of Virginia
5. The University of Washington Center for Evaluation & Research for STEM Equity provided both formative and summative evaluation of the project

The project guided and supported the efforts of college/university departments for a two-year period as they worked to increase their recruitment and retention of undergraduate women. Each client institution was required to obtain high-level administrative commitment and establish an interdepartmental team of change agents from computer science and at least one engineering department. In many cases, the cooperative department teams included multiple computing and engineering departments. Between 2013 and 2016, the ES-UP served 30 U.S. institutions divided into two cohorts, totaling 72 undergraduate degree programs: 33 Computing (including Computer Science, Computer and Information Science, Information Technology), 2 Aerospace Engineering, 12 Computer Engineering, 16 Electrical Engineering, and 9 Mechanical Engineering.

Objectives

The overarching goal of the project was to attract more and diverse women to undergraduate computing and engineering majors. Interdisciplinary computing and engineering teams on each client campus collaborated to expand the pool of women students who apply to, enroll in, and graduate from their majors; in the past, departments have competed for the same pool of women. Our approach to accomplish this goal included: 1) client departments working together to increase their pool of potential women students, instead of raiding each other's limited numbers and 2) client teams collaboratively creating and implementing a strategic recruiting plan and adopting a minimum of two retention strategies.

Progress was measured against three objectives:

1. Increases in number and percent of female applicants, admissions, and enrollments
2. Enrollments of women increase in client departments at a faster rate of increase than men's
3. Women's bachelor's completions increase at a faster rate of increase than men's

Program Description

Cooperative teams were supported by experienced consultants who are social scientist or evaluators, trained by the ES-UP scientists and principal investigators to identify and address the specific conditions that lead to women's underrepresentation in computing and engineering disciplines. A dedicated consultant educated, coached, and guided each client team over a two-year period. Each client team worked together to develop a strategic recruiting plan and retention strategies, received a $10,000 mini-grant to implement activities, and received travel funds to attend an annual meeting to share goals, ideas, and practices with other ES-UP client teams. Additionally, teams were required to provide data on applicants, enrollments, retention, and graduations for independent measurement of progress and to formally report outcomes of recruiting and retention activities.

Recruiting: The ES-UP created the workbook *Strategic Planning for Recruiting Women into Undergraduate Computing: High Yield in the Short Term*. This workbook prepared clients to develop a recruiting plan based on existing assets and local conditions [4]. The ES-UP strongly recommended that departments focus on reaching students with appropriate aptitudes who were

available to declare a major or minor within one to three years and recruitment efforts that target students already on campus, community college students, or juniors/seniors in high school rather than strategies with a longer time frame (e.g., outreach to middle schools).

Retention: The ES-UP also created the workbook *Strategic Planning for Retaining Women in Undergraduate Computing*, preparing clients to create a multi-pronged approach to retain women — and all students — in undergraduate computing and engineering programs of study [5]. We recommended retention practices that are mainstreamed into the institutional processes and procedures that affect all students, rather than initiatives such as extracurricular support groups that may help in the short term and benefit only those students who choose to participate. Moreover, one way to increase women's confidence in engineering is using Everyday Examples in Engineering (E^3s) [6] and improving their spatial visualization skills.

NCWIT Tracking Tool: The NCWIT Tracking Tool — a web-based database and presentation tool — allows academic departments to evaluate and promote their efforts for recruiting and retaining students. Departments provide numeric data to track enrollments (applicants, acceptances, new enrollments, total enrollments) and outcomes of students (attrition, retention, graduations) by major. The data is provided each year and includes gender, race/ethnicity, and transfer data. Once data is entered, the tool generates 14 unique "Reports" showing raw data, totals, and percentages by gender and academic year. These reports allow departments to assess how well they are doing with recruiting, retaining, and graduating students in their majors, and to pinpoint particular areas of concern. In addition, departments can visualize their data in dynamically-created, longitudinal trend charts; client departments submitted 4 to 10 years of data for each major [7].

Results – Quantitative and Qualitative Outcomes

Using data gathered through the NCWIT Tracking Tool by 30 clients (representing 62 computing and engineering degree programs), that participated in our project between 2013 and 2016, we investigated the numeric impact on applications, admissions, new-enrollments and graduations to underrepresented students. To measure the impact ES-UP had on recruiting efforts and increased undergraduate enrollments in computing and engineering majors, we conducted a matched pre/post analysis for Cohort 1 institutions (29 programs) that submitted data for academic years ending in 2012 (pre-participation) and 2015 (post-participation), before and after we served them. For Cohort 2 institutions (33 programs), we matched pre/post analysis for institutions that provided data for 2013 (pre-participation) and 2016 (post-participation); we did not have matched data for ten programs. After receiving consultation from ES-UP – and despite the recent surge in enrollments and unprecedented interested by male students in computer science – to date, departments reported the following recruitment successes:

- Women applicants to these ES-UP client departments combined grew from 2,973 (13% of all applicants) in 2012 to 5,784 (16% of all applicants) in 2016, representing 2,811 net new women applicants. On average, 703 new female applicants applied each year across the four year timeframe, representing a 24% increase per year. While the number of men applicants also increased, the increase was at a lower rate than that of women (95% for women, 52% for men). *It is important to point out that these are applicants, not*

acceptances, so the results can only be due to improved messaging and outreach, not to acceptance policies.

- Extension Services clients accepted 3,660 women applicants for admission in 2016, compared to 1,731 in 2012. Of all applicants accepted, 18% were women in 2016, while only 13% were women in 2012. On average, 482 women applicants were accepted each year over the four year timeframe, representing a 28% increase per year.
- The number of women who actually enrolled after being accepted also increased from 2012 to 2016. In 2012, 669 women enrolled in our clients' programs, while 1,170 enrolled in 2016. This represents an increase in newly-enrolled women from 2012 to 2016, from 11% to 14%. On average, 125 newly-enrolled students were women each year across the four year timeframe, representing a 19% increase per year. *(Many students apply to multiple institutions, so the number who actually enroll in an institution is generally smaller than the acceptances.)*

Using data collected from the National Center for Education Statistics Integrated Postsecondary Education Data System (NCES IPEDS) [8] for 15 Cohort 1 institutions (representing 46 computing and engineering degree programs), we compared pre/post data for academic years ending in 2012 (pre-participation) and 2016 (post-participation) to measure the impact ES-UP had on retention efforts and increased women's bachelor's graduation rates in each client's computing and engineering majors. For each institution, we downloaded IPEDS Completions data by gender for 2012 and 2016 for the following Classification Instruction Program (CIP) codes:

- Computer and Information Sciences, General (11.0101)
- Computer Science (11.07)
- Computer Engineering (14.09)
- Electrical, Electronics and Communications Engineering (14.10)
- Mechanical Engineering (14.19)

We found that the number of graduated students who were women increased from 412 (12% of all graduations) in 2012 to 768 (14% of all graduations) in 2016, representing 356 net new women graduates. On average, 71 graduated students were women each year across a five year timeframe, representing a 17% increase per year. While the number of men graduated also increased, the increase was at a lower rate than that of women (86% for women, 51% for men).

Adoption of Recruiting and Retention Interventions

The ES-UP reviewed each teams' recruitment plan and retention strategies, their mini-grant progress of activities, client survey results, and activities and outcomes reported in their final reports. Each client team reported on multiple activities and outcomes, below are a few systemic change interventions that were most impactful in increasing recruitment and/or retention.

Recruiting Strategies

- All client institutions conducted high school outreach events. Particularly, teams created information sessions that were accessible to prospective students through local high school college fairs, "teas" with the department, state fairs, diversity talks, "road shows" with student ambassadors in local high schools, residential campus experiences, and

targeted collaboration with high school teachers, counselors, and principals. For instance, an institution developed an ongoing relationship with principals and counselors at their feeder high schools that has allowed them to contact female juniors and seniors to advertise their computing and engineering programs.

- Departments improved their messaging about their programs by reaching audiences using different media such as improving their websites in ways that demonstrate that they are welcoming diverse faculty and students; clients also developed diverse videos that represents all students. In addition, departments provided relevant and accurate information (e.g., Talking Points") to admissions, advising, and other offices that might speak on their behalf to "tell the right story."
- Departments developed partnerships with Admissions to increase academic program knowledge and improve recruitment. For example, one team holds an annual training session to discuss key features of each program in their department, as well as current activities and opportunities. As a result, the admissions staff is more aware of the need to be inclusive and responsive to recruiting women in computing and engineering.
- Departments proposed seeking out women with undeclared majors with strong math ability as demonstrated by their ACT or SAT, or women who have been accepted to their program but who have not yet enrolled. An approach implemented included calling and sending personal email and/or paper letters to prospective students.
- Departments planned to work with other departments on campus that have higher proportions of female students such as Women's Studies or the College of Education to recruit women majors or minors who may be interested in computing or engineering.
- A computing and engineering department collaboratively developed a comprehensive articulation agreement with the largest community college network in their state, which resulted in an increase of female transfer applicants.

Retain with Teaching/Pedagogy

- In introductory computing and engineering classes, departments increased awareness of career opportunities with guest lectures exploring career pathways in academia and industry. Students were exposed to a broad range of topics such as virtual reality, data mining, human computer interaction and computer engineering. This helped students understand the field of computing and engineering.
- Departments redesigned labs to explicitly support pair programming in introductory programming classes. Departments also redesigned engineering lab exercises to include more examples based on real-world problems, following the recommendations of the ENGAGE program [6].
- Departments trained undergraduate teaching assistants (TAs) to foster collaboration among students, encourage students using "growth mindset" practices [9], and to be aware of unconscious bias.

Retain with Curriculum

- Departments restructured their introductory computing and engineering courses with projects and assignments intended to encourage all students to remain in the disciplines. For example, computing departments incorporated real-world applications of computer science topics including crime forecasting using real crime data, image processing, cryptography, and string processing problems from biology. As a result, students gained a

more in depth understanding of how computer science can be applied to real-world applications and make a significant societal impact.
- Departments created multiple sections for introductory programming courses, a section for inexperienced students, and another class for experienced programmers [10].

Retain with Student Support
- Faculty increased engagement with students in undergraduate research in computing (REU) [11].
- Departments implemented new supports for students such as the creation of study hall or mentoring programs open to all students.
- One institution holds an annual "Women's Summit," which brings together students, industry professionals, and alumni to discuss current topics relevant to women in STEM through panel discussions and breakout sessions. This event increased community building with faculty, alumnae, and industry professionals.

Institutional Policies and Support Initiatives
- One client team reported that the ES-UP project helped to focus their Provost's attention on the department's goal to recruit and retain women in computer science programs. The Provost attended all of the department's outreach events and took an active role in working with faculty on recruitment plans and grant fundraising to reach their recruiting and retention goals.
- Departments prioritized hiring high-quality female faculty in computing and engineering using NCWIT's resources on writing better job ads [12], reducing unconscious bias in job descriptions [13], and tips for conducting inclusive faculty searches [14].
- Institutions created dedicated administrative positions for diversity and inclusion and STEM positions to work on recruitment and retention.
- Departments held professional development workshops for faculty, staff, and graduate teaching assistants on topics such as sense of belonging, unconscious bias, stereotype threat, microagressions, and growth mindset.

Evaluation and Tracking Strategies
- All departments used the NCWIT Tracking Tool, which resulted in providing on-going annual collection of data that helped them identify that a weak point in their recruitment efforts was the yield of accepted students into enrolled students, which led departments to focus more attention on recruiting activities after students had been accepted.
- One client team reported that their most impactful activity with ES-UP was the use of NCWIT's Student Experience of the Major (SEM) Survey [15]. Administered in multiple computing and engineering courses, their findings indicated that students perceived their experiences differently based on race and gender. Therefore, the departments are implementing changes such as providing implicit bias training and modifying web and promotional materials.

Conclusions

The Extension Services for Undergraduate Programs (ES-UP) project worked with 30 client institutions (representing 72 computing and engineering degree programs) to furnish them with evidence-based resources to bring about systemic reform in disciplines where women and other groups are severely underrepresented. Our approach included client teams creating strategic recruitment and retention plans that were implemented within their institutional structure. These recruitment and retention strategies significantly raise the number of women who enroll and receive bachelor's degrees in fields such as computer science, computer engineering, electrical engineering, and mechanical engineering. Women's participation in these disciplines have significant impacts in the future of the computing and engineering disciplines.

Overall, the ES-UP approach was a successful intervention model for changing the way students experience the major. Between 2013 and 2016, departments working with the ES-UP increased women applicants from 13% to 16%, increased women acceptances from 13% to 18%, increased newly enrolled female majors from 11% to 14% and increased women graduation rates by 17% per year across the five year timeframe.

Additionally, new initiatives or programs were started at client institutions as a result of participation in the ES-UP project. Clients improved or increased the level of support available to all students in their program or college; departments engaged in outreach to their community; improved interactions between faculty and students; faculty and staff knowledge about diversity issues increased; and support for diversity work at the college or university level improved. This project has brought explicit, widespread attention to the institutions making concerted efforts towards attracting more and diverse women to undergraduate computing and engineering disciplines and documented their recruiting and retention interventions so that other institutions may emulate their practices.

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