Increasing the Enrollment, Retention, and Graduation of Undergraduate Women Majoring in Computing

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Abstract

Increasing the participation of women in undergraduate computing requires a multi-pronged, systemic approach that include strategic student recruitment, teaching practices, program curriculum, student support, high-level institutional policies and support, and evaluation of initiatives. The Extension Services for Undergraduate Program (ES-UP) at the National Center for Women & Information Technology (NCWIT) employs this systemic approach for changing the way students experience computing majors and has yielding notable success; computing departments that participated in ES-UP steadily increased the percentage of women declared majors from 12% in 2008 to 23% in 2019, ES participants steadily increased the retention rate of women declared computing majors from 77% in 2008 to 88% in 2017, and the percentage of degrees awarded to women steadily increased from 12% in 2008 to 22% in 2019. Moreover, ES participants continue to make progress over time. The greater the number of years since ES-UP consultation and implementing our systemic change strategies, the greater the progress in women declared majors and graduates with bachelor’s degrees in computing. While the results in this paper focus on computing departments, the recruitment and retention recommendations are applicable to engineering and other STEM disciplines where women are severely underrepresented.

Introduction

The Extension Services for Undergraduate Program (ES-UP) at the National Center for Women & Information Technology (NCWIT), promotes systemic reform in computing and engineering disciplines where women are severely underrepresented. Guiding our work are a wide range of empirically-supported social theories, such as expectancy value [1], social learning [2], social identity [3] and stereotype threat [4], implicit bias [5] and belonging [6]. The program is also influenced by theory and empirical findings particular to recruiting and retaining women at the undergraduate level [7-10], as well as studies of change in higher education organizations [11-14].

Since 2008, ES-UP has worked with computing or engineering departments at 129 U.S. institutions. Each ES participating institution worked with the program for a minimum of one-year up to a maximum of a four-year timeframe with a trained consultant, access to NCWIT’s extensive collection of research-based resources, and a community of peers; the timeframe depended on the funding available. To help academic departments identify aspects of their undergraduate programs that limit and enable women’s participation in computing and engineering, ES-UP developed the Undergraduate Systemic Change Model that include six components: 1) institutional policies and support, 2) student recruitment, 3) teaching practices, 4) program curriculum, 5) student support, and 6) evaluation of initiatives (Figure 1). The components, each based in theory and empirical studies, represent strategic recruitment and what gets students into the major (e.g., enrollment and other administrative policies); retention (supporting student’s sense of identity and belonging in the major through teaching, curriculum,
and extracurricular activities); and evaluation and tracking, to identify what is working and what is not working to shape mid-course and ongoing corrections to reach and maintain goals [15].

**Recommended Strategies for Recruitment and Retention**

Strategically, ES-UP strongly recommends that computing and engineering departments choose recruitment efforts with the greatest return on investment, shortest time to result in benefits, have the least impact on resources, and change the experience for all students. For example, initiatives include: targeting the low-hanging fruit - students with aptitude and motivation who can be in the classroom within a few years; leveraging existing on-campus assets and programs such as existing outreach programs or events held by admissions or other campus offices; crafting messages for students and their influencers such as parents, teachers, and advisors; aligning messaging with prospective students’ existing values, beliefs, expectations, or goals; ensuring that those representing the department “tell the right story;” reaching audiences using media such as the department website, post cards, and brochures that have a high chance of being accessed; and tracking results to determine which efforts are worth the scarce resources. Additionally, departments can create a minor or tracks in their existing major and treat student’s presence in early courses as recruiting opportunities since students can easily switch to other majors where they feel more comfortable [16].

**Figure 1: Undergraduate Systemic Change Model**

ES-UP recommends retention practices that are mainstreamed into the experiences for all students. Department-wide efforts which entails retaining with curriculum by engaging students with personally meaningful, social relevant assignments and offering multiple pathways into the major for inexperienced and experienced students. Retaining with pedagogy, which involves using teaching strategies to keep students engaged and learning together, such as collaborative learning and increase awareness of career opportunities. Retaining with student support that creates a sense of belonging and identity in classrooms, student-teaching assistant (TA) interaction, cultivate positive student-student and faculty-student interactions, such as mentoring programs and research experiences for undergraduates (REU’s), and give students more effective feedback using a growth mindset [17-20]. In addition to implementing recruitment and retention
strategies, systemic change requires adjustments to institutional policies and practices that comprise of high-level administrative support.

Finally, on-going evaluation of initiatives and tracking of progress should help guide the choice and implementation of recruitment and retention to identify what works and what doesn't to determine where to put your scarce resources. We highly recommend that departments develop and implement strategic initiatives rather than piecemeal efforts and put into action various initiatives to change the system.

**NCWIT Tracking Tool**

ES-UP developed a department-level longitudinal evaluation tool to track student participation and outcomes of recruitment and retention efforts, broken down by gender, race/ethnicity, academic level, and academic year [21]. This web-based database and presentation tool (Figure 2)\(^1\) helps departments improve progress toward increasing women's representation in computing and engineering by showing how many students have applied to their program, the number of students who were accepted into their program, and the actual number of students who enrolled in their program for an academic year. In addition, our tool shows a department how many students declared a computing or engineering major and determines the retention and attrition rate of the declared majors by gender. Furthermore, with enrollment data, we are able to ascertain graduation rates and inform a department about the representation of women and minorities in their program. The data collection process requires a department to work with its Office of Institutional Research to provide a minimum of four years of data so the tool can show trends over time.

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\(^1\) Generic C University is a fictitious institution name and is shown as an example of the NCWIT Academic Tracking Tool features.
The data in our sample for this paper is for computing only departments and focused on 62 ES-UP participating institutions. The sample profile consists of 4-year public or private not-for-profit U.S. institutions designated as doctoral universities with “very high” or “high” research activity (N=52), doctoral/professional universities (N=2), master’s colleges and universities with “large” or “medium” programs (N=6), a baccalaureate college (N=1), and a special focus institution (N=1) that offers bachelor’s degrees in Computer Science or Computer and Information Science. Participating institutions are geographically located in the Northeast (N=14), Southeast (N=15), Southwest (N=4), Midwest (N=15), Mountain West (N=4), the West (N=10).

Two data sources were used in the analysis. One source was the NCWIT Tracking Tool database regarding declared majors from 2008 to 2019 as well as attrition and retention data from 2008 to 2017. We are still collecting 2018 and 2019 retention data from ES participants. The other source was the National Center for Education Statistics (NCES) Integrated Postsecondary Educational Data System (IPEDS) [22] regarding first and second bachelor's awards/degrees conferred by program (CIP) from computing programs, Computer and Information Sciences (CIP 11.01) and Computer Science (CIP 11.07) for both the ES participants and all other 4-year public or private not-for-profit U.S. colleges or universities from 2008 to 2019. Community colleges and single-sex colleges and universities were excluded from the analysis.
IPEDS data analysis allows us to compare ES participants with non-ES institutions regarding the percentage of women graduating with bachelor’s degrees in computing. The finding informs us about ES participants’ percentage of women graduates from computing against the national average. Unfortunately, we couldn’t find a national data source to conduct similar comparisons regarding the percentage of women declared majors in computing. However, the NCWIT Tracking Tool data analysis still informs us whether ES-UP helps institutions recruit and retain more women in computing undergraduate programs.

We also investigated if the greater the number of years since ES-UP consultation and implementing our systemic change strategies, the greater the progress in women declared majors and graduates with computing bachelor’s degrees. We divided our participants into two groups: 1) ES 2008-2010 participants (N=31) that included institutions that joined ES-UP between 2008 and 2010; 2) ES 2013-2016 participants (N=31) that included institutions that joined ES-UP between 2013 and 2016. Analyses were conducted to show changes of women percentages from the first year institutions joined ES-UP to 2019 on declared majors and graduation.

Results

We first compared the percentage of women graduating with bachelor’s degrees in computing from ES participants with non-ES institutions between 2008 and 2019. The results are demonstrated in Figure 3. In 2008, ES participants had a much lower percentage of women graduating with BS degrees in computing than institutions of higher education that were not ES institutions (12% vs. 15%). Between 2008 and 2019, ES participants increased their percentage of women graduates from 12% to 22%. During this same timeframe, the percentage of women graduates from non-ES institutions increased from 15% to 19%. ES participants exceeded the national average by 3-percentage points in 2019.

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2 Non-ES Institutions are all U.S. 4-year public or private not-for-profit institutions, not served by the ES program by 2016. Community colleges and single-sex colleges and universities were excluded.
To further illustrate how important ES-UP is in increasing the number of women graduating from computing undergraduate programs, Figure 4 depicts the growth in raw numbers and percentages of women graduates from ES participants among the total bachelor’s degrees awarded to women in the U.S. Of the total computing bachelor’s degrees awarded to women among all U.S institutions, ES participants have increased their percentage from 6% in 2008 to 31% in 2019. To take two time points as examples, in 2011, one of every 10 women who graduated with a bachelor’s degree in computing was from an ES participating institution. Since 2016, one of every four women graduates has been from an ES participating institution. Meanwhile, ES-UP increased the total participant number from 22 to 62 by 2019, which only made up approximately 5% of U.S. institutions. This finding indicates that the ES-UP program plays a critical role in raising the number of women computing graduates in the United States.
 Besides the analyses using IPEDS bachelor’s awards/degrees conferred by program (CIP) data, we also examined declared majors, retention and attrition data for ES participants based on the NCWIT Tracking Tool. Since institutions have different admission processes and data tracking systems, not all of them provided data for declared majors and student retention. Therefore, the number of institutions reported varied by years. For those who reported to the NCWIT Tracking Tool, results showed that ES participants steadily increased the percentage of women declared majors in computing from 12% in 2008 to 23% in 2019 (Figure 5). They also steadily increased the retention rate of women declared computing majors from 77% in 2008 to 88% in 2017 and narrowed the attrition gap between women and men declared majors from 7% in 2008 to 2% in 2017 (Figure 6). These findings provide evidence that ES-UP’s systematic approach helped computing departments to recruit and retain more women in their programs.
Figure 5: ES Participants Steadily Increased the Percentage of Women Majoring in Computing Over the Years

Figure 6: ES Participants Increased the Retention Rate of Women and Narrowed the Attrition Gap Between Men and Women within Computing Majors
Moreover, we further investigated if ES participants continue to make progress over time by examining the percentage changes from the first year institutions joined ES-UP to 2019 on women declared majors and graduation in computing. Table 1 and Table 2 demonstrate changes in percentages for ES 2008-2010 participants and ES 2013-2016 participants. The results showed that ES participants from both groups increased percentages of women who declared majors and graduated from computing programs. ES 2008-2010 participants had bigger increases in the percentage of women declared majors and graduated students than the ES 2013-2016 participants. This finding provided evidence that the greater the number of years since ES consultation and implementing the systemic change strategies, the greater the progress in women declared majors and graduates with bachelor’s degrees in computing.

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<tr>
<th>Table 1: Change in Percentage of Women Declared Majors in ES Participants</th>
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<tr>
<td><strong>First Year of ES-UP</strong></td>
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<tr>
<td>ES 2008-2010 Participants (N=25)</td>
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<tr>
<td>ES 2013-2016 Participants (N=30)</td>
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<tr>
<th>Table 2: Change in Percentage of Women Graduated Students from ES Participants</th>
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<tr>
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To understand how recruiting and retention practices have influenced enrollment, retention and graduation, the authors examined institutions’ self-reported recruiting and retention strategies and activities. These strategies were reported in client survey results and final reports with progress of recruitment and retention activities. Figure 7 highlights systemic change interventions that were most widely used in increasing recruitment and/or retention among ES participants [23]. Please note that it is beyond the scope of this paper to infer any causal claims between adopted strategies and the increase of women percentages in enrollment and graduation.
ES participating institutions have played a critical role in closing the gender parity gap of undergraduate women in computing. ES participants started off with a lower percentage of women with computing bachelor’s degrees in 2008 as compared to other U.S. institutions (11% vs. 15%), but exceeded the national average by 3 percentage points in 2019. They also steadily increased the percentage of women declared majors in computing and the retention rate of both men and women declared majors. The greater the number of years since ES consultation and implementing our systemic change strategies, the greater the progress in women declared majors and computing bachelor’s degrees. Moreover, ES participants utilized the Undergraduate Systemic Change Model to revise socio-educational systems rather than “fixing” the women and demonstrated sustainability of systemic change initiatives. For faculty and staff in undergraduate computing interested in making similar improvements, the strategies discussed are worth considering, and if found suitable, customizing, trying, and revising.

ES-UP is an on-going project. With previous funding, we worked with institutions that were required to create collaborative teams that included both computing and engineering departments and our recruitment and retention strategies were implemented for both disciplines [23]. Recently, we have created a new implementation and consulting process that serves small institutions (e.g., liberal arts colleges and universities and community colleges). Additionally, the Extension Services Graduate Program (ES-Grad) has been established to provide consulting services to doctoral Computer Science programs to support them in admitting women into their
programs, retaining them through completion, and placing them in research careers [24]. The National Center for Women & Information Technology (NCWIT) also addresses workplace cultures and practices for women in industry through our Workforce Alliance [25].

It is important to note that the adoption of recruitment and retention interventions highlighted in this paper is a compilation of activities of what ES participants have done; however, it’s not a one-on-one relationship between the practices and the enrollment and graduation outcomes. At this time, we can’t say which of the individual practices are responsible (if any) for the increase in recruitment or retention of women into computing though one of our recent papers used a mixed methods design to investigate recruiting strategies and outcomes (i.e., women’s applications, acceptances, new enrollments, and declared majors in computer science) of seven ES participants. The findings shed light on some recruitment practices which helped these institutions make substantial improvements in attracting women into their computer science programs [26]. ES-UP will continue our research efforts to determine which recruitment and retention practices are directly related to the enrollment and graduation outcomes. Future research will also include collecting more qualitative intervention data and quantitative outcome data to examine the Undergraduate Systemic Change Model.
References


