A Systemic Approach to Recruiting and Retaining Women in Undergraduate Computing

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ABSTRACT

Extension Services for Undergraduate Programs (ES-UP) at the National Center for Women & Information Technology (NCWIT) employs a multi-pronged, systemic approach to increasing the enrollment and retention of women in undergraduate computing departments. ES-UP advocates for improving the environment for all students using research-based strategies that correspond to the six components of the NCWIT ES-UP Systemic Change Model. This paper describes the ES-UP Systemic Change Model, presents evidence supporting the effectiveness of ES-UP’s approach, shares innovative examples from successful ES-UP client departments, and highlights relevant resources and strategies that undergraduate computing departments can implement themselves. Many of ES-UP’s recommendations are broadly applicable to engineering and other STEM departments where women are under-represented.

INTRODUCTION

Extension Services for Undergraduate Programs (ES-UP) at the National Center for Women & Information Technology (NCWIT) employs a multi-pronged, systemic approach to increasing the enrollment and retention of women in undergraduate computing departments. ES-UP advocates improving the environment for all students using research-based strategies that correspond to the six components of the NCWIT ES-UP Systemic Change Model. The components include creating a Recruiting Strategic Plan; retaining students with Inclusive Pedagogy, Curriculum, and Student Support; securing appropriate Institutional Policies and Support; and finally, implementing a comprehensive Evaluation and Tracking System (See Figure 1.)

Figure 1. Systemic Change in Undergraduate Computing
The following points are key to ES-UP’s approach:

1. Strategies are chosen that bring the greatest return on investment in the least amount of time to bring results.
2. Efforts focus on changing the system, rather than changing the student.
3. Institutional contexts vary, thus solutions must be adapted to local conditions.
4. Change must be systemic in order to be sustainable.
5. Components of the model are highly interconnected. For example, it makes little sense to put effort into recruiting students if they cannot be retained. Similarly, ongoing evaluation and tracking should guide recruitment and retention initiatives, and institutional support is needed to implement significant and sustainable changes in other areas.

Below, we first present recent outcome data supporting the effectiveness of ES-UP’s approach. Then, we describe the individual components of the NCWIT ES-UP Systemic Change model and relevant practices for recruiting and retaining undergraduate women. Specific examples from successful ES-UP client departments are highlighted.

**SUPPORT FOR THE ES-UP SYSTEMIC CHANGE MODEL**

ES-UP provides client department(s) with a trained consultant who assists with the development and implementation of a strategic plan that addresses all components of the systemic change model. Consultants typically hold doctoral degrees in education, sociology, evaluation, or other relevant social sciences and are deeply knowledgeable about social theory and change.

To date, NCWIT ES-UP has worked with 72 institutions, representing 74 computing departments and 92 undergraduate computing majors. (Some efforts also included engineering departments (n=41) with historically low representation of women, however, data presented are for computing only.) We have served these clients across multiple cohorts, beginning in 2007 through the present. We present an analysis of short-term gains achieved by clients we served beginning in 2013, followed by a long-term analysis of clients we served in our first five years of funding (from 2007-2012). We demonstrate gains in attracting women into the major, in retaining them in the short term, and in graduation rates.

**Short-term Gains: 2013-2016 Clients**

We combined data from institutions using the NCWIT Tracking Tool [1], an online tool into which clients submit data on applications, acceptances, and new enrollments; total declared majors and students retained; and graduations. We also use graduation data from the National Center for Education Statistics [2]. Below, we present data from analysis of clients who submitted data for both the baseline year that preceded their work with ES-UP, and data for the post-service year following consultation (n=28 institutions). The pre-ES-UP baseline data includes academic years 2011-2012 or 2012-2013, depending on whether the clients began their work with us in 2012 or 2013. The post-ES-UP data is from three years later, academic years 2014-2015 or 2015-2016.
More women applied to client departments’ majors over baseline. Clients created a strategic recruiting plan in the first year, which they implemented within one year of beginning as an ES-UP client. Figure 2 shows that clients successfully marketed their majors to increase applications of women.

- 2.5 times more women applied compared to 2 times as many men.
- Women applicants grew from 14% to 18% in just two years.

The increase in applicants is due only to improved marketing and outreach efforts, not due to any changes in policy as might be seen with increased acceptances.

Clients accepted more women and a higher percentage of women over baseline. Facing a huge enrollment boom over the past five years, clients accepted many more students, both men and women, but accepted women at a higher rate than men, as shown in Figure 3.

- 2.2 times more women who applied were accepted, compared to 1.6 times as many men between the baseline year and the outcome year.
- Acceptances of women grew from 16% to 20% in just two to three years.

Figure 1. More Women Applied to Computing Majors from Baseline to Post-Consultation (source: NCWIT Tracking Tool)

Figure 2. Women’s Share of Acceptances Increased from Baseline (source: NCWIT Tracking Tool)
More women enrolled in clients’ majors.
Enrollment yield is the percent of students accepted who actually enroll in the major. The yield of both men and women increased in client departments, but women’s yield increased at a higher rate than that of men, as shown in Figure 4.

- 2.2 times more women enrolled in the majors, while only 1.6 times as many men enrolled over the pre-ES-UP baseline.
- Women made up 17% of newly-enrolled students, up by 4% in two to three years.
- Women also made up 18% of total declared majors after two years, up by 5% from before ES-UP consultation.

Graduations, a lagging indicator, increased.
Although the time frame studied was too short to track students from first year through graduation, the percentage of women who graduated from the most recent cohorts increased between 2012 and 2016. Many of the clients ES-UP worked with during this period were among the largest producers of bachelor’s degrees in computing in the U.S., and the larger the major, the smaller the percentage of women tends to be [3]. As shown in Figure 5,

- ES-UP clients graduated 2.6 times as many women, but only 1.9 times as many men in 2016.
- The percent of women graduates in these departments grew from 13% to 18% over four years.

Long Term Gains: Earliest ES-UP Clients Surpass National Rate of BS Degrees Awarded to Women
During 2007-2011, ES-UP served 32 clients awarding bachelor’s degrees in computing. These degrees are categorized as Computer and Information Sciences, General and Computer Science
Recruiting and Retaining Women

(Classification of Instructional Program [CIP] 11.01 and 11.07, respectively\(^1\)). In 2016, these 32 earliest clients awarded nearly one-eighth of these BS degrees in public and not-for-profit private institutions in the U.S. Like many large departments [3], they were among the worst performing in the U.S. with respect to graduations of women when they began their work in 2007. After putting sustainable programs in place, by 2016 they awarded 21% of their bachelor’s degrees to women, as shown in Figure 6, surpassing the national average of 18%. (Data source: National Center for Education Statistics [3])

Figure 5. For NCWIT ES-UP 32 Earliest Clients, % Women Awarded BS Exceeded National Average in 2016 (Data source: National Center for Education Statistics)

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\(^1\) This analysis presents data from degrees awarded under Classification of Instructional Program (CIP) code 11 and sub-codes, as categorized by the National Center for Education Statistics. CIP 11 is an umbrella code for all program types. Three program types made up 87% of the degrees awarded in 2016. These include 11.01 (Computer and Information Sciences, General; 42% of all CIP 11), 11.04 (Information Science; 11% of all CIP 11), and 11.07 (Computer Science; 34% of all CIP 11). 11.04, Information Science, can be either a technical degree or non-technical degree, including majors called “informatics,” “IT security policy analysis,” and “library and information science.” Nationally, Information science awards 24% of bachelor’s degrees to women on average, ranging from 6% to 54% among programs that awarded 30 or more degrees in 2016. However, when using only 11.01 and 11.07 in the analysis, the national average degrees awarded to women is 18%. Because 96% of the degrees reported by earliest ES-UP clients were in CIPs 11.01 and 11.07, we compare to the national average of these two categories above. Also excluded is the all-women school we served to avoid the slight skewing of the data.
THE ES-UP SYSTEMIC CHANGE MODEL

The following sections explain the components of the ES-UP Systemic Change Model and identify related resources. Successful strategies implemented by recipients of the NCWIT Extension Services Transformation Award (NEXT)\(^2\) are highlighted.

**Systemic Change Model Component 1: Strategic Recruiting**

Strategic recruiting focuses on achieving the greatest return with the least investment of resources. For example, outreach to students in middle school and younger is not a recommended recruiting strategy because the likelihood that participants will eventually enroll in a particular undergraduate program is low and far in the future. Instead, ES-UP recommends prioritizing women who are available to declare a computing major within the next 1 to 3 years, such as high school students, community college transfer students, and students who are already accepted or enrolled at the institution. For example, high school students can be targeted with outreach to feeder schools and by establishing relationships between the undergraduate program and important influencers such as guidance counselors and teachers. Encourage students already accepted to an undergraduate program to enroll by hosting events to help them get to know the department and by having faculty or current students establish personal contact through phone calls, email, or mail. Introductory CS classes and classes for non-majors provide an opportunity to reach undecided students who are already enrolled at the institution. Introductory classes should be designed to encourage, not discourage, students’ interest in computing, and faculty can explicitly encourage promising students to consider a computing major.

Effective messaging is vital for recruiting. Focus on broadly appealing aspects of computing such as collaboration and application to real-world, socially relevant problems [4], [5], [6], and avoid perpetuating stereotypes of computing that are off-putting or lead women to believe they won’t fit in [7], [8]. For marketing materials and websites, choose images that show diverse people working together on interesting projects, and emphasize the wide variety of careers in computing. Provide “talking points” for those who come in contact with prospective majors, such as advising and

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\(^2\) NCWIT’s NEXT Award recognize ES-UP client institutions for excellence in successfully implementing ES-UP recommended strategies and demonstrating sustained progress in increasing the representation of women in their undergraduate computing programs.
admissions personnel, and make sure they understand and can effectively communicate about the reality of computing and the diversity of people who can succeed at it. Address barriers to entry such as admissions criteria or unnecessary course prerequisites that may disadvantage certain students or be biased against those who lack programming experience.

ES-UP strongly recommends creating a Recruiting Strategic Plan to guide efforts. A strategic plan identifies the issues to be addressed, sets specific goals, describes the activities or initiatives to be implemented, specifies the timeframe, assigns tasks to specific people, and plans for evaluation and reporting of results.

**Recommended Resources**
A strategic plan template and additional information on recruiting can be found in the workbook *Recruit Strategically: A “High Yield in the Short Term” Workbook for Attracting Women to Undergraduate Computing and Engineering*. The workbook, along with *Tips for Creating Inclusive Academic Website*, and many additional Promising Practices, Programs-In-A-Box, and other resources, can be found at NCWIT.org/resources.

**Systemic Change Model Components 2, 3, and 4: Retaining with Pedagogy, Curriculum, and Student Support**
Pedagogy, Curriculum, and Student Support comprise the three components of ES-UP’s Systemic Change Model that address the challenges of retaining students. Women not only enter computing majors at lower rates than men, but they are also more likely to leave [9], [10]. Contributing factors include stereotypes that undermine feelings of belonging, lack of positive interactions with peers and faculty, loss of confidence in their abilities, and lectures and assignments that are unappealing or lack real-world context [10]-[16]. ES-UP strongly recommends mainstreaming retention practices that counteract these conditions into the experiences of all students, not just those of underrepresented students. Efforts that specifically support women or other underrepresented students, such as extracurricular support groups, reach only those students who choose to participate and often only for as long as funding or a champion is available.

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**Case Study: Retaining with Pedagogy**
(P)rimary changes were to introduce pair programming to enable collaborative learning, along with placing undergraduate peer tutors in the labs to provide immediate help for students who get stuck. Both changes helped to develop a sense of community in the labs rather than a competitive environment. Results showed that these changes were extremely successful as determined by passing rates and follow-on surveys. – University of California, Irvine, NEXT Award 1st Place, 2016.
Retaining with Pedagogy. The use of personally meaningful, socially relevant assignments promotes retention of women and underrepresented students [12], [14]. Instructors can explain how a concept is used for different types of applications, describe the rewards of a career in computing, survey the class to gauge interests, and offer choices to students. However, care should be taken to avoid falling back on stereotypes of what women and men like (for example, assuming that women like communicating and men like games). Teaching practices that create an inclusive, collaborative environment should be integrated early in the curriculum and include pair programming, peer-led team learning, discussion and problem solving groups in class, and the conversational classroom [17]-[19]. Providing timely feedback on assignments and sharing information such as the class mean and standard deviation helps students accurately judge their progress. Encouraging students to adopt a “growth mindset,” where they understand that success results from effort and hard work rather than innate ability, has been shown to improve confidence, performance, and the ability to persist in the face of challenge [20].

Retaining with Curriculum. Students entering computing programs vary in their previous programing experience. Introductory classes that separate students by experience level prevent inexperienced students from being intimidated by more experienced classmates and help ensure that they are well-prepared for successive courses. Furthermore, true introductory-level classes can be valuable recruiting opportunities, as they often attract non-majors and undecided students. If offering separate classes is not feasible, other methods such as supplementary support classes, study groups, or summer bridge programs can help inexperienced students succeed. If points where students tend to leave the program can be identified, departments should consider whether modifications to specific courses or to the course sequence (e.g. avoiding requiring two particularly difficult courses to be taken simultaneously) are warranted. Offering

Case Study: Retaining with Pedagogy
When re-evaluating (the introductory course), it became clear that most students have no idea of what Computer Science is about. They have never taken a course in it; most of them have never heard of it. The course now starts with what CS is, how CS impacts the students’ lives, and how CS is an integral part of every major at U-M. How CS is in every aspect of our lives. When students are challenged to give one career that CS does not impact, they conclude that CS impacts every degree at U-M. – University of Michigan, NEXT Award 2nd Place, 2017

Case Study: Recruiting and Retaining with Curriculum
Based in part on the success of the Informatics Minor, in 2010 we began developing a “CS+X” set of majors within the College of Liberal Arts and Sciences (LAS). The vision was to provide students with a strong computing foundation – no weaker than that of the CS majors in the Engineering College – but coupled with advanced work in an LAS discipline rather than more advanced work in areas such as operating systems, compilers, theory, networking, etc. … Our first four new degrees were CS+Anthropology, CS+Astronomy, CS+Chemistry, and CS+Linguistics, all which began admitting freshmen in fall 2014… Each of the three years they’ve existed, roughly 27% - 30% of enrolling majors were women. – University of Illinois at Urbana-Champaign, NXT Award 1st Place, 2017 (see also [21])
curricula that align with students’ career interests is another way to both attract and retain students. Many computing departments now offer major, minors, or tracks within their programs that combine computing with another field of study.

**Retaining with Student Support.** Positive student-student and student-faculty interactions promote student engagement and create a sense of community. Interactions can be facilitated through collaborative learning in classrooms and peer, tier, or faculty mentoring programs. Research experiences for undergraduates (REUs), attendance at conferences such as Grace Hopper and Regional Celebrations for Women in Computing, and participation in departmental outreach and recruiting activities can help solidify a student’s computing identity. A welcoming physical environment that doesn’t invoke negative stereotypes of computing also contributes to a sense of belonging [22]. Mandatory advising and an early alert system for students who fall behind can identify students in need of assistance.

ES-UP generally discourages student support initiatives aimed at women only, such as women’s groups. Although potentially helpful in the short term, they are effective only for those who participate and risk reinforcing stereotypes that women are deficient or in need of extra help [23], [24].

**Recommended Resources**

ES-UP strongly recommends creating a *Retention Strategic Plan* to guide efforts. A template can be found in the workbook *Strategic Planning for Retaining Women in Undergraduate Computing*, which along with many Promising Practices, Programs-In-A-Box, and other resources can be found at NCWIT.org/resources. EngageCSEdu.org is a free online repository of CS1 and CS2 materials selected for their use of research-supported student engagement practices. All materials in the repository are contributed by CS faculty and peer-reviewed.
Systemic Change Model Component 5: Institutional Policies and Support

Long-lasting systemic change requires adjustments to institutional policies and practices and visible, high-level support from administration. For example, providing release time for faculty or creating an office, committee, or staff positions focused on diversity and inclusion helps ensure that efforts are ongoing and sustained. Faculty who engage in diversity efforts should be recognized and rewarded in meaningful ways, for example, by counting their work towards tenure or promotion. Resources and administrative support are needed for initiatives such as creating new majors and minors, changing curriculum, modifying admissions procedures, and hiring more and diverse faculty (particularly those who are skilled instructors and demonstrate commitment to diversity and inclusion).

Systemic Change Model Component 6: Evaluation and Tracking

To ensure that limited time and resources are well-spent, ongoing evaluation of practices and tracking of progress should guide the choice and implementation of the recruiting and retention initiatives. Evaluation can be relatively simple, use pre-existing survey instruments, or make use of information already collected by the institution. For example, evaluate recruitment events by monitoring attendance and outcomes and by surveying or briefly interviewing participants. Entry and exit surveys of enrolled students can help illuminate what attracted them to the program and the quality of their experiences while there. NCWIT’s Student Experience of the Major Survey assesses departmental climate and identifies factors in the program that increase or decrease students’ intention to complete the major.
Track overall recruitment and retention outcomes with data collected by the department or institutional research office to document progress towards larger goals and to evaluate the department’s progress relative to peer institutions. The NCWIT Extension Services Tracking Tool is free and can be used to chart enrollment and outcome data broken down by sex, race/ethnicity, and academic year. Evaluation data can also be used to support bids for internal and external support for recruiting and retention activities.

*Recommended Resources*

Survey-in-a-Box: Student Experience of the Major Survey and NCWIT’s Evaluation Tools collection are available at NCWIT.org/resources and information about the NCWIT Tracking Tool is at trackingtool.ncwit.org.

**CONCLUSIONS**

The ES-UP Systemic Change Model provides a useful and proven framework for changing the system (not the student) to increase representation of women in undergraduate computing departments. This multi-pronged approach entails implementation of research-based strategies to increase recruitment and retention of women, backed by favorable institutional policies and support, and guided by comprehensive evaluation and tracking of progress.
REFERENCES


