



Assessing the Success of Programs for Women in Engineering

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In 2009 Dr. Bottomley was selected for a Presidential Award for Excellence in Mathematics, Science and Engineering Mentoring by the White House Office of Science and Technology Policy and by the Educational Activities Board of the IEEE for an Informal Education Award. She was also inducted into the YWCA Academy of Women in 2008 for her contributions to eliminating racism and empowering women and was selected as the 2011 Woman of the Year by the RTP chapter of Women in Transportation. In 2013 she was named one of 125 Transformational Women by NC State University.

In her role as director of The Engineering Place at NC State, Dr. Bottomley and her colleagues reach more than 10,000 students, 2000 teachers and 1500 parents each year. The programs she leads include summer camps for K-12 students; programs that send undergraduates and graduate students into schools to work with elementary and middle school students; training sessions for NC State engineering alumni who want to be volunteer teachers in their communities; and professional development and classroom support for K-12 teachers who want to introduce engineering concepts to their young students. In addition, she co-authored statewide engineering standards for K-12 and delivers teacher professional development in integrated STEM. Bottomley also directs NC State's Women in Engineering program, which works to boost the number of women engineers in academia and industry. The NC State Women in Engineering Program was selected as the outstanding program for 2008 by WEPAN, the Women in Engineering Program Advocates Network for the progress made in recruiting and retaining women students in engineering at NC State University. In addition to her roles at the University, Dr. Bottomley has taught fifth grade science as a volunteer consultant, helped schools reinvent themselves as engineering magnet schools and acted as a consultant to the N.C. Dept. of Public Instruction and Wake County Public Schools. She served on a national team for the National Assessment of Educational Progress developing an assessment for engineering and technological literacy, works with IEEE and the National Academy of Engineering on the Engineering Equity Extension Project and served as a curriculum consultant on a National Science Foundation Gender Equity grant. She also co-authored the Engineering Connections to STEM document published by the North Carolina Department of Public Instruction. She is currently serving on a committee with the National Academy of Engineering, Guiding the Implementation of K-12 Engineering.

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Most professionals working in the field of diversity at a College of Engineering are aware that the nationwide percentage of females in engineering has been relatively stagnant. With ample highly qualified students at the high school level, colleges and universities are yet challenged to recruit those students to their engineering programs, and keep them there. Many efforts have been and are underway to make a difference in this regard. The National Academy of Engineering document, Changing the Conversation¹, suggests several approaches to changing the view of the identity of engineering both as a field of study and a field of work. North Carolina State University has had in place a Women in Engineering Program (WIE) for 15 years and a Women in Science (WISE) Living and Learning Community for seven years. This WISE community has played an integral role in the strategy to increase the percentage of women in the College of Engineering through both recruitment and retention. In addition to WISE, certain other select recruitment strategies have also been put in place, such as a bridge program for incoming female students, a revision of recruiting materials, and others. This paper will describe some of the assessment data collected to determine the effectiveness of these strategies with regards to both recruitment and retention of female students. Data provided will include performance and retention data for women participating in various programs, such as WISE, versus non-participating females and males. Also described will be specific, innovative strategies that have been put into place, such as a department head workshop and specific department partnerships aimed at retention. All of these strategies have resulted in an eleven percentage point increase in women in engineering and a retention rate for females that exceeds that of males.

Introduction

The Women in Engineering Program at NC State University has been undergoing a renaissance in a concerted effort to shift the paradigm of our approach to recruitment and retention. The language we use to portray ourselves is very much in line with the NAE report on Changing the Conversation¹. Programs and special efforts can be found in several areas, specifically targeting different goals such as recruitment of a higher percentage of female students to the college, recruitment of a more even distribution of female students across the various engineering disciplines and retention of female students in engineering through joining a department (in their second year, normally) and graduation.

The thought model used by the Women in Engineering Program at NC State is that of a journey, rather than a pipeline. In grades K-10, students must be interested in and informed about engineering, including the coursework that will be helpful for them to take in high school. In grades 11 and 12, students must be kept interested and recruited to the university. Once students arrive on campus, they need to be brought in and incorporated into the “engineering family,” so that they are retained through the first year. In their second year, students join a particular engineering department, so the retention focus shifts to departmental culture and pathways. Finally, students who are retained through graduation need to be supported as they move on to industry, government or academia. Women in Engineering programming is designed around this visualization.

Recruitment

Recruitment of students has two primary pathways: email blasts and receptions for high achieving students. Changing the Conversation¹ has been a guide for reworking both. At receptions for admitted students, aimed at increasing yield, very simple-seeming changes have been made. Engineering staff who present are selected to include half women. Students who present are also carefully selected for the image they portray. More pictures of people are used in the presentations,

and they portray a diverse student body. Overt references to women being underrepresented have been removed. Instead, the ways in which the College addresses real-world problems and the diverse College faculty who do so, are highlighted. Some sample PowerPoint slides are shown in Figure 1.



Figure 1: Sample PowerPoint slides used at recruiting events

These slides not only show diverse faculty and real-world engineering projects, but they show engineers as people, not things, which can appeal more broadly to underrepresented students, particularly women¹. Once students apply, the focus shifts to getting them to attend.

Focused communications

Female admitted students receive a series of three focused communications from the Women in Engineering Program. These communications are designed to offer contacts and connections for the students to individuals in the College. A traditional letter, an email and a post card are sent that talk about opportunities on campus which are available for all students and also introduce the WISE living and learning community and give information about how to apply. The purpose of these communications is to make human contact and provide additional avenues for students and their parents to ask questions, etc. The students will typically meet at least one of the persons from whom they received communication when they visit campus, which humanizes the rather large College of Engineering.

As shown in Figure 2, the percentage of female students who arrive on campus for a particular engineering cohort has increased steadily over the previous several years. This percentage increase has occurred as the total size of the cohort increased from 1176 students in fall 2005 to 1480 students in fall 2014.

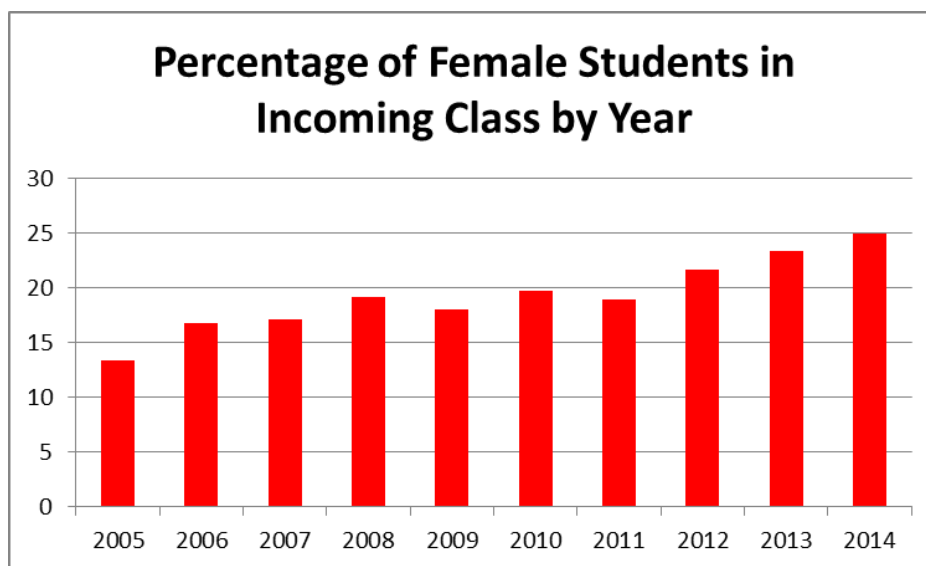


Figure 2: Percentage of Female Students in Incoming Engineering Class

Retention Efforts

Several programmatic efforts have been implemented in recent years to target retention. The College participated in several nationwide studies, starting with the WECE project² in 2002. The most impactful of these so far has been the data garnered from the Project to Assess Climate in Engineering Project⁴, in which the College participated in 2008 and again in 2013. Because this project was able to highlight responses by students at NC State, the results could be used in program design and formation. In addition, the faculty and staff of the College were more likely to read the results as directly applicable.

The following paragraphs outline some of the results of the PACE survey and changes in programs that were implemented to address them.

- PACE recommendation: Integrate relevant applications into the curriculum⁵.
The required class that all first year students take their first semester has been reworked to include several aspects designed to be appealing to diverse students and is being taught in smaller sections (50-60 instead of 200). Problems that require a hands-on component and are tied directly to real-world situations have been added. Presentations show more people doing engineering instead of objects, and those people are diverse. Engineering is portrayed as more cooperative, requiring teamwork and ingenuity. Specific examples are cross-disciplinary and are selected to show all types of engineering, not just the “big four” of electrical, mechanical, civil and chemical, and relate to societal problems.
- PACE recommendation: Facilitate communities for women and minorities².
Community building has been implemented in multiple forms. Before freshman year begins, a summer bridge program, called ESCAPE to Engineering³, is held for fifty incoming first-year women with the lowest SAT math scores. The program includes introductions to college math, their first computing class, female faculty and students and other aspects that research on campus has shown to have an impact on success and retention. The ESCAPE

program has specific goals tied to retention of incoming female students and based on the collective experience of WIE and other faculty in the college.

The Women in Science and Engineering Living and Learning Community was formed in 2003 when the College of Engineering partnered with four other STEM-oriented colleges on campus to incorporate a community for female first and second year students. The community includes upper class mentors, deliberate faculty mentoring, a summer bridge experience, speakers, study groups and more. Of the approximately 300 students in the community each year, half are engineers.

At least one event is held each semester to increase the sense of community for female students. In Taste of Engineering, students visit female faculty from each engineering department, do a small hands-on project at their station, learn about undergraduate research, graduate school, etc. and taste a food or drink that related to the particular discipline in a very open and celebratory atmosphere. For example, chemical engineering makes dry-ice cooled punch; materials science makes nano-ice cream with liquid nitrogen. In the Tools workshop, students are introduced to skills that are often taken for granted by individual departments (like soldering, breadboarding, sizing PVC pipes, pipetting, etc.). The workshop is offered by women for women, but many men also attend. Additional events have included “How to prepare for your first programming class” and twice yearly ESCAPE cohort reunions that may be held as an afternoon tea, making smores around a fire pit or some other seasonally relevant activity.

The 2012 PACE survey indicated a statistically significant increase in several areas of student perception, which may have been due to the interventions implemented. Table 2 summarizes these results.

Table 2: 2012 PACE Results

On average, there is an increase in students feeling like part of an engineering community from 2008 to 2013 for all students (mean 3.5 to 3.7).
The impression that engineers are well-paid increased from 2008. This was a significant increase for all students (mean 4.5 to 4.6), females (4.5 to 4.7), and non-URMs (4.5 to 4.6).
The impression that engineering supports people who want to have children and continue working increased for males (mean 3.6 to 3.8) and URMs (3.2 to 3.6).
The perception that society values the work engineers do improved for all students (mean 4.1 to 4.3), males (4.0 to 4.3), non-URMs (4.1 to 4.3), and URMs (4.0 to 4.4) from 2008 to 2013.
Students' perception that engineers help to make the world a better place improved. This was a significant increase for all students (mean 4.5 to 4.6), females (4.5 to 4.7), and URMs (4.4 to 4.8).
The impression that engineering will be a rewarding career increased for all students (mean 4.5 to 4.6), males (4.5 to 4.7), and URMs (4.4 to 4.7).

Additional assessment results have been obtained for ESCAPE. In 2011 a matched sample grade analysis was performed for the 2008 entering cohort of attendees. These results are summarized in the form of grade point averages and retention of participating students in subsequent semesters. The sample analysis in Table 2 is interesting for two reasons. Women who attend the ESCAPE bridge program are identified from a group at risk of leaving the College. The grade analysis indicates that they perform at least as well as women who do not attend and out-perform males.

Table 2: ESCAPE Matched Sample Grade Analysis for 2008 Cohort

	Escape Attendees	Non-Escape Females	Non-Escape Males
SAT Math Score	590	590	590.30
High School GPA	4.286	4.303	4.313
Fall 2008 Semester GPA	2.972	2.912	2.703
Spring 2009 Semester GPA	2.907	2.835	
Fall 2010 Semester GPA	2.843		

For the WISE program, assessment data includes the retention of participants versus non-participating females and males. An early indication of likely retention to graduation is the successful entry of students into an engineering department (called matriculation). All students enter as un-matriculated and must apply to a particular discipline after completing basic courses. Students who follow a “recommended” path would matriculate after two semesters and would be counted at the fall census in their second year. In the following table, female engineering students who are in WISE are compared to those female engineering students not in WISE and all male students. Table 3 shows some sample matriculation data for comparison. The matriculation rates of the WISE cohorts were markedly higher than for other female students in engineering programs, as well being higher than for male students.

Table 3: Matriculation rates of WISE, non-WISE female and male engineering students by cohort year

Engineering matriculation rates by cohort year			Fall Census fall yr 2	Fall Census fall yr 3	Fall Census fall yr 4	Total N
Gender	Cohort Year	Wise				
Female	2008	No	44.8	60.5	64	172
		Yes	47.3	60.4	67	91
	2009	No	35.3	56.9	60.1	153
		Yes	47.4	67	75.3	97
	2010	No	54.5	65.2	67.4	178
		Yes	57.6	67.1	69.4	85
	2011	No	55.3	66.8		208
		Yes	72.9	81.3		48
	2012	No	58.6	71.8		227
		Yes	56.3	69		71
	2013	No	57.7	64.9		194
		Yes	61.9	67.6		84
Male	2008	N/A	41.3	61.7	64.8	1107
	2009	N/A	33.1	58.4	60.8	1138
	2010	N/A	45.3	60.3	64.4	1074
	2011	N/A	44.7	63.7		1102
	2012	N/A	53.5	73		1075
	2013	N/A	63.3	63.4		912

In addition to matriculation, retention can be defined as persistence. Tables 4 shows a breakdown of graduation rates for cohorts entering in 2008 to 2010. WISE females are compared to non-WISE females and males. The 4, 5, and 6-year graduation percentages are listed for graduating in engineering and at the university. In addition, over the course of time, the graduation rates for female engineering students in general has exceeded that of male engineering students, whether they graduated in engineering or simply at the university. Five year graduation rates tend to be so much higher due to a large percentage of students who participate in co-op work programs.

Table 4: Graduation rates for female students, in and not in WISE, and male students (in percentage)

2008 cohort	Cohort totals	4 year NCSU graduation rate		5 year NCSU graduation rate		6 year NCSU graduation rate	
		Engr	All	Engr	All	Engr	All
Female non-WISE	172	28.5	40.1	53.5	72.7	56.4	78.5
Female WISE	91	28.6	44	57.1	81.3	58.2	83.5
Male	1107	20.8	25.4	48.9	64.4	54.8	75.1
2009 cohort	Cohort totals	4 year NCSU graduation rate		5 year NCSU graduation rate		6 year NCSU graduation rate	
		Engr	All	Engr	All	Engr	All
Female Non-WISE	153	28.1	42.5	48.4	75.8		
Female WISE	97	32	40.2	56.7	77.3		
Male	1138	21.5	27	48.3	63.9		
2010 cohort	Cohort totals	4 year NCSU graduation rate		5 year NCSU graduation rate		6 year NCSU graduation rate	
		Engr	All	Engr	All	Engr	All
Female Non-WISE	178	31.5	43.3				
Female WISE	85	30.6	45.9				
Male	1074	22.2	27.3				

A final bit of assessment data shows retention rates in engineering for female and male students from year to year. These data, listed in table 5, show that retention rates are increasing in general, but women, overall, slightly lag men.

Table 5: COE Cohorts Retention by Gender, WISE and not WISE (in percentage)

First-Year Cohort	2nd Year	3rd Year	4th Year	2nd Year	3rd Year	4th Year
2008	University			Engineering		
Female, non-WISE	92.4	88.4	86.6	84.3	66.9	61.6
Female, WISE	95.6	92.3	89	87.9	73.6	63.7
Male	87.2	86.9	83.6	90.2	75.7	63.1
2009	University			Engineering		
Female, non-WISE	88.9	86.3	83	78.4	62.1	56.9
Female, WISE	91.8	88.7	86.6	89.7	76.3	69.1
Male	88.9	83.4	81.5	84	69.7	63.5
2010	University			Engineering		
Female, non-WISE	93.8	88.2	87.1	88.2	66.9	61.8
Female, WISE	92.9	88.2	88.2	83.5	69.4	62.4
Male	89.4	84	81.8	85.1	71.9	64.3
2011	University			Engineering		
Female, non-WISE	95.2	90.9	89.4	87	69.7	62
Female, WISE	97.9	95.8	93.8	93.8	81.3	81.3
Male	93.2	88.1	83.9	88.4	73.8	64.6
2012	University			Engineering		
Female, non-WISE	95	92.1		87.2	75.3	
Female, WISE	97.9	88.7		93	71.8	
Male	93	87.7		88.6	77	

Following the thought model for women in engineering, the next step has been for the WIE staff to work closely with departments to ensure increased retention and graduation of females. In the summer of 2014, a department head workshop was held where research-based retention strategies were outlined (many of them from the ENGAGE project⁶), and the heads were asked to pursue at least one of the strategies. Figure 3 shows the agenda for this workshop. Additionally, two new programs have been started, targeting upper class females. A tool-use workshop that provides introduction or refresher for skills needed in sophomore and junior labs was held in conjunction with industry partners. Additionally, a “Dinner Dialogs” series was started which involved undergraduate, graduate and faculty women having dinner together, by department affiliation. The agenda for the dialog was loose, and discussion was encouraged across the age groups, with faculty women acting as discussion facilitators. Clearly, retention in engineering between the second and third year involves the WIE staff working closely with departments.

A Goal-Oriented Workshop for NC State COE Department Heads

Continuing the Progress for Women in our College

Several years ago, Academic Affairs instituted changes in our outreach and recruiting efforts based on research and national efforts. We now have the largest class of entering female students in our history.

As a College of Engineering Department Head, you are invited to a workshop designed to present research-based strategies that can be implemented this semester in your own department. The workshop will last 90 minutes. You are invited to attend and bring with you one ally of your choice. Lunch will be provided. The workshop will be very fast-paced and will be designed to present the strategies very quickly. The research behind the strategies will NOT be presented, although a packet with all of the references and evidence will be provided as a take away from the day. The purpose of the workshop is to give the participants all of the tools they need to implement the strategies and use the workshop time to greatest effect.

- Workshop philosophy: Research is clearly showing how to successfully increase the percentages of females in engineering departments. Successful strategies focus on making changes in the departments, not on changing the women. The soil in which you plant your students matters. You want to be able to grow a variety of plants, and you want that soil to be good for ALL plants.

Goal: Choose a minimum of two strategies to implement this semester

- Choose based on:
 - Status of your own faculty
 - Status of your own students
 - What appeals to your own interests
 - What aligns with your own experiences or those of your allies

Workshop contents

- Faculty/student interaction strategies
- Institutional policies and support strategies
- Curriculum and pedagogy strategies
- Recruitment strategies
- Student support strategies
- Evaluation and tracking

Figure 3: Department Head workshop agenda

The final measure of the status of women in engineering for this analysis is the distribution of our female students across the curricula. As the percentage of female students increased, one hypothesis is that this could be due to increases in the traditionally more female-oriented fields of biomedical and chemical engineering. The following graphs show that this is not so. Figure 4 shows that from 2008 to 2011, the distribution of female students across disciplines began to even out.

Comparison of Percentage Female from Spring 2008 to 2011 Across Disciplines

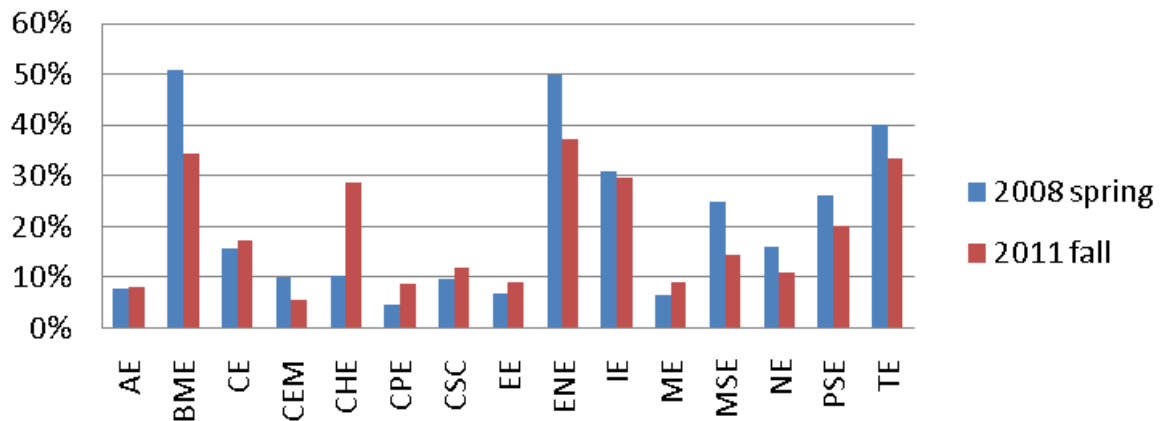


Figure 4: Shift in Female Student Percentage from Spring 2008 to Fall 2010

Conclusions

The history of women in engineering programs encompasses a wide variety of programmatic foci designed to recruit and retain higher numbers of female students in the broad array of engineering programs. Traditional features include mentoring, specialized recruitment events, bridge programs, mentoring programs, and many others. These programs, which are directed at the female students, can have the appearance of attempting to change the women to attract them or help them fit in to established programs, like a patient who needs some sort of treatment. Still, if a college does not offer these types of programs, it may be perceived as unfriendly.

These programs DO have an effect. The data clearly show that the percentage of women in engineering increases and holds steady with these types of “interventions.” But...historical data also show that national percentages have been stuck at this level for more than twenty years. Colleges of engineering that have broken this barrier seem to have done so by making change a priority across the entire program, rather than delegating responsibility to a Women in Engineering program alone. The Women in Engineering program may still run specialized events, but the entire college works together to shift the paradigm away from “fixing” the women so that they feel more comfortable fitting in, and more toward a learning environment that is better for all types of students, including women. How they accomplish this varies, but it may involve less of an emphasis on traditional segregated departments and more on cross-curricular learning like Arizona State University. It may involve an emphasis on instruction grounded in practical engineering problems like the Grand Challenges, as in the several universities implementing the NAE Grand Challenge Scholars program. Students who have come through high schools where learning is more hands on and problem oriented are entering engineering programs that are very much like those of 75 years ago, and a disconnect is occurring. Programs like ENGAGE⁶ are helping Colleges of Engineering make changes that are very positive for students’ success in engineering. What is clear is that a paradigm shift is absolutely necessary if we really want significant change in the make-up of our engineering classes, and this change cannot be brought about solely by Women in Engineering Programs working alone.

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