
AC 2011-881: PROGRAMS AND PRACTICES MAKING A DIFFERENCE: A CROSS-CASE ANALYSIS IDENTIFYING PROGRAMS AND FACTORS THAT INFLUENCE RECRUITMENT AND RETENTION OF WOMEN EN- GINEERING STUDENTS

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Programs and Practices Making a Difference: A Cross-Case Analysis Identifying Programs and Factors that Influence Recruitment and Retention of Women Engineering Students

Abstract

Despite nearly 20 years of recruitment and retention efforts focused on female students, women constituted only 19% of engineering students in 2007. A cross-case analysis of six engineering schools based on rich qualitative data from faculty, student, and administrator interviews, as well as observations and documents, provides a unique opportunity to identify trends and unique practices used to address the recruitment and retention of women engineering students. This paper focuses specifically on how these institutions implement K-12 outreach, admissions, summer/bridge, and first and second-year support programs. We find three themes that support recruitment of female students: 1) historical commitment, institutional type, and geographical location; 2) flexible and strategic admissions policies and “high touch” efforts; and 3) outreach programs for K-12. We also highlight five themes that lead to female students’ retaining an engineering degree: 1) Campus climate, 2) support services during early undergraduate years, 3) strong ties to faculty and student interaction in and out of the classroom, 4) high support for student organizations and activities, and 5) learning and living communities.

Introduction

Despite nearly 20 years of recruitment and retention efforts focused on female students, women constitute only 19% of engineering students in 2007^{1,2}, while female representation at universities, in general, is well over fifty percent. The 2006 Spellings’ Commission has challenged the U.S. to diversify the science, technology, engineering and mathematics (STEM) student population in regards to gender and racial/ethnicity numbers. With the exception of Asian Americans, students of color are also underrepresented in engineering. Black and Hispanic students each earned eight percent of all engineering bachelor’s degrees in 2007, and American Indian and Alaskan Native students represent less than one percent of engineering degree recipients². Thus, we still find ourselves needing to better understand what works in the recruitment and retention of female and underrepresented minority engineering students. This paper will focus specifically on female recruitment and retention of undergraduate engineers with emphasis on supportive institutional cultures, practices, and policies especially identified with outreach and support in the early years of undergraduate education.

A cross-case analysis of six engineering schools selected from survey-based evidence of graduating students prepared to be the “Engineering of 2020”³ provides a unique opportunity to identify trends and unique practices used to address this ongoing area of inquiry regarding the recruitment and retention of women engineering students. Based on our qualitative analysis of faculty, student, and administrator interviews, as well as document analysis from all six institutions, this paper uses rich qualitative data to describe both the commonalities of these institutions’ approaches to women engineering student recruitment and retention, as well as what constitutes and necessitates unique approaches when they exist.

This paper focuses specifically on how these institutions implement K-12 outreach, admissions, summer/bridge, and first and second-year support programs. To further enhance the implications of this work, we share our results regarding some themes shared by these institutions and focus our discussion on possible practices over which administrators and faculty members have some programmatic or policy control by providing illustrative examples of how these institutions have enacted such programs and policies within their unique higher education settings and still make them effective towards the goal of women student recruitment and retention.

Theoretical framework and literature

Although the representation of U.S. women in science, technology, engineering and mathematics fields has risen dramatically in recent decades, there is a need for more women in engineering⁴. Women are still concentrated in certain disciplines and most professions continue to be sex-segregated⁵. In general, women are less likely to choose a major in engineering and more likely to switch out of an engineering major than are men. The benefits of having more female and underrepresented engineers include adding new perspectives to scientific and technical innovation.

The report by Women's Experiences in College Engineering (WECE)⁶ was the first cross-institutional, longitudinal study of its kind. The report showed a number of factors that influence women's overall engineering experience and involvement. In the study, challenges mentioned by Deans to increase the number of female and minority students included increasing K-12 outreach activities and recruiting female and minority faculty. For example, precollege exposure encourages students to pursue an engineering major by introducing girls to women who are majoring or working in engineering. In addition, recognizing engineering's altruistic bent – engineering can and does improve society and help people – as well as making first year courses less competitive and encouraging a broad range of general education classes, highlighting courses with applications and problem solving, providing advisors, and developing a sense of community can all contribute to retaining budding female engineers⁶.

The WECE report recommended an increase in efforts and opportunities to participate in on-campus community building and also development in other interests and skills in the first two years. Freshmen and sophomore years find women most likely to actually leave engineering. One-third of the leavers stated negative aspects of their school's climate (e.g., competition, lack of support, and discouraging faculty and peers); while sources of encouragement mentioned were parents, support activities (e.g., study groups, student organizations) and having internships and research experiences and sources of discouragement included grades, amount of time required for the major, restrictive curriculum, no time for other activities, lack of female faculty, and competition⁶.

A number of formal Women in Engineering (WIE) programs have been developed at U.S. institutions to assist in recruiting and retaining women in engineering majors. These programs offer social and academic support through mentoring, study and laboratory skills workshops, career exploration, social opportunities and support, outreach activities, scholarships and awards, and media contact (e.g., newsletters).

The programs offered by many Women in Engineering programs – and programs in general designed to recruit and retain women into engineering may be viewed within a conceptual framework that depicts how different aspects of the “college experience” interact to influence student outcomes. The conceptual framework characterizes the student learning experience by focusing on three dimensions – the organizational context (including administrative practices and policies, curricula and instruction, and faculty culture); the peer environment, and the individual student experience, see Figure 1⁷. The conceptual model assumes the peer environment – which encompasses several aspects of students’ in-class and out-of-class experiences -- is a central mediating force in student learning⁸.

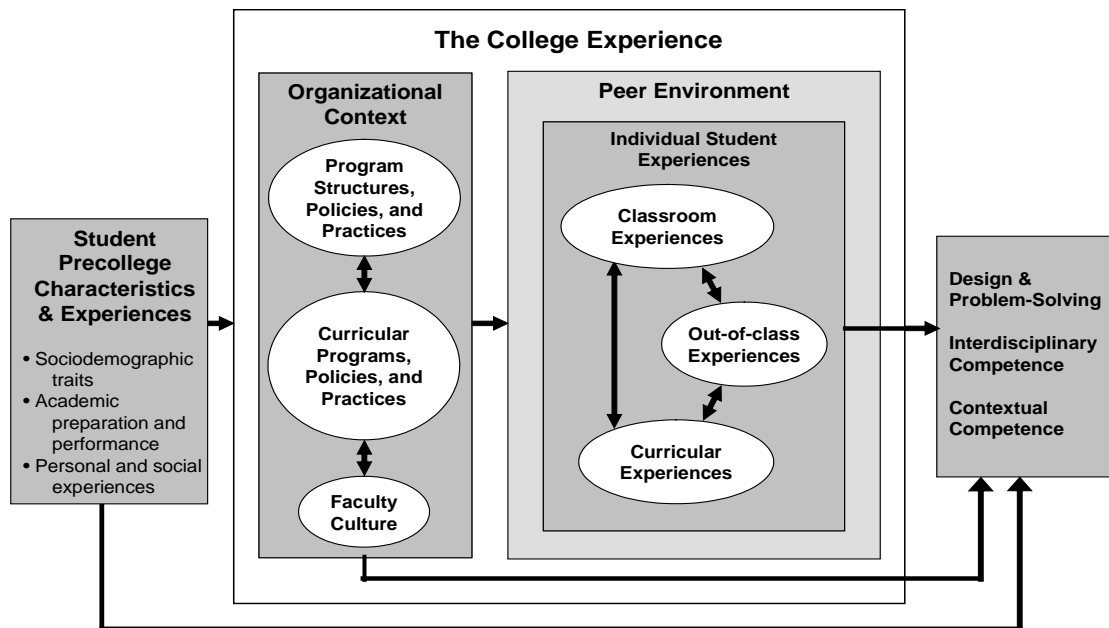


Figure 1. Comprehensive framework of influences on student learning and persistence (Terenzini & Reason, 2005).

An instantiation of a program that is part of many institutions’ “organizational context and is designed to influence the student “peer environment” are engineering summer bridge programs that are designed to create a “bridge” for students between high school work and the rigors of completing an engineering degree. Engineering summer bridge programs may introduce students to engineering lab work, address what it means to work in science and/or math areas, familiarize students with group and problem-based learning, and develop mentoring relationships. Summer bridge programs can provide an effective method to reduce college readiness gap between incoming students⁹, while another study¹⁰ reports that institutions that were high producers of female and underrepresented degree recipients also offered summer bridge programs.

Since the dimension of organizational context can be integral to the learning, recruitment, and retention of female and underrepresented students and to the recruitment and retention of female and underrepresented faculty members in engineering, it is the main focus of this research paper. The guiding questions for this inquiry are:

- What institutional cultures, practices and policies play a role in recruiting women undergraduates at these institutions?
- What outreach, summer/bridge, or other women-in-engineering support programs and practices exist at these institutions to encourage retention of women?
- How do these efforts aid the recruitment and retention of female students in engineering?
- What are the existing challenges in recruiting and retaining female undergraduate engineering majors?

Methods

Data for this study were gathered as part of the NSF-funded study entitled Prototyping the Engineer 2020: A 360-degree Study of Effective Engineering” (NSF-DUE-061871). . The study took its inspiration from the National Academy of Engineering’s report entitled, *Educating the Engineer of 2020: Visions of Engineering in the New Century*³, which distinguishes the attributes and skills needed for engineers to maintain U.S. technological and economic competitiveness. It envisions the workplace of the near future as one of dynamic technological change that requires an understanding of complex societal, global, and professional contexts. The goal of the P360 study is to identify and analyze the curricular, pedagogical, cultural, and organizational features that support engineering education that appear to be aligned with the goals of the Engineer of 2020. Although concerned with the education of all undergraduate engineering students, the P2P study paid particular attention to the educational practices and programs that foster the success of women and underrepresented minority students.

Site selection

The research team analyzed data collected for a nationally representative dataset developed for the *Engineering Change* study¹¹, which assessed the impact of ABET’s outcomes-based EC2000 accreditation criteria, to empirically select six case study sites. In consultation with a National Advisory Board, the team identified five institutions that exhibited superior performance on the focal learning outcomes and/or in recruiting and graduating women and underrepresented students: Arizona State University (ASU), Howard University, Massachusetts Institute of Technology (MIT), the University of Michigan (UM), and Virginia Tech (VT). Upon the recommendation of the Board, Harvey Mudd College (HMC) was added to the study in recognition of its national reputation for graduating engineers with superior design and problem-solving skills. Four of the six institutions studied – although diverse in terms of size, institution type (public or private, research focus), geographical region, and student body characteristics – outperformed their peers on measures of women students’ enrollment and graduate rates.

Data collection and analysis

In 2007–08, the research team divided into three smaller teams, each comprised of four to five faculty and graduate research assistants from the fields of engineering and education. Each team was responsible for data collection and reporting for two case studies. Data collection relied on multiple sources of evidence: personal and group (or focus) interviews with faculty, administrators, students, and professional staff (e.g., student support services); observations of

classes and events (e.g., Projects Day), archival records (e.g., meeting minutes), and other artifacts (e.g., websites, syllabi, institutional data and documents). Triangulation of these data sources enabled corroboration of facts and events at each case study site. In addition, the use of multiple investigators for each site (each team included at least one faculty member from engineering and one from education), contributed to construct validity¹².

Each case study site was visited at least twice to identify and study the factors shaping each institution's performance. The full team developed a set of protocols for different groups of interviewees for the first set of case study site visits. This visit examined organizational and curricular structures and policies identified from websites, engineering education literature, and discussions with academic administrators at each site. Researchers also identified additional individuals and educational experiences to be studied during the second site visit. For the subsequent visits, the teams customized protocols for the various groups of participants.

Data collection was completed by Fall 2008. Personal and group interviews were fully transcribed and entered into NVivo, a software program that supports the management and analysis of qualitative data. Each team analyzed the data from the two case studies it conducted. Coding and preliminary analysis of data began when each team completed its visits. During Fall 2009 and Spring 2010, the research teams completed their analyses in preparation for a cross-case analysis held Summer 2010 that identified common themes across the six case study sites, including why and how these institutions are able to recruit and graduate women students. The number of participants that were interviewed at each institution is recorded in Table 1.

Reliability was enhanced throughout the data collection process by researchers taking field notes and performing inter-coder agreement tests during the analysis process. To achieve inter-coder agreement, multiple coders analyzed transcript data and performed inter-rater reliability checks using NVivo qualitative software¹³.

Table 1. Number of participants interviewed at each institution.

Institution	Number of Interviews		
	Administrator	Faculty	Students
Howard	12	28	62
MIT	20	17	16
University of Michigan	27	31	45
Harvey Mudd College	11	20	24
Virginia Tech	11	30	21
Arizona State University	24	33	21
Total	105	159	189

Paired coders were randomly assigned the same number of transcripts. The reliability results were calculated by dividing the number of agreements by the total number of passages. Inter-coder reliability for each of the pairs averaged around 92.69%.

Results

Most respondents in our study stressed many of the pipeline issues involved in recruiting and retaining female and underrepresented faculty. Administrators, faculty, and students were extremely dedicated to talking about their institution's and department's efforts, as well as their own, to increase the representation of women engineering students. As we discuss our results, we will add some concrete examples within each theme that plays a role in increasing the numbers of female students. We also note that some programs and themes discussed may not be solely aimed at women students but benefit both *all* engineering students.

Retention

We found three themes that support recruitment of female students: 1) historical commitment, institutional type, and geographical location; 2) flexible and strategic admissions policies and “high touch” efforts; and 3) outreach programs.

Historical commitment, institutional type, and geographical location

At each of the six campuses, we found a historically strong commitment to recruit and retain women students. Each institution had strong leadership and a commitment to diversity that has helped to foster and develop many programs designed to ensure the success of women (and minority) students. At University of Michigan (UM), students, faculty, and staff alike expressed that the administration of the college and university both have made visible efforts to prioritize the recruitment and retention of a diverse student population. An administrator explained that one of the reasons why women are so successful at UM is because “...the leadership in various departments understands the importance of climate issues and the women faculty members go out of their way to ensure the female students are well-served.” She also cited a specific project, an oral history project developed by WISE (Women in Science and Engineering program), in which generations of women explain the history of engineering at the university. At Virginia Tech (VT) the Principles of Community document illustrates the institution-wide commitment to diversity, specifically addressing the need to “increase access and inclusion” and create a community beneficial to the growth of all its members¹⁴.

More recently, Harvey Mudd College (HMC) had marked success in recruiting women to both the student body and faculty. In the Engineering Department, women students are roughly 30 percent of the student body. Most of the faculty members interviewed believe that the proportional representation of women in engineering at HMC is a strength of their program. Admissions officers at the College noted that this “critical mass” of women students makes the task of recruiting women to the College easier. According to one admissions officer, having a “whole bunch of happy women studying here” has changed the atmosphere on campus, and also helped spread the word at feeder high schools. The College's decision to hire a “dynamic and committed female President” has also been a boon to the college. While admissions staff attributed some of their success in recruiting a high number of women students to campus to the presence of a female President, faculty members further identified as influential the College's recent successes in hiring outstanding women faculty members and administrators. In the past decade, the proportion of women faculty at HMC increased to 35 percent overall, with the engineering faculty being one-third female (HMC 2020, 2007). (N.B.: In addition to HMC, the

University of Michigan and MIT currently have female presidents: Sue Colman and Susan Hockfield.

Geographic location can play a role on recruitment. Recruitment of female students (and all students) for VT -- located in a beautiful rural setting -- requires some effort. Although this lovely setting is a strong asset toward creating a traditional college setting that is attractive to both faculty and students, at the same time the setting presents a challenge to recruiting a diverse student population. The faculty and leadership in the College of Engineering are aware of this challenge and perhaps with this awareness, the college makes extra efforts to both recruit and retain female and minority students and faculty. Many recruiting activities include a strong current -student component and showcase the College's many opportunities for hands on design experiences and student-led engineering competition teams. For instance, the college sends a diverse student team (diverse in terms of gender as well as year in school) that has participated in building a racing type car to the state fair. The exhibit, which included the car, attracted a lot of attention and reached an audience of potential students and their parents in a part of the state not known for sending students to Virginia Tech.

Arizona State University (ASU) a large urban institution with many of its students commuting to campus. This creates both challenges and opportunities in recruiting and retaining minority and women students. One theme emphasized is the creation of a sense of belonging and community for the students. This sense of creating community is one that permeates recruitment and retention of minority and women students at ASU whether it is through direct institutional efforts. The College of Engineering's approach to the recruitment and retention of women students has evolved and seen many changes in the last number of years. In the mid-1990s, ASU had strong leadership and advocacy. In fact, one former administrator emphasized that ASU was early amongst engineering colleges nationwide to create such programs. The programs included dedicated physical spaces for studying and gathering that were centrally located and made it easy for students to access them.

Institutions can also possess a historical identity or legacy – an institution's legacy reflects what it has attempted to be over the years and what it has become in the present. Howard University, an HBCU, is one example of this legacy. And one engineering faculty member explained to us what was a distinguishing feature: “. . .first of all, the legacy, obviously Howard has so many great minds that came out of Howard . . . that [students] come to Howard to get out of all whatever prejudice . . .They are really themselves. Howard gives that. There is something about Howard.”

One of the first observations at MIT is that the student population is diverse. Researchers do not notice an imbalance between males and females. Pursuing diversity and excellence are twin goals of MIT Admissions. One administrator describes the first hurdle for applicants; he states that students have to be able to get through the multiple calculus classes. “It doesn't matter if they (students) are male or female or werewolf, they have got to do the math. But we have so many people applying to us...that you tape that filter on and we still have too many people. So then we say ok, go focus on women, go focus on underrepresented minorities.”

Flexible and strategic admissions policies and “high touch” efforts

Both MIT and Howard draw students from their sense of legacy, as well as drawing from students who may be first generation. Each institution took different approaches to admitting their students. They described some of their strategies and policies that gave them flexibility in being able to increase female (and minority) students on their campus. Being MIT, we would expect no less of a mostly numerical response to their admission policies and strategies. MIT's Dean of Undergraduate Education explains who sets the policy:

... some combination of the faculty committee and then the president and myself and they are told this is part of our goals. So one of the tests that they are asked to apply [involves] our initial calculus class and multivariate calculus. So one of the tests they don't apply is never admit somebody who won't pass through . . . they actually put into a matrix and they compute two scores on a person so one is what we call a numerical index (NI) and that score is just, it is weighted sum of SAT and QPS, so it is just numbers, the computer computes that. And the other score is what we get from, each folder . . . is read by five people and each one is asked to score the individual applicant . . . on a qualitative basis, but give them a number from 1 to 5 and they are supposed to take into account things like perceptions of fit as seen by what they say in their essays, evidence of passion. . . And we choose the people with high NIs and high on their passion.

Regardless of these procedures, numbers and scores are not important to some members at MIT. A faculty member at MIT explained to us how some engineering faculty helped to add depth to the admissions process by adding a creative question that has applicants using only one sheet of blank paper:

. . . so I read a lot of freshman folders . . . we search in our admissions for that spark of brilliance of creativity of brightness that maybe it will manifest itself, hopefully somewhere beyond the scores and grades and stuff. . . Everyone has got great scores, and great grades, and checked the boxes, little Johnny or Jamie is brilliant and wonderful and should be admitted. There is no depth data. So, let's give a questions, we say, you have a sheet of paper do whatever you want with it. I think the number is around 10 or 20% of the applicants are smart enough to actually do something with it.

This initiative brought in some interesting students, a female student who had designed and sold her own jewelry, with the proceeds going to aid women in an underdeveloped country.

At Howard's engineering school, they are very competitive for one main demographic -- African American students. Clearly, other HBCUs are obviously in competition with Howard for this student pool. In addition, Howard does derive a student population from international students, mostly Caribbean and African, who feel very comfortable with Howard's message, role and history. Howard respondents told us "because of Howard's legacy we get people whose parents have graduated from Howard and they are middle class, upper middle class and then you have other people who are in the first generation college, so those tend to be two very different type of students". Right now the recruiting is done at the university level and then at the college level. Many faculty chairs and the Dean, told us that they had received a list of possible students that then they were going to personally contact. Howard's Dean does get involved in the admissions process - "I'm responsible for it all, so [I] have to get involved." Furthermore, the Dean further strategizes and uses Howard's mission and values in explaining the importance of a phone call:

. . . that I'm not some person that they'll never see, and this goes all the way down. If they have a concern that rises to my level they will get my attention, cause that's what was done [for] me when I was at Howard . . .you will not only get a great education, but you will also have somebody who will know who you are . . . the students -- they typically think it's [phone call's] a big deal.”

HMC administration and faculty have made significant and sustained efforts to recruit women students. In order to get women into the pool of potential HMC students, the admissions office uses targeted searches based on PSAT scores and interest areas identified by prospective students. HMC also practices a “high touch” method of recruiting in which all students are strongly encouraged to visit campus and spend a night in the residence halls with a current student host. Admissions officers also try to personalize their contacts with admitted students. In 2006 and 2007, HMC president Maria Klawe wrote hand-written notes to every admitted female student to encourage them to enroll. Efforts like these seem to be paying off. During our site visits, a member of the admissions staff recalled that 50% of the audience at a recent recruitment event were women. Another recruitment effort that seeks to meet students where they are is an electronic message board maintained by the admissions office. This forum allows admitted students to pose questions and share their excitement about attending HMC. Admissions officers noted that this forum is particularly appealing to women, suggesting that “ women journal a lot more than men do” and that ability to connect online with peers is very important to them.

Student organizations such as the Society of Women Engineers (SWE) also organize activities designed to attract potential students to HMC and to engineering and science disciplines. The Women Engineers and Scientists for Tomorrow (WEST) workshop is one example. SWE has received a number of awards for the annual WEST conference, which familiarizes pre-college students to available opportunities in engineering and science-related careers. Each year, over 100 students, parents, and teachers attend the WEST conferences. Participants choose two workshops (one in engineering and the other in a science field of their choice), and hear keynote speakers from engineering and science fields (HMC 2020, 2007). Senior faculty members volunteer to run the program workshops.

At Virginia Tech (VT), recruiting female students is targeted via some simple, but effective methods. For instance, promotional materials for the College are customized for different student populations – including women. So women recruits receive the standard college materials but also a set of informational items on all the programs specifically designed to support the success of women students: mentoring, engineering residence communities, and student organizations such as SWE. Once a female student makes it to campus for a visit, she will find a welcoming environment and a traditional college campus that many find very appealing. One first year female student described her experience of visiting VT's campus for the first time; she didn't expect to like it so much but its traditional feel, consistent architectural style, and lovely grounds coupled with the strong sense of “pride” and community were enough to convince her that this is where she belonged. Once a female student makes a commitment to VT, she is offered opportunities to participate in many programs designed to ensure her success. An underlying theme to these activities is the desire to build a sense with the female students that they are part of the larger community of the college of engineering. This can in turn lead to a desire and motivation to stay in that community and thus be retained and earn an engineering

degree. This college administrator describes the importance of community to retention: “And I cannot express the community aspect [enough]. If you don’t feel as though you’re a part, if you don’t know where you’re at, you’ll leave. But the majority of the students won’t.”

At UM, an associate dean explained that the support of the engineering dean is essential to a successful recruitment and retention effort. Many of those interviewed for this study noted that the dean believes that diversity is essential and warranted. The dean, in turn, gave the college’s staff credit for these efforts:

[The student affairs] staff gets a lot of credit. We are going after women students and minority students . . . there is nothing in Proposition 2 [a state ballot measure that bans preferential treatment] that prevents us from recruiting women students and minority students extra hard, making extra phone calls or whatever. And [the executive director of student affairs] and her staff, they do everything they need to do.

The executive director of student affairs explained the motivation behind some of the staff’s goals in regard to recruitment, which includes increasing the proportion of women in the incoming class from 23 percent to 30 percent:

I see thirty percent as a critical mass... women in those classrooms will feel comfortable and I think that faculty would understand better how to teach them. How to deal with them. So that is really important to me. The women here are leaders in organizations. They are out there making social change. They are doing tremendously GPA-wise. Our retention of women is incredible. I think by building that number -- and a lot of us are committed to that including the dean, you know -- I think it would benefit all of our students and our entire faculty.

In addition to engaging the student affairs staff in efforts at diversification, the college has also found meaningful ways to engage faculty in efforts at diversification of the student population. Although the return (in terms of women enrolled) attributed to any single recruiting effort may be small, the breadth of the efforts and the integration of students, faculty and professional staff as ‘unofficial’ recruiters appears to create an appealing and welcoming atmosphere for women students.

Strong outreach programs

All six institutions have a variety of outreach programs and connections with diverse middle schools and high schools in their community and also nationally. These outreach programs are usually designed to attract women and underrepresented minorities. For example, MIT has a commitment to attract women, underrepresented minorities, first generation students, and students who have fewer opportunities in the STEM disciplines. One professor stated it succinctly, “we try and do outreach things to break the stereotype [of being an engineer] as best we can.” The newly assigned assistant dean of engineering for development and strategic initiatives at MIT explained that the focus shifted “more on strategic initiatives that include outreach . . . the goal of that program is to try and increase diversity and access in engineering disciplines . . .encouraging excitement in STEM disciplines.” He felt there was a strong willingness of faculty support with these types of outreach: “I think the faculty around here really want to help and even the busiest faculty members see the desire, that you have the desire, and they really do want to be involved. “

One of these programs, Women's Technology Program (WTP), was started in electrical engineering and has been cloned in mechanical engineering. Women student engineers who wanted to find a way to encourage more women originally started it. WTP is an in-resident summer program for rising high school seniors. It is specifically targeted at young women who have strong aptitude in math and serious doubts about engineering:

. . . so we occasionally annoy some parents when we turn down their daughter who has already done AP up the wahzoo and is clearly going to be an engineer. This is really aimed at young women where we want to get them here to understand that this is a career you could do – 'there are other young women like you' -- which is probably one of the biggest selling points."

The program has 40 female students annually that come to MIT over the summer for six weeks where they experience engineering hands on experiences facilitated by graduate student women.

At UM outreach programs focused on women include partnerships with local high schools and post-secondary institutions, and other programs on campus also spearhead recruitment programs for women engineering students. The WISE program sponsors several of these, including the Girls in Science and Engineering program (more commonly known as WISE GISE), the Grace Hopper Project, and the Sally Ride Science Festival. WISE GISE is a four-day summer program for female 7th and 8th grade students. Groups of 15-17 campers are chaperoned by two Michigan students, with each group instructed by faculty, research scientists and graduate students. With a focus on hands-on activities, groups meet in lab spaces around campus, an at the College of Engineering, the Medical School, the Departments of Chemistry and Physics.

One student explained that the impact of her involvement in WISE was one of her most rewarding experiences. She explained that it allowed her to build a network that was academically and socially beneficial. This "small community in a large university" gave her a sense of where she could go for support. This student not only reaped benefits from the program, but she also served as a mentor for younger students and was a program board member. Another student, who was not active in SWE or WISE, suggested that just knowing the resources provided by the group were there was a comfort. She said, "...that kind of helps knowing there's other females out there." While the existence of numerous outreach programs appears to offer a variety of ways to foster relationships with K-12 schools, one administrator saw a challenge in how to best leverage such opportunities, avoid duplication of efforts, and build more meaningful experiences for prospective students that reach deeper into the students' K-12 experiences than eleventh and twelfth grade.

At ASU, SWE runs both middle school and high school focused outreach activities. A college administrator described the SWE activities in particular and communicated that nearly all of the college's organizations have outreach activities:

. . . they bring high school students to campus. They do Middle School Days where they go to the middle school and do hands-on projects with them. And then they have a Gear Day where they bring 75 to 100 girl scouts here as well. And we have outreach programs in pretty much all of our student organizations.

Similarly, MIT has a middle school focused activity called the Women's Initiative which is organized out of Beta Kappa Nu Honors Society. Every January women undergraduate

engineering students go around the country to middle schools, talking about what it is like to be a woman engineering student at MIT – “the excitement of it . . . reach down early to encourage students to think about these career opportunities before they have that horrible high school teacher that tells them that girls don’t do math and therefore stop thinking about this.”

Retention

We have also identified specific themes/ strategies and/or experiences that lead to student retention and impact not only female students’ retaining an engineering degree, but also prepare them for their careers post-graduation. Our findings highlight five themes, some mentioned by Seymour and Hewitt¹⁵ and some obtained from our observations, interviews and artifact analyses: 1) Campus climate, 2) support services during early undergraduate years, 3) strong ties to faculty and student interaction in and out of the classroom, 4) high support for student organizations and activities, and 5) learning and living communities.

Campus climate

The presence of women students and faculty at an institution is one component of creating a positive environment for women and underrepresented students. A number of faculty and administrative staff at HMC believe the College was close to accomplishing its goals to attract more women students and faculty. As one female engineering faculty member stated, “We almost feel like we’ve got the female thing -- not done -- but down.” Students interviewed at HMC seemed unconcerned about gender or racial issues, suggesting that academic ability was the defining factor of “a Mudder.” One remarked: “I really like that just because I am a girl it does not mean that people are going to look at me differently because we all got into the same school and we all are thinking at the same level.” Another female engineer noted that while there may be few female students at HMC, the fact that the College is a member of the five-college Claremont Consortium created the sense of a greater number. She further noted: “There are a lot of female faculty, and there is a lot of support if you need it, and I don’t witness personally much bias at all for female students. A male engineering suggested “Once you are here, we all recognize each other as equals. We respect each other’s gifts, abilities, and talents, and you know that if you got into HMC you deserved it for something.” A female engineering faculty member agreed:

There is a real sense that your academic and intellectual qualities are what are valued here. And I am not at all saying that there are not issues of the way that people are treated in the community, and there are not unintentional things here, but above all it is academic and intellectual things that people care about here, with the students.

Both women students and faculty at HMC considered the presence of women faculty an important factor in creating a positive environment for female students. These faculty members served as role models and mentors to students. . Research has demonstrated the positive influence of an advisor (male or female) is a significant predictor of persistence in female engineering students (Brainard & Carlin, 1997). One female junior engineering major expressed her pleasure at seeing more women join the faculty:

I think it is comforting... So we are not just staying in our old ways of “Wow, engineering is for males. Old white men. It is angry old white men.” Yes. The world is

changing and [so is] the world's view on science. And women's view on science and women in science and it is all changing and the dynamics are changing. So I think it is really great that they are adding more females to the faculty and I think it is great taking classes with intelligent females that I can relate to because they are women.

An HMC faculty member noted the palpable change in the engineering department when the second woman faculty member was hired:

I know there was a change going from zero to one, but I could feel the change going from one to two, and the next year there were two more. There were four.... And so somehow the combination of more female faculty in this department and also in the college and sort of the increased to just above the critical number as far as students are concerned, has made it really different.

Our institutions also showed collaborative efforts among various offices throughout their institutions in recruitment and retention efforts. For example, at UM, the Office of Recruitment and Admissions for the College of Engineering works closely with the central admissions office and other offices that are identified to recruit prospective students, mostly at the end of the K-12 pipeline such as the Women in Engineering Office. Similarly, at VT, the associate deans office that is in charge of recruiting students is co-located with the college's student affairs office that helps to monitor student progress towards their degrees – thus enabling more effective communication that can help retain women – and all engineering students.

Our research teams also talked to faculty and administrators who spend time trying to understand why more women are not entering certain areas of engineering. An associate dean at MIT told that site visit team:

They went to the high schools and talked to these kids, these women who strong in math and science and they said, well we want to do something good for the world. So they had a disconnect between doing something good for the world and engineering. ... We need to repair that because how can it possible be that people don't think you could do good for the world with engineering. But instead they kind of have that view of the pocket protector, and the pens and the mechanical things like a calculator and so we need to get that word out more... So, one of the things that we have to do I think is just a better job of saying how what we do can relate to these [interests].

Support services during early undergraduate years

Because retention in engineering at these six institutions -- like most across the country -- is mostly an issue in the first and second years, many retention programs are focused on this timeframe. MIT's programs provide one example. Because students at MIT choose an engineering major at the end of their first- year, there is a desire to raise awareness of each of the different engineering majors during the first year. These efforts include first year laboratory experiences, first-year seminars and project orientated experiences. One faculty member in electrical engineering described how these efforts can benefit women students in particular:

We've been encouraging over the last few years more exposure of that, which we think has a bigger effect on our ability to attract women ... So we're really trying to sort of get real information about what both the discipline is about and what the department is like, because often we're competing of trying to combat historical misperceptions about . . . a programmer is somebody who has the bag of Cheetos in a basement somewhere looking at a computer,

working alone by themselves. That's actually not how software development and software engineering and all these sorts of things are done now. It's much more team oriented, much more collaborative, much more interactive and so trying to get more exposure to that. Another example targeted especially at the first- year was the creation of Introduction to Programming for freshman, explicitly targeting people who have never programmed before-- including women and minorities.

ASU has recently created a new support program for all incoming first year students. The "E2" camp is a two-day and three-night activity that serves as a welcoming event and orientation for all new first-year engineering students. This camp represents ASU's movement towards retention efforts that will be effective for not only women and minority but *all* engineering students. The E2 camp is described as follows:

[The camp] offers first-year students an opportunity to participate in fun and have creative programs that will introduce them to . . . the [College of Engineering]. Faculty, staff and upperclassmen act as a resource for students during the camp experience. [The camp] is required for all first-time, full-time freshmen. Studies show that students who are immediately engaged in their academic environment have higher retention and graduation rates.

According to the schools' website, the camp experience is designed to create a sense of community in the schools, build camaraderie and solidarity amongst the students, develop leadership skills and overall get students revved up and excited about studying engineering. An administrator says the camp is a key strategy that is the foundation of their efforts to build a sense of community and address student retention.

Additionally, engineering at ASU offers a variety of "pipeline" activities including single day or afternoon activities at local schools to the extensive summer "bridge" programs designed to help newly admitted women students to successfully transition into the college. Beyond the organizational structure and focus of the K-12 activities, former student participants offer supportive evidence for the positive impact they can have. A female student expanded on how the bridge program made a difference for her:

And, definitely, participating in a bridge program before helped me to get to know people. It wasn't just a two- or three-day thing. We lived together for two weeks and did school type things and did a project and we actually got to know each other better as people . . . We ended up switching a lot of dorms so we could live together and that really made a big difference, to have study groups that were your friends and not just in your classes.

At UM a few dozen students participated in the M-STEM Academy, and all of the College of Engineering incoming students participate in a three-day orientation during the summer prior to their first semester. Before arriving at orientation, students are asked to perform several tasks on-line, including a learning styles questionnaire (which gives respondents immediate results and information about their respective learning styles and an advising survey. During orientation, students stay on campus in a residence hall for two nights, along with 175 other members of their orientation group. The first orientation day consists of a larger campus-wide program, but the second and third days of orientation are reserved for activities specific to the College of Engineering. During these two days, the Engineering Advising Center establishes

its position as the “front door” for admitted students, explained the Director of Advising/Counseling. She said that during orientation, the goal is to “establish a trusting relationship to help improve retention.” During orientation, each student sees the same advisor twice. It is also during this time that students get their first exposure to peer advisors, who, during orientation, give tours of North Campus, participate in Q&A student panels, and assist students with navigating the on-line course registration.

Interaction with peer advisors during orientation is likely to be one of the first of many mentoring relationships a COE student will establish during his/her time at UM, whether it be with a peer, a graduate student, a faculty member, or a staff member. Peer advisors, who are paid employees of the Engineering Advising Center (EAC), meet with every first year student before their advisors and talk with students about what courses they should consider for the following semester and any problems they may be facing in their courses. The EAC hires 10 peer advisors who work about 5 hours a week during the academic year and as many as 30-40 hours a week during the summer. Each peer advisor participates in a week-long training, although one of the peer advisors, who is a senior explained that a lot of the information was redundant because as students they had each been through the process.

VT’s college of engineering also has an extensive peer-mentoring program. While not unique, theirs is certainly well developed and includes specific peer mentoring student groups for females, African Americans, Hispanics, transfer students, and a generalized group as well. Students in the mentoring programs are placed in groups, and each group is matched with a trained junior/senior student mentor who has an outstanding academic record. The responsibilities of the student mentors are to provide guidance and to help the new undergraduates as they learn to navigate their way through the university. The groups meet once a week during the fall (first) semester, and mentors and mentees are encouraged to continue meeting throughout the academic year. The programs have a reputation for success. This university-level official describes how student participants have described mentoring programs:

The one thing that students constantly talk about... is the benefit of the mentoring relationships that that program has had with them. Some have even remarked they don’t think they would have made it through the engineering school without it.

Strong ties to faculty and student interaction in and out of the classroom

Several institutions also illustrated ways of creating strong ties between women students and faculty as a way to encourage student retention. As an example, comments from students at HMC also revealed the close relationships that they have with faculty at the College. Noting that women students and faculty share common experiences, she also noted that she was very pleased with her interactions with her male faculty advisor: “my advisor is a male and I feel like talking to him is like one of the most fantastic things because he has had certain experiences that I will never get as a female. So I feel it is kind of an interesting dynamic. To be able to have you know faculty members that are my intellectual superiors at the moment and be able to have them.”

Another student noted that women students “flock” to do research with the women faculty members: “we find we have predominantly women in our lab, and I don’t know how much of it is that we seem more non-threatening, or that they are interested in how we balance --

they are certainly interested in how we balance life and work. I get a lot of questions on that.” And “be both male and female and there is all races and you know have that awesome dynamic and to be able to be friends with them and go out to dinner with them and have it not be awkward. “ Faculty members were also portrayed as open to women students’ experiences on this predominantly male campus. One engineering student said:

I approached one professor about an issue I was having within my engineering, one of my engineering classes, and I said, “Well I feel sometimes my voice is not being heard within a group. How can I address this issue?” and they were very willing to -- one of the faculty was willing to listen. They may not have been able to relate to my situation, however, they were attentive and they actually did care, and were willing to take the time out of their schedule to address this issue.

Faculty also view themselves as role models for students and also mentors for junior faculty members. Here is a comment made by a faculty member at Howard about role making for students:

. . . role models makes a difference... so I think having role models that you can look to and sit down one on one and say tell me a little bit about, how did you get there . . . in fact you can go further than I am, cause they didn’t know, I’m getting to you so that you can go a little bit forward. So, I think having positive role models around...good positive role models and good mentors to students that it makes a difference.

Furthermore, at these institutions, we found faculty relating to students and the problems they may be having. One engineering faculty member stated:

. . . [Students] see their instructors as advisors, as mentors and have access to them...there is a friendliness that is very, very evident. How are you doing today, and you know them by name . .From my standpoint, I enjoy the students. I enjoy seeing them learn, I relate to some of the problems that they have.”

This role modeling can be especially important for females and underrepresented groups in engineering For example in departments, like Howard’s civil engineering that has 40% female faculty—“so we could show females to students and that is something that is kind of unusual at a lot of places, and so we have female representation under a majority of our departments.”

A commitment to providing undergraduate research opportunities and experiences is also a means for faculty-student interaction that can benefit women students. For example, MIT’s Undergraduate Research Opportunities Program (UROP) states that 85% of their undergraduates have research experience. Howard University has an active Nano Lab and also places students for research experiences in some of the area’s industrial institutions. Both institutions also integrate research into the classroom allowing for meaningful classroom experiences (e.g., capstone courses).

High support for student organizations and activities

In our selected institutions, we also found that student organizations, and the colleges’ support of these organizations were an important component in retention of women students. These organizations often provide opportunities for further learning and leadership.

At HMC, Clubs such as SWE and GirlSHMC provide a support network for HMC women. Research suggests that such organizations have a positive influence on the retention of women students – even those students who don't actively participate -- in engineering and science (Brainard & Carlin, 1997). A faculty member described how one student organization made it okay to be “girly” at HMC:

One of the biggest mailing lists on campus is GirlSHMC. So all of the student organizations . . . end with HMC, so students of Harvey Mudd College, or SHMC, so the organization GirlSHMC. So they go and get pedicures and that kind of thing. And faculty are involved in that too, people on the faculty on the list, they can go. So it is really the full range of acceptable ways to be a woman at Harvey Mudd now.

A student mentioned SWE as another important dimension of the climate for women students, saying, “I guess I am just very comfortable here at Harvey Mudd in general, and SWE especially. Just the people. I understand what is expected . . . and the people have always been great about helping out when you get stuck.”

At ASU, student organizations play a key role in the recruitment and retention efforts and community building for women students. These organizations, while certainly designed to build community, have a wide array of specific functions and activities ranging from membership professional development (e.g., resume writing and interview skills) to K-12 outreach activities and of course purely social activities designed to develop camaraderie and community. Overall, the importance of student organizations in terms of building community and ultimately student retention, particularly to women and minority students is summed up by this college administrator,

And then also getting students into something where they feel like there's a community -- because this is a huge place. So if they don't find some kind of community and sense of belonging, that's an area where we lose students”. “[s]o my belief is that when the students get involved in the organization, there's more buy-in, there's more commitment. There's unity. They help each other.”

At MIT, several of the student organizations and at least one of the academic departments have established programs with a peer mentoring component. SWE, which has as many as 300 members and NSBE, which has more than 150 members both have peer mentoring components embedded in their programs. The president of NSBE explained that upper division mentors give members advice on classes, professors, and homework assignments. The campus-wide programs WISE and UROP also offer peer mentoring to their participants. An administrator associated with UROP explained how the peer mentoring process works in her program and its origin:

They [peer mentors] are alumni of our program and we match them [with younger students] by common academic interest. . . . So they each have a group of some twenty-five to thirty students that they are responsible for. They meet with them early in the academic year to get the students that are ready to go out and interview. The whole goal with UROP was that we knew juniors and seniors and your typical white guys were probably finding their ways into research labs, but we wanted to create a mechanism where all students could be able to think about how they can do that and be able to call a faculty member, feel comfortable going into the research setting. I really felt that for those students. They really need a guide, so that is the role of the peer advisor. And so the students meet with the peer advisors on a monthly basis just to make sure the projects

are going well, communication going well. Are there any issues? Are they feeling intimidated? ...So we really wanted to have some mechanism to insure that the partnerships would be successful.

Another Howard faculty member discussed the importance of student organizations and the leadership role it played for females to be included in engineering:

We do have many societies. Every engineering program has a society of some kind. And the societies are known to be inclusive. For example, the American Society of Civil Engineering chapter here at this university has had female presidents, or course secretaries. I remember a time when almost all the offices happen to be women, because the women volunteered. . . for example we have our bridge team competition that is done by the American Society of Civil Engineers, a national group which involve the local chapter for civil engineers and DC Alpha chapter for example that involves us to get involved in competition. So we build bridges and so on and compete. There are women doing all the analysis and you know they put on their hard hat and they are doing everything just like the guys. So in many ways I think by not, I guess by showing there is no hurdle there is nothing that we have psychologically built in to exclude you. They [women] know they are welcome.

Learning and living communities

Perhaps one of the most all-inclusive means of supporting student retention are the “learning and living” communities. Four of our institutions had some sort of learning and living community. In VT’s College of Engineering, there are two such communities – male and female. The living/ learning communities are designed to bring students together in a residential environment and to provide support in their pursuit of an engineering career; participants also have the opportunity to stay on a second year if they take on a leadership role.

An important aspect of these communities is the two-hour required seminar that focuses on developing student success strategies, professionalism and networking. The seminar occurs in both lectures and small work sessions. During the larger meetings, speakers are brought in from around campus and provide information regarding career services, internships, co-ops, etc – all activities that can help female students learn important success skills and again – feel more connected to their engineering college and future degree.

But the female student living in these communities finds that the less formal aspects of the community are a huge factor in feeling connected. Students describe the informal study sessions that occur in the residence halls where these students reside in proximate rooms. This physical set up makes it easy for female students to find other female engineering students, study as a group for the upcoming test and divide and conquer on those first year engineering design projects and homework that are often so challenging.

Discussion and Conclusions

Our study has highlighted some of the strategies and practices used to recruit and retain women in engineering at these six institutions. Many of these institutions had a historical commitment and mission to increase women in engineering. They employed flexible admissions

policies and had strong outreach and innovative programs in place. Immediately notable is that all six institutions had summer bridge programs of varying characteristics.

Retention practices at these institutions have shown success. Other cross-case findings – all of which are supported with quotations and document analysis evidence – show that these early programs and practices help the institutions and the engineering departments to strategize and increase the representation of women in engineering via strategies such as:

- Capitalizing on the existing diversity of peer environment within their institutions (e.g. the existing diversity of their student body), alumni, the institution’s facilities and resources,
- Creating early opportunities for faculty/student interaction to recruit and retain these women students in outreach, bridge, and support programs.
- Building a sense of community

These institutions’ success in increasing the number of women they enroll and graduate also appears to be tied to several aspects of their culture and organization. First, personalized recruiting efforts, including specific activities for admitted women students, assure the new women recruits that they will be respected and embraced by each institution’s culture. Second, these institutions’ success in attracting dynamic men and women faculty who are highly involved with students appears to be a significant factor in creating a positive environment for women on campus and in the engineering programs specifically. Third, peer interaction and leadership through clubs appears to provide a support network for women in particular. For example, many male students did not mention organizations in our interviews. Although women remain a minority in engineering programs, the interventions described create a positive climate for women that may provide the necessary support to completion of an engineering degree.

Our findings can help other institutions assess their recruitment and retention strategies using outreach, summer/bridge, and other support programs to increase the representation of women students in the engineering disciplines. In all these institutions, there was a sense that anybody can be an engineer and it was important to keep all students engaged and feeling part of the engineering community. One Howard professor in chemical engineering summed it up:

. . .I think anybody can be an engineer, as a matter of fact that is the problem for us. Engineers that we have now and we have young women and young men [come] away . . .it looks boring, it looks too hard. It is very hard and yuck. Well that is the thing. We want to try not to make it that, and one of the ways is to use, of course, people, but it is to use technology toward the way of making it fun, making it interesting, and making it so you can do it. It doesn’t really need any special talent. Everybody can do it.

There continues to be a growing concern in the engineering community to increase the representation of women students. Therefore, this paper’s focus on effective educational environments and experiences for preparing and retaining women students is extremely important. Many more research questions are starting to surface, as well, that can be answered with more in-depth qualitative analysis of these institutions. Do institutions that produce higher numbers of female and underrepresented students have more diversified faculty? How can these environments be reproduced or introduced at other institutions? Future work will explore these and other questions with data obtained across all six case study institutions.

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