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Engaging women in computer science and engineering:
Insights from a national study of undergraduate research experiences

By Karen A. Kim, Amy J. Fann, & Kimberly O. Misa-Escalante

Background

The high-tech industry is becoming increasingly complex, requiring that more people in the workforce obtain advanced degrees (BLS, 2008). At the same time, computer science departments have seen a decline in the number of new Ph.D. students as well as a decline in undergraduate enrollment, especially women and students of color (Zweben, 2008). Yet, while we have seen progress over the last few decades, the number of women college students still lag far behind their male counterparts in engineering and computer science departments, especially at the doctoral level. In 2005, women comprised 22 percent of bachelor's degrees earned in computer science and 20 percent of bachelor's degrees earned in engineering, despite the fact that women comprised 58 percent of bachelor's degrees in all fields (NSF, 2008). These disparities increase as fewer women advance through graduate programs in engineering and computer science. The low representation of females in these fields aggravates a learning environment that is often alienating and unfair (Nelson, 2005). Undergraduate research programs are often seen as key catalysts to promoting students long-term interest in science and engineering (Lopatto 2003, 2004; Seymour & Hewitt, 1997). Therefore, understanding how these experiences encourage students to continue to graduate school and to pursue technical careers may help us to better focus efforts to increase the number and diversity of students in computer science and engineering, which is indeed the focus of this paper.

Undergraduate research programs in the sciences and engineering, referred to as Research Experience for Undergraduates or "REUs" in National Science Foundation (NSF) parlance, are touted as important pathways for women and underrepresented students of color into graduate programs and careers (Lapatto, 2004, 2003). Unlike traditional, especially lower division coursework in STEM, where students are expected to acquire a large body of rudimentary knowledge decontextualized from real-world experiences and application (Katz, et. al. 2006), REUs provide students with opportunities to actively engage in the "real work" of scientists by actively participating in the full research process from conceptualizing a problem, to collecting data, to analyzing results and connecting them to real world applications (Jesse, 2006; Kardash, 2000; Seymour et. al., 2003). Furthermore, REU programs routinely offer professional development workshops about applying to graduate school and career options, and interns have overwhelmingly reported that the REU experience helped them to clarify career paths including graduate school (Jesse, 2006; Kardash, 2000; Seymour et. al., 2003). An NSF (2005) study reported that the undergraduate internship experience elevated expectations of advanced degree attainment relative to non-participating students. Unarguably, these outcomes, if achieved, are positive for all students, women and men. Given that the majority of REUs purposefully recruit women interns, and in our study, nearly half of all REUs in computer science and engineering had 50% or more women participants, REUs promote gender equity by virtue of including a relatively high percentage of women interns in their programs, providing them with a hands-on research experience and access to faculty mentors. Are these efforts alone enough to promote gender equity, or are additional practices and professional development that explicitly addresses barriers to women's advancement in these fields also important?

Understanding the Issues through Evaluation and a National Study

At UCLA, the Center for Embedded Network Sensing (CENS) in the School of Engineering received NSF funding for a unique project titled: Women @ CENS, created to explore issues of gender equity in

engineering and computer science (ECS) undergraduate research internship programs. The Women @ CENS project includes two studies: 1) an evaluation of our own CENS REU program and 2) a national study of REUs in ECS. The goals of these studies were to learn about promising practices in addressing gender equity in the REU setting from our own summer internship program, and to learn about what other REUs were doing in regards to promoting gender equity such that more women will choose to pursue advanced degrees and faculty careers in ECS. *Study One* utilizes the evaluation of the CENS REU over four program years to understand what has and has not worked for our female students in particular. For *Study Two*, we surveyed program directors of NSF funded Computer Science and Engineering REUs nationwide about espoused program goals, practices, participant demographics, and in particular, specific efforts designed to address gender inequity in these fields. To that end, the following questions were addressed.

1)   What can we understand about the specific mechanisms and components of the CENS REU that benefit female students?
2)   Do REU programs in ECS offer specific mentoring, programming or professional development components addressing gender-equity issues? If so, what do these look like?

The strength of our combined studies is the focus on the role of REU practices in supporting women participants' interest and long-term commitment to engineering and computer science from multiple perspectives, chiefly those of student interns and REU program administrators. This paper will therefore provide a complementary perspective to previous research, and additional information useful to better understanding institutional efforts at increasing the number of women in the Ph.D.s in the sciences and engineering.

Theoretical Framework
Research on gender inequity in higher education, particularly in science, has shown that although women may perform at the same levels, they report less confidence in their individual abilities and accomplishments than men (Jesse, 2006; Margolis and Fisher, 2000; WEPAN, 1999), are less likely to aggressively promote themselves then men (Babcock, and Laschever, 2003; Cuny and Aspray, 2000), and are less likely to ask questions and engage in all types of negotiation (Babcock, and Laschever, 2003; Valian, 1999). In the context of the CENS co-ed REU in which half women participants were female, we observed that women interns were less likely to ask questions in small and larger group settings, and at the end of the program rate themselves slightly lower in ability and self-confidence than male participants even though they successfully contributed to the same research projects and had the same set of mentors.

Virginia Valian's research (1999) on women in the sciences is an especially useful lens for framing this study. Valian found that two key concepts drive the disparities between men's and women's advancement in academia, particularly in the sciences. The first is what she refers to as *gender schemas*, psychological and social conceptions of what it means to be a man or a woman, conceptions that we all share, both male and female. Gender schemas are implicit, often non-conscious perceptions that we use to categorize people and anticipate behavior. Similarly, Hirshbein (2006) asserts that gender refers to a complex set of social and cultural assumptions that govern individuals in a system and is intimately connected to power: the dichotomy is used to denote relationships between the powerful and the powerless, the active and the passive, the dominant and the submissive. Gender schemas play a large role in evaluating professional competence when schemas make a clear differentiation between males and females and when evidence or criteria for success is ambiguous and open to interpretation (Valian, 1999).

Using the terms "gender blindness" or "gender consciousness" are related ways to understand how gender schemas come into play. The terms "blindness" and "consciousness" have been used in discussions of racial ideology (Bonilla-Silva, 2006; Collins, 2000; Kang, 2005). These concepts also work in the present context to describe students' recognition and understanding of gender differences. Gender-blindness describes an attitude of indifference with regards to the possibility of differences experienced as a result of one's gender (Harding, 1986). This attitude can stem from ignorance or a hope that gender inequity is a problem of the past. In contrast, gender-consciousness is an acknowledgment and cognizance of differences by gender and a rationalizing of why these differences exist (Gurin, 1985). Valian's second key principle is the *accumulation of advantage*. Gender schemas operate as implicit or invisible factors that most times favor males in academia such that male academics can accumulate advantages, small gains being the building blocks of greater ones. In the case of women in academic science, small, often subtle imbalances lead up to greater disadvantages for women and in essence "molehills become mountains" lowering women's confidence, expectations and ability to advance. Valian asserts that it is the subtle forms of bias that women experience as much or more than overt or intended discrimination that keeps women from advancing in these fields. The National Academy of Science (2006) released a report citing a decade of research of women in the sciences. The report concluded that it was "not lack of talent or interest but unintentional biases and outmoded institutional structures that are hindering the advancement of women in the academic sciences and engineering," (p. 8). Outside of the ideal REU experience, women are still a minority in computer science and engineering and are likely to experience barriers once they return to their home institution, and as they continue to advance in these fields. Given this, we share data from two studies.

Study One- Evaluation of CENS REU: Four Program Years

CENS recently completed its fourth summer undergraduate research experience. Our REU began as an 8-week paid internship position, whose participants conducted research in small teams under the guidance of a faculty mentor and graduate students. Through our REU, we aimed to show students the rewarding benefits of graduate level education by giving them the opportunity to do real, hands-on research. We also aimed to increase women participants' long-term commitment to computer science and engineering through professional development activities which encouraged students to consider academic careers. (See Appendix: Table 1 for a full description of activities by Program Year.)

Methodology
Evaluation activities served multiple purposes: to collect formative and summative feedback on the program, to understand the gender climate for students in our program, and to provide students a structured opportunity to reflect on and share their experiences during the summer. Evaluation assessments were collected from various perspectives and at different times throughout the summer. Both quantitative and qualitative methods were employed. The approach taken allowed assessments to be an integrated part of the summer experience and were designed to be meaningful to all program participants. The specific evaluation activities included: administration of student surveys and focus groups; observing laboratories, meetings, and program components; and analyzing student journal entries. (See Appendix: Table 2 for detailed description of evaluation activities by program year)

Program Demographics
Over the four years, 96 interns have participated in our REU. Overall, the program was comprised of 56% women and 44% men. Additionally, 39% of the participants were from underrepresented communities. See Table 1 for these statistics.

Table 1. Participation in Women@CENS, 2004-2007

Participants	Year 1 2004	Year 2 2005	Year 3 2006	Year 4 2007	TOTAL
Total	41	21	21	13	96
Number of Female participants	22	13	12	7	54
Number of Male participants	19	8	9	6	42
Number of Underrepresented Students	20	3	9	5	37

Key Findings

Examining students' outcomes, engagement and satisfaction in the program shows the CENS REU to be a successful and rich experience. Consistent with previous research, the greatest benefit of the program has been providing students with a full-time, "graduate school-like" research experience. Students often ranked the engagement in hands-on research as the most satisfying aspect of the program. Because CENS technology is interdisciplinary and linked to many different types of application, students recognized the relevance and importance of the projects in which they were involved.

By immersing students in the research environment, they also indirectly learn about graduate school and can potentially develop or refine aspirations to pursue a doctorate. Many interns are looking to their graduate student mentors as examples and role models of what graduate school involves. While formal seminars describe the application process and ways to finance graduate education, interaction with mentors in the laboratory socializes students to the graduate school culture, areas of research to pursue, and the everyday routine of being a graduate student. This type of information may be more important in the long run as undergraduates research graduate programs and look for the correct "fit" for them.

Addressing Gender Equity

Based on feedback the gender component continually evolved over the 4 program years. In Year 1, gender issues were addressed directly from the start of the program by assigning research literature followed by a workshop directly addressing gender bias in ECS. This created much tension among the female and male participants, such that it created a victim/perpetrator dichotomy. In addition, separate gender meetings (i.e., one for female and one for male participants) were scheduled biweekly throughout the summer. These meetings were aimed at exploring issues of gender inequity in engineering. However, students, both men and women, were opposed to having separate gender meetings. As a result, meetings were combined, in which both men and women were included at all sessions. However, opportunities were provided for voluntary split-gender meetings. Ten women expressed interest in having these meetings and met informally over lunch for a directed group discussion.

Because of the tension that was created as a result of addressing gender issues directly, there was much less of a focus specifically on gender issues in Years 2, 3, and 4. Instead, we incorporated gender issues more organically into broader topics such as teamwork, diversity and graduate school and faculty experiences. Moreover, program staff sought to establish community and rapport among students first before tackling potentially controversial topics such as gender inequity.

The gender component was one of, if not the, most challenging aspects of program planning and development. Because undergraduate students may not be in situations that currently manifest gender inequity, or they might not be conscious of these situations, they are not familiar with these issues and

unused to these types of discussions. To some students, the gender component meetings were perceived as an imposition or an artificially appended educational lecture. Feedback from the students and graduate student mentors also suggested that discussions should focus less on "feelings" and more on current research, topics of climate, policies, and ways to improve the situation as opposed to dwelling on topics of underrepresentation and discrimination.   In addition to the general evolution of our REU, we observed that women interns were less likely to ask questions in small and large group settings and at the end of the program rate themselves slightly lower in ability and self-confidence than male participants even though they successfully contributed to the same research projects and had the same set of mentors.

Gender-Blindness
Two major themes that emerged from the data on gender equity were gender-blindness and gender consciousness. In each REU cohort, many interns, both women and men, approached their participation in engineering from a gender-blind perspective. For example, when students were asked whether they perceived gender inequity in the field of engineering, one student felt:

> I don't feel like anyone feels uncomfortable from what I have seen at least. I have friends that are girls that are engineers. I don't think they are discriminated against in any way or treated differently. – Male participant

Notably, these types of comments were more commonly elicited from male students. However, both genders often perceived the field from a male-normed perspective. Students had come to expect engineering classmates, faculty members, and research group members to be male. One male student remarked, "If I walk into a certain section of class, and I don't see any women, it isn't surprising or anything. It's normal." While the majority of female students were aware of their underrepresentation in these fields and had very personal experiences and reactions to it, others were unbothered by it.

> I really don't feel like I am a minority in class. Every once in a while there will be five girls compared to thirty guys. I have always had that so it is not out of the ordinary for me, and I don't have a problem with it. It doesn't bother me at all. – Female participant

As these students expressed, not seeing many women in engineering environments is "normal" and "not out of the ordinary." However, considering something to be "ordinary" also works to obscure what may be problematic with the ordinary. As such, incidences of discrimination may in fact be subtle and not easily recognized. This subtlety obscures the underlying inequity which makes confronting and combating gender discrimination all the more difficult.

Gender-Consciousness
The majority of, both male and female interns who participated in the program were conscious of the persistent underrepresentation of women in these fields. Many students felt that gender inequity in engineering starts very early, beginning with how children are raised and socialized either toward or away from engineering (i.e. Legos vs. dolls). Students also felt that the lifestyle associated with being an engineer might be less attractive to women and effectively deter them from pursuing the field. Getting married, having a family, and taking leave to have a baby were concerns more commonly associated with women and their participation in engineering but rarely mentioned as issues facing men.

While only a few students cited a difference in ability or even interest as reasons for the underrepresentation of women in engineering, many more noted a discrepancy in confidence and sense

of belonging once in the field. Students had witnessed a steady decline in the numbers of female classmates in their math and engineering classes starting in the first year of college. Whereas first year classes might be 40 percent female, by the time students reached their upper division engineering courses, women comprised only 15 percent or less of each class.

Using gender-consciousness as a lens for understanding students' perceptions, students not only recognized barriers and challenges that women face, they also perceived a difference in the work ethic and attitudes of men and women who persist in engineering. Female students were described as more focused and dedicated because their roads to and places in the field are more difficult.

> I feel like some guys end up in [engineering] because it is just something they kind of fell into. Whereas if a girl is in it, she has made a really large choice to be in it. I feel like all the girls I know in classes are really motivated. They like to study all the time to make sure that they do well. I know a lot of guys that are half-ass about it. Maybe they started in engineering because of family or because they thought it was something to do but not something that they really enjoy, not like most women that are in the field. Obviously it is a more out-of-the-ordinary decision for [women]. It is definitely something that they want to do. – Male participant

Female participants more commonly brought up the importance of forging study groups. While males would speak of the importance of interacting with other engineers for the purposes of networking and learning of opportunities, women more frequently used words like "support" and "help" to describe peer interactions. Beyond the academic support that peers might provide, some women also talked about the need to confide in other women and share common experiences, for example, "I think it is easier to get along with guys in general, but I like having female friends to talk more about girl stuff. I have found two or three girls this year that I have been studying a lot with." A couple of students had joined student organizations at their campuses specifically for female engineering students. When asked why they participated in these groups, reasons cited included opportunities for socializing, and also a sense of responsibility to help other women who might be struggling.

Addressing Gender Issues: Lessons Learned from the CENS REU
Engaging students in difficult topics of discussion like gender inequity in ECS in addition to providing an actual research experience can be a powerful pairing of components to truly combat the underrepresentation of women in these fields. In 2004, 2005, 2006, and 2007 programs, a number of students revealed that they had never formally discussed these topics as part of their engineering curriculum. However, certain lessons have been learned about the gender component. These include: (1) involve both genders in these components, (2) create a safe space for discussion by first establishing a sense of community, (3) organize separate gender and co-ed discussions, (4) allow topics to arise organically from participants' curiosity, interest and experiences, and (5) focus on broader issues of implicit bias (See Kang, 2005) and discuss implications of gender bias secondarily,

Lastly, tracking program alumni is crucial to understanding how the undergraduate summer research experience impacts future plans. Over half of those that responded to the tracking survey, plan to pursue either a Masters or Ph.D in Computer Science or Engineering. However a number of respondents[1] indicated that they would not pursue a profession or career that was related to their undergraduate major. Several respondents expressed no desire to be in academia. Additional research is needed to

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[1] Eleven percent of women and eight percent of men indicated that they would pursue a profession that is not related to their undergraduate major.

examine why students invest themselves in an undergraduate major that they do not pursue as a career, profession or as graduate study.

Study Two-Women @ CENS REU Study

The purpose of the Women @ CENS REU study was to learn about the state of gender equity programming in engineering and computer science (ECS) undergraduate research internship programs and to identify promising practices. To that end, we wanted to learn if other REU programs in ECS offered specific mentoring, programming or professional development components addressing gender-equity issues, and if so, what did they look like.

A two part, mixed method study was conducted. For Part I of the study, a 30 item online survey was emailed to program directors of NSF funded undergraduate research internships in engineering, computer science and related fields. Part II of the study included follow-up interviews with a subset of survey respondents. Below is a description of the survey and survey results, followed by findings from the qualitative follow-up interviews.

Part I: Online Survey of REU Programs
Survey questions were based on a thorough review of the literature addressing both the REU experience and women in the sciences, and the collective research and practical experience of our team members. The survey included questions on program goals, learning outcomes, design and practices, administrative issues, and characteristics of participants. In addition, participants were asked to rate the importance of providing gender-specific programming and complete open-ended questions on aspects of their program that they found most effective in promoting women participants' self-confidence and long-term interest in engineering and computer science, and what, if anything, was still needed to help them achieve this goal. An initial draft of the survey was piloted by four REU program directors and by an additional faculty member from another institution who conducts research on women in computer science. Each survey reviewer was then interviewed by phone or in person to discuss survey content and questions. The final survey reflects additions, omissions and changes to questions as suggested by our colleagues who piloted the survey. The final survey was emailed to program directors at 342 NSF funded REU programs in ECS and related fields. Program Directors were identified through the NSF Website. After sending up to four reminders, we received a total of 117 completed surveys, representing a 37% response rate. Below are descriptive findings from the national survey of NSF funded REU programs in engineering and computer science. We have chosen to highlight those survey findings related directly to gender-equity issues.

Survey Findings
While cohort sizes varied, the majority of REUs recruited small groups of interns. Most programs, (95 out of 117) hosted between 8 and 25 students each summer. Although underrepresented in engineering and computer science at all levels, women are significantly better represented as undergraduate researchers in summer programs. The majority of respondents, 83 percent, indicated that they specifically targeted women students as part of their recruitment efforts. Overall, 90 percent of these programs had at least 30 percent or more female participants. Nearly half of all the programs indicated that they had 50 percent or more women participants in their most recent program. Two programs were designed specifically for women and had 100 percent women participants.

Only sixteen percent of participants (18:117 programs) indicated that they offered a professional development workshop or seminar addressing gender-equity issues in their programs. Program directors were asked a series of questions on a five point scale (1= not important, 2= somewhat important, 3=important, 4=very important, and 5= essential) about the importance of pairing women participants

with women mentors, and the importance of providing women role models. As summarized in the table below, we found that pairing women interns with women mentors was not important from an administrative standpoint. This may be in part related to the fact that there are fewer women faculty in Engineering and Computer Science, and therefore fewer women faculty available to participate as mentors. As later noted, when asked to respond to an open-ended question of what, if anything, was needed to help programs support women interns, several respondents wrote that more women faculty were needed.

Slightly over half of the respondents indicated that providing women role models was important, very important or essential. The survey included a separate question about role modeling as it is different from mentoring, although it is typically an element of mentoring. Role modeling is less interactive than mentoring and less direct. Barker and Cohoon (2006) explain role modeling as follows, "Women role models exemplify the values, attitudes and behavior associated with a position, and in so doing; make it possible for other women to imagine themselves in a similar role." As reported by program directors, providing women interns with access to women role models was substantially more important than matching women interns with women mentors or connecting female interns to professional organizations for women such as the Society of Women Engineers (SWE), the National Center for Women in Information Technology (NCWIT).

Following this survey item were two open-ended questions. The first asked participants to list the component of their programs that they felt were the most effective in promoting women participants' self-confidence and long-term interest in engineering and computer science. The second asked participants to list what, if anything was still needed to promoting women participants' self-confidence and long-term interest in engineering and computer science.

For the first open-ended question, a total of 88 participants (out of 117) responded. All responses were coded. See Appendix C for a table of all coded, open-ended responses to this question. The majority of open-ended respondents wrote that their most successful practice in supporting women interns was providing women role models. Examples of this included having research seminars with women speakers from government and academia, small group discussions about research with women faculty and staff, and social activities with senior women. The second most prominent response listed was "the research experience itself." In other words, providing women students with a meaningful research experience was in and of itself the most important aspect supporting women interns. Three themes tied for third place: 1) having a large proportion, or critical mass of women participants, 2) Providing women mentors, and 3) "We treat all participants equally."

For the second open-ended question, respondents were given an opportunity to list what, if anything would help them further promote women participants' self-confidence and long-term interest in engineering and computer science. A total of 59 participants (out of 117) choose to respond to this question. The majority of respondents stated that there was a need for more women role models and more women faculty in engineering and computer science, hardly surprising given the near absence of women in many of these departments across the country. Second, respondents indicated that more funding was needed to enable them to host more women students, as well as more funding for developing new initiatives that would help women advance in engineering and computer science.

Part II: Follow-Up Interviews
The second part of the Women @ CENS REU study included follow-up phone interviews with a subset of survey respondents so that we could probe more deeply into the specifics of REU program practices

addressing gender equity. REU program administrators who completed the survey were emailed an invitation to participate in a phone interview based upon the following criteria:
1. Survey respondents who indicated that they offered a professional development workshop or seminar addressing gender-equity issues
2. Survey respondents who indicated that increasing the number of women who enter Ph.D. programs in computer science was an *essential* goal of their program

Not surprisingly, there was a great deal of overlap in programs meeting both of these criteria. Sixteen percent of survey respondents (18:117) indicated that they offered a professional development workshop or seminar addressing gender-equity issues and 34% (40:117) of respondents indicated that increasing the number of women who enter Ph.D. programs in computer science was an *"essential"* goal of their program. However, among programs directed by administrators who chose to participate in the follow-up interview, only three out of twenty had indicated that they included a workshop addressing gender equity issues in the survey. Twenty program administrators (12 women and 8 men) volunteered to participate in semi-structured telephone interviews that lasted from 30 minutes to an hour. Among the participants, 11 were ladder faculty within their respective department as well as the chief administrator for their respective REU program, and 9 participants were non-faculty program coordinators or directors in charge of the REU. Seventeen of the participants worked at research institutions, two participants worked at Master's Comprehensive universities, and one participant coordinated a collaborative program between a university and medical center. Two of the programs in the sample represent REUs designed for women with all women participants.

Data Analysis
Detailed hand notes were taken during the telephone interviews which were then transcribed and coded. Data analysis or coding began by reading transcripts and identifying an initial set of codes or "things that go together" (LeCompte, 2000). The following five themes emerged: 1) The backlash in directly addressing gender equity issues within the REU context, 2) "The stealth approach," strategies for addressing gender equity indirectly, 3) "safe" gender issues, and 4) Role Modeling and 5) The role of interdisciplinary participation.

Addressing Gender Equity Directly in the REU Context
Only three interview participants stated that they purposely addressed gender equity issues in their REU through a professional development workshop or other programming, while four interview participants stated something to the effect that they had never thought about addressing [gender issues] in the REU setting,

> [Gender equity issues] are not addressed overtly. It would be great to have a panel discussion on women in the sciences. I never really looked at it from a gender standpoint. I never looked for gender issues in patterns in evaluation and exit interviews.

Two interviewees noted that they did not see gender equity as an issue in their field and therefore do not have a need to address gender equity in their undergraduate internship program. For example, "From my perspective in bio-technical engineering, there are lots of women around at all levels, as faculty, as lab managers. There is chance for advancement for all folks here- we have determined, highly motivated people, even just observing from the outside, I don't see any [bias] myself." Three of the program administrators who did offer workshops specific to gender equity described a trial and error process of how they modified their practices each year to indirectly address these issues, and described using a *stealth* or *back door* approach to address gender bias issues in engineering and computer science. Two of

these programs were REU programs designed for women only. Overall, these participants explained that they now take an indirect route to addressing gender-equity issues due to past resistance from a handful of *women* participants to acknowledging gender bias.

> We started out being very direct in addressing gender issues and the students hated it, they thought we were telling them that because you are a woman, you need help."

> Incoming students will say, "I've never been discriminated against because I am a woman." But by the time they are an advanced graduate student or faculty they feel differently.

> The new female students see us [female faculty] as their mom's age and think gender bias no longer exists so we stopped talking directly about gender issues.

> We had a round table session that was not meant to be some kind of "Ooooh, it's *so* hard to be a woman in engineering," but rather, what were the experiences of the women faculty and graduate students. It went badly and we will never do it again…[W]hen one of our women faculty spoke about her experiences and shared how tough it was for her, she had this girl tell her, "your experience is illegitimate." This disrupted the whole meeting. She went on to say that her father was a professor at such and such university and always has to try to hire female candidates over male candidates even if they are less qualified, and that she had never experienced bias.

What was especially disheartening is that the initial resistance of some female participants to acknowledge or talk about gender bias meant that efforts to engage in a dialog about gender equity and or share strategies that might support young women's efforts to remain in the field are lost to many interns who may in fact be quite interested. In the case of the roundtable described above, the program administer went to say that, "We found out later that the other female interns enjoyed the discussion and were annoyed by the one intern, and found the talk to be inspiring. However, the faculty member was really upset and angry. We stopped doing the roundtable."

Addressing Gender Bias Indirectly and Organically
As a result of a backlash from a handful of participants in explicitly or directly including an exploration of gender equity in the REU setting, program administrators described using an "indirect," or "backdoor" method that would allow for gender issues to come up naturally. This approach primarily involved bringing in women scientists as guest speakers with the idea that it is acceptable for guest speakers to bring up gender issues when talking about their *own* experiences in engineering and computer science. Additionally, female interns have the opportunity to ask questions and follow-up with guest speakers one-on-one after the presentation.

> Women tend to have less self confidence than their male peers so we tried talking with them, not directly but by open discussion. We have guest scientists come in and present, and one guest speaker was a women scientist who talked about the glass ceiling. One female freshman said that she never encountered any bias as a female and I thought, "is she oblivious, and is that tREU?

> A female faculty member gave a workshop on careers in academia and described the experience of starting out, and the gender issues came up.   We try to find a happy medium and not be overtly blunt about it- but making it clear that there are issues in both group and individual settings.

We can weave in gender issues in a round table type discussion. For example, a female professor will talk about her research, how she got where she is, any epiphanies, turning points, etc. We have a sort of a script in the back of minds of things we hope the speaker covers. For example, being a professor and having family, hindrances of being a female in a male dominated field.

Four program administrators, who did not indicate on the survey that they provided any type of professional development on gender equity, indicated in the interview that although they did not necessarily bring up gender equity issues directly, they provided a variety of forums where gender issues could be addressed, for example, "[I] realized that women interns could identify a little bit more with women speakers. Two out of the four "hot topics" speakers were women. In so doing, women faculty share their background, epiphanies, etc. What happened was that we found that interns followed up with some of the speakers and asked them more personal questions- about family issues, alternative lifestyle, etc."

Introducing "Safe" Gender Issues
After coding the interviews, it was apparent that there were a set gender issues that were seemingly safe to address in the REU context. Whether addressed directly or indirectly, the most prominent issue brought to light was the balance between work and family, in particular the balance between being a faculty member and a parent. Although this is of potential interest to both young women and men, the balance between work and family was seen as a "gender issue" primarily affecting women and was a "safe" issue to discuss in various forums, as opposed to more contentious issues of gender bias and inequity such as the glass ceiling, chilly climate and differences in hiring, salary and tenure promotion and other forms of discrimination against women. For example, "Gender issues are more consciously addressed when we bring in women scientists for the brown bag and they talk about balancing work and family…and this is something all students are interested in."

The Benefits of Role Models
Providing women role models is one direct way that undergraduate research programs support women interns. In every interview, program administrators stated that they involved women faculty and women graduate students as much as possible. Many programs were run through departments or centers with few women faculty and graduate students. In the case of the REU programs designed for women only, all of the faculty and graduate student mentors were women. Regardless of available women faculty, staff and graduate students, programs provided access to women role models by inviting guest speakers and hosting other formal and informal social events featuring women scientists.

For our orientation symposia, different women come in everyday. Women faculty in the field talk about their own lives in STEM, plus all of the faculty do a workshop or session on identity and team building.

We host a special 'Women in Computing Day…' We start with presentations on what it's like to be a professional computer scientist, and we prepare some questions ahead of time... Once issues of gender equity come up, it seems natural, the issues come up more or less depending on the speaker. Balancing work and family life is frequently talked about.

The Value of Interdisciplinary Collaboration
As noted above in the survey results, a primary REU program goal was to provide interns with exposure to interdisciplinary research. This can be accomplished by attracting faculty mentors from diverse fields as well as recruiting interns with different academic backgrounds. Several interview participants described

how interdisciplinary research teams "broke the mold of the "typical" computer scientist or engineer," by creating a situation where no one academic background dominated. Faculty, graduate students and interns alike had to find ways to forgo disciplinary jargon and communicate and work across disciplinary norms to complete a common project. Recruiting students across disciplines also opens the applicant pool to more women by including females from biological and environmental sciences and from the social sciences and humanities.

> In many exit surveys, women don't feel like they fit at all. All male students act and dress the same way and speak in code language and the art students have helped transcend this. [Male students] are not allowed to use acronyms and have to be able to describe what they are doing to other students and they can't fall back on the more comfortable way as if presenting to other men in the CS program.

> We found that when group norms are not the same, you can't engage in your fall-back behavior. We have done research on a couple of cruises to learn about the Tsunami and the arctic. What we learned is that if you have a person who is not an expert it makes the experts feel more at ease to explain things at a basic level. This reflects the phenomenon of what happens to a woman when she walks into a classroom.

> We approached a broader context of all underrepresented groups. One of things we focused on is that interdisciplinary programs tend to attract women, especially where women can see connections between what they doing and how it will be applied. We brought in women from an art program doing graphic designs to help work on computer programs. Our computer science students really appreciated working with the art students. One of the art students decided to take programming courses afterwards. Students were already engaged in digital art, but the art students changed the atmosphere of the program.

Discussion and Implications
Overall, we learned that programs do recruit and enroll a critical mass of female interns and provide a valuable hands-on research experience under faculty mentorship. A great many programs intentionally provide at least informal exposure to women role models in ECS, oftentimes through inviting women scientists as guest speakers. A small handful of programs purposefully provide training or professional development that addresses gender bias and discrimination against women in ECS, although program administrators described how they have come to eschew explicit exploration of these issues in favor of more indirect, less obvious and covert ways, similar to our own experiences with the CENS REU.

Overall, ninety percent of programs included 30% or more women participants, which is far above the norm of women's participation in either engineering or computer science. Nearly half of the programs included 50% or more women. In response to an open-ended question on the survey, a large number of respondents indicated that they supported women's advancement in ECS by virtue of the number of women they recruited and enrolled in their program and the resulting positive affect that having a critical mass of women in the programs has on female interns. This is keeping with research literature stating that a critical mass of women participants in the sciences is a significant positive factor in women's retention and satisfaction (Cohoon, 2001; Margolis and Fisher, 2002). When male and female enrollment is more or less equalized, the culture changes in ways that are positive for women (Etzkowitz et. al., 1992; Margolis and Fisher, 2000). However, assuming that increasing the numbers of women alone will remove barriers places a burden on the women who participate: "not only must they do the same (if not better) scientific work than their male counterparts, they are also responsible for changing the workplace climate" (Level

Playing Field, 2005, p. 18). Ultimately, targeting women interns for program participation is necessary, but must be joined with structural change that will eventually make targeting unnecessary (Level Playing Field, 2005). Over half of the programs indicated that providing female interns with access to women scientists was important if not essential. The majority of interview participants also indicated that they actively strove to bring role models into the program, even if informally through guest speakers. Role models are important and can help female interns overcome the negative effects of stereotypes by increasing confidence and helping them to see themselves as successful in the ECS field and potentially see themselves as ECS faculty. It is important to note that in all cases, the purpose of addressing gender equity issues is not simply to point out that biases exist, but to provide knowledge and strategies for overcoming biases, and a safe forum in which to talk about experiences of discrimination. The conundrum for program administrators is how to bring a problem into the light when the audience is not yet ready to examine it? Even in all-women REUs, participants described that enough undergraduate women in their program felt that gender bias was not a problem, or no longer existed, such that they felt forced to use "indirect" ways for the subject manner to organically come up, which constrains and minimizes opportunities to talk about things like gender schemas, gender blindness or gender-consciousness and how to overcome gender-based barriers to academic and career advancement.

Interestingly, 12 survey respondents wrote that they treat all interns the same, regardless of gender. Certainly women interns should receive the same respect, attention and high expectations as men interns. However, treating both male and female interns equally can also be interpreted to mean that all interns are held to White male standards of behavior and communication, and that these standards, and the advantage they confer to men, are unacknowledged. Barres (2006) writes that "for talented women, academia is all too often not a meritocracy… when it comes to bias, it seems that the desire to believe in a meritocracy is so powerful that until a person has experienced sufficient career-harming bias themselves they simply do believe that it exists," (p. 134).

Finally, interdisciplinary recruiting has dual positive benefits. On the one hand recruiting outside of engineering and computer science will yield a larger pool of potential women interns. Secondly, having an academically diverse research team can help "[break] the mold of the "typical" computer scientist or engineer," by creating a situation where no one academic background dominates. Faculty, graduate students and interns alike must forgo disciplinary jargon and communicate and work across disciplinary norms. Interdisciplinary collaboration has the potential to alter the power structure, group think and group norms in ECS.

Conclusion
From both studies we have learned that a rich, hands-on research experience under faculty mentorship is beneficial to all interns, female and male. This faculty mentorship component may indeed be particularly influential in women's decisions to pursue advanced degrees, as highlighted by a qualitative study of women REU students (Barker, 2009). Having a critical mass of female participants is an essential first component in creating a more welcoming environment for female interns. Role modeling has dual purposes: 1) helping women interns see themselves in academic and professional roles, and 2) through talking about their own experiences, women role models may share insights on how they overcame barriers and balanced work and life/family.

We assert that REUs are in a unique position to take action in preparing women interns to successfully compete in engineering and computer science. Further research is needed to explore the efficacy of addressing gender equity explicitly and implicitly in the REU setting and beyond, and how this will benefit both women and men participants.

Appendix A

Program Activities By Program Year

Need	Engagement Structure	Description	Y1	Y2	Y3	Y4
Personal, Academic, and Professional Development, Social, and Basic	1-Day Orientation	During the first year of the program, orientation was 1 day. It included an overall orientation to CENS, completion of paperwork, participation in focus groups, a campus tour, and reception.	✓			
	Orientation Week	In subsequent years, orientation was a week long. It introduced all interns to the Center, the research, the mentors, and each other. Students learned about their projects within the context of the overall theme and participated in tutorials and lab orientations to introduce them to foundational knowledge that helped them succeed in their research projects.		✓	✓	✓
	Tech Camp	Interns traveled to the James Reserve (JR), CENS testbed, and participated in a two-day hands-on Tech Camp with graduate student and faculty mentors. In addition to conducting field deployments and making connections between the JR testbed and their projects, the Tech Camp introduced interns to the technology and enhanced community building with hosted team-building activities.		✓	✓	✓
Personal	Mentoring Community	All faculty, graduate students, and undergraduate scholars were included as members of CENS Mentoring Community. Each intern was assigned to a faculty mentor and graduate student mentors but also worked with their project team.	✓	✓	✓	✓
	One-on-One Meetings	These meetings created time for each intern to speak with mentors and staff. Students discussed issues and goals and connected with mentors and staff, helping staff and mentors to better serve the needs of the interns.		✓	✓	✓
Academic	Technical Seminars	Interns attended CENS Technical Seminars where invited speakers, faculty, and graduate students presented on various research topics.	✓	✓	✓	✓
	Weekly Progress Report Meetings	Interns and mentors met for weekly progress report meetings. Each week, project teams made a presentation on the status of their research followed by discussions of their projects with the faculty, graduate students, and undergraduates.		✓	✓	✓
	Research Project Tutorials	Faculty and graduate mentors hosted research project tutorials for groups of undergraduate interns to help guide students on projects.		✓	✓	✓
	Poster Session Symposium	Undergraduate interns presented their research projects to the community at a final poster session. A journal featuring interns' posters and papers was also prepared.	✓	✓	✓	✓
	CENS Journal			✓	✓	✓
Professional Development	Professional Development Workshops	Workshops focused on providing interns interactive discussions on the following topics: Chat with CENS Director Deborah Estrin			✓	✓
		Writing a Scientific Paper Students were given instructions and guidelines to complete a technical paper about their research project.				✓
		Faculty Showcase featuring female and underrepresented faculty Faculty shared their experiences within academia.	✓	✓	✓	✓
		Pathways to Graduate School and Engineering Careers Presenters provided insight on how to get into graduate school. Presenters also spoke about industry jobs.		✓	✓	✓

			Y1	Y2	Y3	Y4
		Graduate Students Students addressed a number of topics including time management, getting started, mentoring, and teamwork.	✓	✓	✓	✓
		Gender and Diversity Issues in Engineering The content of this workshop evolved over time to become more holistic. In Year 1, a speaker presented on the underrepresentation of women in the sciences. In Year 2, staff facilitated a game. In Year 3, a speaker presented his work on implicit bias. In the final year, diversity was integrated throughout the summer.	✓	✓	✓	
		Teamwork and Group Dynamics Students felt this workshop was too artificial. In subsequent years, this topic was addressed by staff and graduate students during the Graduate Student panel.		✓		
		Women lunch/Gendered lunch/Intern's rap – This workshop also evolved over time. In Year 1, women were invited to the "Women's Lunches" but were not required. In Year 2, there were gendered lunches. In Year 3 & 4, the Intern's Rap provided a safe space for both men and women to talk about any issues raised during the summer.			✓	✓
	Summer Ethics Program	This special program was open to all undergraduates, graduate students, and faculty, highlighting important ethical issues and an interactive session on use of ENS technology in the environment.	✓	✓	✓	✓
	GRE Prep Course	CENS offered a GRE preparation course for interns.	✓	✓	✓	✓
Social	Welcome Reception	A reception promoted interaction and introduction of interns, faculty, graduate student mentors, and the CENS community.	✓	✓	✓	✓
	Social Engagements	Formal events (e.g., trip to Catalina, beach bonfire, LA Tour) were planned to facilitate networking among participants and mentors.	✓	✓	✓	✓
	Informal student organized events	Interns and graduate students organized informal events during the summer (e.g., dinners, sight seeing).		✓	✓	✓
	CENS Events	Interns were invited to CENS activities, such as the weekly Tuesday Teatime networking event.				✓
	CENS Barbeque	Interns were invited to CENS-wide event where students, faculty and staff could network, socialize and enjoy food.	✓	✓		
	Closing Dinner	A closing dinner and recognition ceremony was held for interns, faculty, and grad students.	✓	✓	✓	✓
Basic	Financial Incentives	Each undergraduate scholar received a monthly stipend and travel reimbursements.	✓	✓	✓	✓
	Room & Board	In Year 1, not all participants were local. Some students were from USC and UC Merced. In subsequent year, through coordination with CARE, room and board was provided for interns who needed it.	✓	✓	✓	✓

Appendix B

Evaluation Activities by Program Year

Activity	Administration	Description	Y1	Y2	Y3	Y4
Undergrad Paper Surveys	Pretest	The student surveys consisted of a variety of items that assessed students' background characteristics (such as academic preparation, activities in college, and high school exposure to research), abilities and skills, aspirations, and attitudes toward science, mathematics, and engineering. The surveys contained a majority of Likert-scaled items but also several open-ended questions that elicited students' feedback on their goals of and reactions to the program.	✓	✓	✓	✓
	Posttest		✓	✓	✓	✓
Undergrad Focus groups	Pretest	Focus groups were conducted at the beginning and the end of the summer. Focus groups were assigned by gender. Similarly, facilitators were also matched to each group by gender. The questions guiding the focus group interviews covered the following topics: students' interest and background in science and engineering, goals for the program, opinions on gender inequity in the field, and reactions to the program. Feedback elicited by students early on was incorporated into shaping the remainder of the summer program.	✓	✓	✓	✓
	Posttest		✓	✓	✓	✓
	Tech Camp	To specifically assess an added component of the 2005 program (James Reserve Tech Camp), an informal co-ed focus group was conducted during the second week of the program. The Tech Camp was established in response to student feedback from previous years' programs that more orientation to CENS technology and social interaction early in the summer was needed.		✓		
Journal Entries	Week 3	Journal prompts were sent via email. Week 3 focused on participants' involvement and knowledge of their assigned research project/group.	✓	✓	✓	✓
	Week 5	Week 5 focused on the interaction and communication that occurs in their research environment. However this journal prompt was combined with week 3's when the program went from a 10-week to an 8-week program.	✓			
	Week 7/8	Week 7/8 focused on participants' perceptions of gender equity in the field of engineering.	✓	✓	✓	✓
Observations	Development Workshops	Observations were conducted of various events and settings throughout the summer. Evaluators took note of the physical setting, arrangement of work groups, and interaction among students. Evaluators looked for overt and subtle gendered interactions by observing how students address one another, who took charge of groups and presentations, and in what manner tasks were delegated. During workshops, the evaluator acted as a participant observer and spoke with students about their impressions of the meetings. Information garnered from the observations provided context for the feedback offered by students through the other means of assessment.	✓	✓	✓	✓
	Lab Settings		✓	✓	✓	✓
	Tech Camp			✓		
	Social Engagements		✓	✓	✓	✓
Faculty interviews	Post-program	Focus groups with the graduate student mentors occurred at the end of Year 1. One-on-one telephone interviews were also conducted with faculty mentors. The focus group discussions and interviews elicited mentors' impressions of their students, thoughts on gender issues facing engineering, and assessments of the strengths and weaknesses of the program. Because groups were much smaller after Year 1, there was no longer a need for formal interviews. Mentors were involved and integrated throughout the program and feedback was on-going.	✓			
Graduate Student Mentor Focus Groups	Post-program		✓			

Appendix C

Survey question: What components of your program are the most effective in promoting women participants' self confidence and long-term commitment to engineering and/or computer science? Coded responses to open-ended question listed in order of frequency. 88 responses total.

Themes	Selected Quotes	Frequency
Aspects of the Research Experience	▪ Introducing students to data collection and analysis, helping them to conduct independent and original research ▪ Succeeding in conducting an original piece of research and presenting this research to their peers ▪ Successfully doing research and finding others interested in talking with them about their work ▪ Giving them a meaningful laboratory research experience ▪ Conducting the completion of the research itself ▪ Showing them that they can solve problems and accomplish tasks	**10**
Women Role Models	▪ Women as role models in the work place ▪ Research seminars with women speakers from academia and government labs. These speakers also address career issues for women in science and engineering. Students have lunch with speakers, have opportunities to ask questions ▪ Small group discussions with women faculty/staff on the scientific, business, professional and social aspects of research ▪ Dinner with women experts in the field who share their life stories and identify with the uncertainty that our women students have regarding success in careers in science and engineering ▪ Social activities with senior women ▪ The percentage of senior personnel that are women fare exceeds the percentage of women in engineering, hence, we have a significant opportunity to provide women role models for both women and men students ▪ All four faculty mentors are female so the direct role models should be very important ▪ REU students are placed in the same laboratory as WISE program ▪	**12**
Purposefully Treat Women and Men Equally	▪ None in particular. The same components for male participants. ▪ We have actually more female participation in our program than male. We don't need to differentiate between how our women and men are treated both require equal promotion. ▪ Interacting with groups of students of both genders as equals. ▪ The women participants have preferred to work with male participants because the real-life situation demands such collaboration ▪ We do not treat women participants in any different manner than their male counterparts. If a student, male or female has self confidence problems, we try to spend more time with that student ▪ Treating women as equal members of the research team	**9**

	▪ We hire many women undergraduates and expect the same vigor of research and critical thinking as we expect of the men. There is no difference, and we do not create one.	
Critical Mass of Women Participants	▪ We have about 80% women in our program ▪ We make sure that we don't have any groups with only one student of one gender ▪ Being able to have a significant cohort of women participate in the program to provide a sense of community and empowerment ▪ We have maintained a 50/50 ratio of men to women in the program, they see that they are equally represented ▪ Good gender balance (typically 50/50)	**9**
Women mentors	▪ We have 2 out of 4 female faculty and typically 1 out of 3 female teaching assistants ▪ We ensure that a significant fraction of the mentors are women ▪ 60%of our Pus and senior investigators are female ▪ We have a number of strong women mentors who lead by example and through interaction ▪ Finding good mentors or groups who are dedicated to promoting women in science and engineering ▪ Matching with other women	**9**
Mentoring	▪ Positive reinforcement from mentors ▪ Individually matched mentors ▪ One-on-mentoring by research supervisor ▪ Continuing mentoring interaction after the end of the program ▪ Strong connection with good faculty and grad student mentors	**9** **9**

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