

AC 2010-723: EXTENDING RESEARCH INTO PRACTICE: RESULTS FROM THE PROJECT TO ASSESS CLIMATE IN ENGINEERING (PACE)

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Extending Research into Practice: Results from the Project to Assess Climate in Engineering (PACE)

Abstract

The Alfred P. Sloan Foundation awarded a grant to the Center for Workforce Development at the University of Washington for a multi-site research project intended to identify issues that affect persistence among engineering undergraduates while paying specific attention to the intersection of race, gender and academic experience. The Project to Assess Climate in Engineering (PACE) had three main data collection components: an online student survey for undergraduates in engineering; interviews with current undergraduate engineering students; and interviews with undergraduate students who left engineering for another major at their university. All 22 PACE schools received a final report that included an overview of methodology, discussion of statistically significant findings and general trends, interview results, recommendations and a detailed analysis of responses to each survey question disaggregated by gender and by race/ethnicity. Each school was also provided with aggregated comparison data from three schools of their choice for anonymized benchmarking.

In the final report to each institution, a set of recommendations was made based on quantitative and qualitative data from the survey and interviews. This paper discusses the prevalence of specific recommendations that appeared across many institutions. The recommendations generated by the PACE research team illustrate some of the critical issues that PACE schools and many other engineering schools need to address to improve the undergraduate experience in engineering for students of all demographic groups.

Introduction

Engineering is critical to the national competitiveness and productivity of the United States. Unfortunately, in spite of our country's urgent needs and challenges in areas such as security, energy, transportation and communications, students' interest in engineering has steadily declined since 1995¹. While this decreased interest has manifested itself in a variety of ways, of particular importance is the difficulty undergraduate engineering programs face in retaining those students who are already enrolled.

According to the Engineering Workforce Commission, there were 100,411 first year engineering students in 2005.² By 2006, the number of second year engineering students had dropped to 78,418 – a decline of 22 percent – and a similar decline was found between 2004 and 2005.³ Retention issues affect all engineering students though retention patterns differ considerably between engineering schools. Using a national data set, Adelman found the rate of attrition for female engineering students was nearly 50 percent whereas for men it was 25 percent, despite the fact that women earned higher grades.⁴ An argument can be made that women should be retained at a considerably higher rate than men because the decision for women to study engineering is less casual given that they remain a non-traditional group in the field. The engineering culture and climate in which women experience isolation, decreased self-confidence and sexism continues to deter women's progress and retention.^{5,6,7}

Building on the success of earlier research and funded by The Alfred P. Sloan Foundation with a supplemental grant from the Engineering Information Foundation, the Project to Assess Climate in Engineering (PACE) is a multi-site research project headquartered at the Center for Workforce Development at the University of Washington.⁸ The overall purpose of PACE is to identify issues that affect persistence among engineering undergraduates while paying specific attention to the intersection of race, gender and academic experience. The action items designed to achieve these goals are as follows:

- Provide data that will help identify areas that require attention in order to improve the academic climate for all students;
- Provide aggregated and institution-specific data regarding student attitudes organized by sex and ethnic/racial categories for benchmarking purposes;
- Supplement quantitative survey findings with aggregated qualitative data from interviews conducted with currently enrolled majority and minority students;
- Supplement institutional climate analysis with qualitative interviews with students who have exited or are in the process of exiting engineering programs; and
- Follow-up with participating colleges/universities to track actions taken to improve the climate.

This paper provides a general sense of the issues existing at a fairly diverse but still representative sample of engineering colleges. Each PACE school was given tailored recommendations. When the research team looked across all the recommendations at all the schools, it turned out that some of the recommendations were highly prevalent at many of the schools. In this paper, those common recommendations are discussed in relation to the quantitative and qualitative findings that supported reasons for the recommendations.

Method

In conjunction with the substantive goals described above, the PACE research team also is committed to a set of scientific standards whereby the data gathered would be valid, reliable and ethical reflections of students' experiences. In order to meet these methodological goals, the team designed and implemented the following protocol.

Quantitative Survey

The PACE questionnaire included questions in the following categories: Quality of Teaching, Professors, Teaching Assistants, Labs, Resources, Student Interaction, Extracurricular Activities, Personal Experience, Perceptions of Engineering Careers, Perceptions of Engineering Major, Confidence and Demographic Information. In addition, Personal Experience included nine questions relevant to sensitive issues such as sex and race discrimination and harassment.

In recognition of the varying Institutional Review Board rules that regulate the release of student data, we created four survey administration options from which each institution could choose. They included 1) school hosts survey, school samples students, schools sends invitations, 2) PACE hosts survey, school samples students and school sends invitations, 3) PACE hosts survey, PACE samples students, school sends invitations and 4) PACE hosts survey, PACE samples students and PACE sends invitations.

To reduce variation across sites, PACE was restricted to those undergraduate engineering programs defined as one-tiered. In other words, each of the programs either enrolls its students directly from high school into the College/School of Engineering and/or provides an engineering advisor to students during the first year who indicated an interest in engineering on their college application form.

The students invited to participate in the online climate survey were selected based on a stratified random sample rather than a voluntary sample, thereby increasing generalizability to those students at similar institutions not included in PACE. Oversampling women and under-represented minority students (URMs) was intentionally done to ensure that these groups would be sufficiently represented among those who completed the survey. The National Science Foundation defines underrepresented groups as African-Americans, Hispanics, Native Americans and Native Hawaiian/Pacific Islanders.

The PACE survey instrument was pre-tested on undergraduate engineering students at a Pacific Northwest university not included in PACE. Internal consistency coefficients were computed for all subscales that were comprised of five or more items. Overall, responses to each of the seven subscales showed adequate to excellent internal consistency with a mean α of .77. In order to examine the construct validity of the questionnaire, an exploratory factor analysis was performed on 63 Likert-type items taken from the items that constituted the core measure of student opinion of the engineering experience: Professors, Teaching Assistants, Student Interaction, Perceptions of Engineering, Engineering Major and Confidence subscales.

The factor solution was obtained using principal axis factoring and varimax rotation. This produced a solution of 14 factors (with eigenvalues greater than 1.0) which cumulatively accounted for 43 percent of the variance. For the most part, items that were intended to tap into a common idea (*e.g.* "Evaluation of professors") did load together onto a common factor. Despite these caveats, the factor analysis results suggested a generally well-constructed set of items for assessing the undergraduate engineering experience.

Three strategies were used to address and reduce the low response rate typically associated with web-based surveys. First, students received an invitation email and up to three reminder emails. Second, each of these emails was either sent from or configured to appear from a local engineering dean or site liaison. And third, each institution was given 100 dollars to be used toward an incentive for the online climate survey. All but two schools chose to use an opportunity drawing in which students voluntarily provided his/her name and email address upon completion of the survey. Two schools did not provide incentives which did not appear to have an impact on response rates.

Qualitative Interviews

There were two different interview groups: current engineering students (climate interviews) and former engineering students at the school (leaver's interviews). The on-site climate interviews addressed, among other things, students' experiences in engineering, reasons for choosing a major in engineering, best and worst classes and why, confidence, thoughts about leaving, and support structures. In addition, students are asked specific questions about their perceptions of female and underrepresented minority students and faculty in their program.

The leaver's interviews include some of the same questions as the climate interviews such as interest in and decision to major in engineering, the experiences in engineering, support structures and mentoring. In addition, the leaver's interviews ask about the decision to change majors including what factors were involved, who they spoke to about their decision, and if anything could have changed their mind. All interviewees were asked for basic demographic information including sex, age, race/ethnicity, year in school and engineering major. In addition, leavers were asked for their new non-engineering major.

The two interview protocols were pre-tested on students enrolled at institutions not affiliated with PACE. Two different sampling strategies were used to recruit students for the on-site interviews. Similar to the online climate survey, students were selected for the on-site climate interviews based on a stratified random sample. In order to be eligible for this sample, students had to be currently enrolled engineering majors who were at least 18 years of age at the time of the sampling. From there, students were divided into three groups: women, under-represented men (*e.g.* African-American, Hispanic, Native American and Native Hawaiian/ Pacific Islander) and over-represented men (*e.g.* Asian American, Caucasian/White American, International, Other and Unknown). Ten names were randomly selected from each of the three groups for a total of 30 students.

In order to be eligible for the on-site leaver's interviews, students had to be at least 18 years old at the time of the sampling and former engineering majors who had transferred to a non-engineering major at the same college/university. Site liaisons were asked to go back as far as one academic year and list all of the students who met these criteria. If this process resulted in more than 30 students, 30 students were randomly selected to participate in the leavers interviews. If this process resulted in fewer than 30 students, the entire list was invited to participate

Congruent with the online climate survey, three strategies were used to maximize the response rate for the on-site interviews. First, students received an invitation email and two reminder emails over the course of the recruitment process. Current students and leavers were recruited simultaneously. Second, each of these emails was either sent from or configured to appear from a local engineering dean or site liaison. Finally, each institution was given five dollars per interview to be used toward an incentive.

PACE School Reports and Recommendations

Overall, 37,958 students were invited to participate in the PACE online climate survey and more than 10,000 students responded. The response rate at individual institutions ranged from seven percent to 52 percent with a mean of 29 percent and a median of 28 percent. Although 22 institutions participated in PACE, one was removed from this report due to its extremely low response rates. In-depth face-to-face interviews were conducted at 16 schools. The number of interviews conducted at each school ranged from five students to 22 students.

All PACE schools received a final report that included an overview of methodology, discussion of statistically significant findings and general trends, interview results, recommendations and a detailed report of each survey question responses disaggregated by gender and by race/ethnicity. Each school was also provided with aggregated comparison data from three schools of their choice for anonymized benchmarking.

Recommendations were made to each institution based on the quantitative survey findings, supplemented by the qualitative interviews. The majority of recommendations included relevant research to support the recommendation. An analysis of the recommendations made to all engineering schools is revealing. The majority of recommendations were grouped into three major categories. These categories, along with the specific recommendation and number of schools that received the recommendation are listed below in Table 1.

Table 1. Categorization and Frequencies of Recommendations Sent to Schools

Recommendation	# of Schools Receiving Recommendation (n=21)
Category 1: Increase and improve faculty-student interaction	
• Develop formal faculty-student mentoring programs	17
• Educate faculty about stereotypes and their impact	11
• Encourage students to ask for help	11
• Facilitate increased student engagement (through student-faculty interaction), particularly in the 1 st two years	10
• Improve language skills of faculty	5
• Provide opportunities for faculty professional development (in areas related to effective student interaction)	4
Category 2: Improve Curriculum	
• Integrate relevant applications in the curriculum	14
• Provide greater flexibility in the engineering curriculum	5
Category 3: Strengthen student engagement in engineering study and knowledge of engineering careers	
• Encourage all students to participate in their professional societies and clubs	9
• Facilitate communities for women and minorities	5
• Provide increased opportunities for students to participate in internships, co-ops and undergraduate research opportunities.	5

Each engineering school received tailored recommendations based on their specific survey findings and interviews results. For the purposes of this paper, a summary of the full recommendations and relevant quantitative and qualitative findings is detailed below. Specific institutional numbers and percentages have been removed for confidentiality. The percentages provided in the recommendations that follow are from the entire PACE sample which includes schools who did not receive the recommendation. Therefore, schools who received the recommendation likely had higher or lower percentages than indicated.

Category 1: Increase and improve faculty-student interaction

Develop formal faculty-student mentoring programs: Research indicates that mentoring has a positive impact on engineering students but only 19 percent of survey respondents had participated in mentoring programs.^{9,10} Also, several interviewees indicated they would like to have stronger connections with professors. Developing stronger relationships among students, faculty and engineers in industry builds student confidence, increases student engagement and increases student understanding of opportunities in engineering.^{11,12} If one-on-one mentoring requires more time and resources than are available, group mentoring with faculty in which five or six students meet with one mentor is another option.

Educate faculty about stereotypes and their impact: Seventeen percent of women surveyed indicated that they were unfairly singled out in classes because they were women. Additionally, slightly more than 22 percent of female students indicated that they had heard faculty express gender stereotypes. Stereotype threat impacts students when a particular part of their identity is named salient. Research has shown that women score lower on math tests when reminded of their gender prior to the exam and that white male engineering students score lower than usual on tests when told that Asian students typically get better grades than students from other groups.^{13,14}

There are specific things that faculty and TAs can do to help mitigate the impacts of stereotype threat. It is recommended that faculty and TAs participate in professional development activities that will help identify personal biases, particularly those associated with gender and race/ethnicity, that research indicates we all exhibit. Working to recognize these biases and developing ways to combat them will help faculty and teaching assistants in and out of the classroom work more effectively with students of all demographic groups. Consider the Implicit Association Test (www.projectimplicit.net) or Interactive Theatre Groups such as the Center for Research on Learning and Teaching Players (<http://www.crlt.umich.edu/>) who are trained to role play typical scenarios that occur in and out of the classroom and facilitate audience discussion.

Encourage students to ask for help: It is often difficult for students who excelled in high school to find themselves needing academic assistance in college. Some former engineering students interviewed reported that if they got better grades in math they would have stayed in engineering and many students are overwhelmed by the workload. Most current and former students interviewed were aware of many of the academic support services available and some used them to varying degrees, while others indicated they should have taken advantage of the services more or did not feel comfortable doing so. Students need to be reminded and reassured that asking for help is a strength and not a weakness. Find ways of promoting this message regularly through various messengers and mechanisms, particularly during the first two years.

Facilitate increased student engagement, particularly in the first two years: Professors play a critical role in facilitating student engagement which can be defined as students' levels of active involvement in their undergraduate programs and related elements such as learning inside the classroom, in student organizations and in research experiences.¹⁵ Acknowledgement and interaction with faculty is particularly important for underrepresented groups.^{16,17,18} Students interviewed experienced a good connection with some professors as their class sizes decreased

and as they became more engaged in their disciplines. However, interviewees indicated that typically, this did not occur until junior year. Finding ways to foster involvement and relationships with students through faculty/student mentoring programs, undergraduate research and participation in extracurricular activities earlier in the process is recommended. It is also important to convey to students directly, continuously and personally the importance of initiating those relationships.

Improve language skills: Twenty percent of male and female students surveyed, indicated that their professors' and TAs' accents (17% of students surveyed) usually or all the time, made it hard to understand course material. It is recommended that this barrier to communication be recognized, evaluate individual's English language abilities and provide additional training if necessary.

Provide opportunities for faculty professional development: Students lose confidence when they perceive an inferior ability compared with their peers. This was a significant finding among female survey respondents with 51%, compared to 39% for males, indicating they were average or below average compared to their peers. This perception could also contribute to female survey respondents who reported that they were less comfortable asking questions in class than were male students. For female students, 17% said they never or rarely were comfortable asking question in class compared with 11% of male students. An instructor's communication style and/or testing process that is viewed as a tactic to weed out students, can contribute to feelings of discouragement and lower self-confidence.¹⁹ Learning and implementing more effective ways to communicate can help alleviate these negative student perceptions that contribute to attrition.

Managing groups is another area that requires professional development for faculty. Group work in engineering is a mainstay and an effective pedagogical tool if managed well. However, if teams or groups are poorly constructed, unmonitored or untrained in group dynamics, the end result may be that any marginalization underrepresented students experience in the classroom becomes magnified.²⁰ Women students discussed this issue during interviews, having experienced relegation to administrative duties by the group, exclusion from the group and/or appointment as leader of the group often resulting in an excessive workload. Faculty and TAs need to be aware of and implement effective group management skills.

Category 2: Improve curriculum

Continue to integrate relevant applications into the curriculum: Many interviewees enjoyed classes that included hands-on experiences, problem-solving activities and real-life examples. In fact, their enthusiasm for hands-on activities and building things motivated them to major in engineering in the first place. Integrating relevant engineering examples into the curriculum, getting students involved in meaningful undergraduate research projects and encouraging professors to bring their industry or research experiences into the classroom would benefit all students. For women in particular, integrating examples into the teaching of fundamental concepts increases recruitment and retention.^{21,22}

Provide greater flexibility in the engineering curriculum: Twenty-seven percent of students surveyed could think of other majors they would like better than engineering. A "perfect attrition

storm” starts to occur when you add interest in other fields to the finding that 38 percent of the survey respondents indicated they usually or all the time felt overwhelmed by the amount of homework they have. In the WECE study half of the women who switched out of engineering majors did so because they were not interested in engineering and one-third of the respondents said they were attracted to another field.²³ Students interviewed for PACE cited competing interests and rigid curriculum as a reason they switched out of engineering or considered leaving engineering. For most students, choosing engineering as a major means opting out of the opportunity to explore other possible majors because the curriculum is so full.

To retain students in engineering, it is beneficial to provide as much flexibility in the curriculum as possible to allow students some opportunity to explore. There are several ways to accomplish this, such as integrating socially relevant examples or non-traditional labs into traditional courses. Offering varied undergraduate research opportunities, internships and study abroad programs that expose students to the diversity of the engineering profession or to non-traditional career avenues for engineers is another approach to attract “different” types of engineering students to the field. Continuing to find ways to expand these opportunities that use engineering skills in a variety of capacities is a useful strategy to retain students with varied interests.

Category 3: Strengthen engagement in engineering study and knowledge of engineering careers.

Encourage all students to participate in their professional societies and clubs: Building professional and social networks counteracts the isolation many women and minorities experience and provides them with the information, support and knowledge they need to persist through graduation.²⁴ This finding supports other major reports focused on recruiting and retaining women and minorities in science engineering.^{25,26} Sixty-four percent of women respondents indicated they felt part of an engineering community, usually or all the time compared to 55% of men. Given the finding that women were already more involved than men in these types of activities with 56% of females and 28% of males involved in student societies, one way to improve retention is to encourage and enable all students to participate in professional societies and clubs. Indeed, it would be beneficial to have a greater sense of community among all engineering students.

Facilitate communities for women and minorities: Forty-three percent of females and 34% of URM students who responded to the PACE survey indicated involvement in the women in engineering/science program and minority in engineering program respectively. Women interviewees joined sororities to find the camaraderie they lacked in the engineering classrooms. It is recommended to continue to support these programs and assess what is working, what is not and what types of programs need to be added to provide the services that facilitate success among underrepresented groups.

Provide increased opportunities for students to participate in internships, co-ops and undergraduate research opportunities: Students consistently discussed the value of work experiences through internships and undergraduate research. These experiences helped increase their awareness of job opportunities and career paths available in various engineering disciplines and connected them with individuals involved in STEM. Additionally, students appreciated

being able to apply what they learned in class to the work environment. For students who were struggling to maintain good grades and were questioning their ability, a positive work experience served as a reminder that they could be successful. In the WECE study, half of the women who switched out of engineering majors did so because they were not interested in engineering and one-third of the respondents said they were attracted to another field²⁷. Often students do not have enough information about engineering or connection to the field to persist. Involving more students in work-related activities will engage students in engineering by tying together theoretical coursework and applied fieldwork.

Conclusion

Based on quantitative and qualitative findings, recommendations were made to each PACE institution. The PACE institutions represent a diverse and representative sample of private and public institutions. The findings from this study are targeted at faculty and administrators interested in improving retention of students, particularly women and underrepresented minorities.

Recommendations made by the PACE research team revealed persistent issues that impact student retention. After further investigation, it became clear that the recommendations clustered into three areas: increase and improve faculty-student interaction; improve curriculum; and strengthen student engagement in engineering study and knowledge of engineering careers. Interestingly, though not surprising, PACE recommendations provide strong support for ASEEs report, *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*.²⁸ This report maintains that although a quality higher education experience involves many stakeholders, the leadership of engineering faculty and administrators is critical since they are responsible for the quality of the engineering education experience. Providing engaging, relevant and welcoming learning environments, all key elements identified in the ASEE report, are confirmed by the PACE findings. In addition, *The Engineer of 2020* identifies the need to shape the engineering curriculum to be responsive to different learning styles to attract a more diverse student population interested in studying engineering.²⁹ The concept of broadening student demographics in engineering involves attracting women, underrepresented minorities and male students who are not traditional engineering students to the field. Developing a more flexible, creative and socially connected curriculum is a necessary step to achieve this objective. However, non-traditional engineering students will only enroll and persist in the major if the culture of the engineering school provides a place where students want to learn, are inspired to learn and have the opportunity to interact with faculty in a positive manner.

Finally, the next steps of this project are for the participating institutions to complete a *Framework for Action* based on their individual PACE reports including findings and recommendations. The PACE team plans to follow-up with each participating institution three times during the next year and a half to track their success in implementing their *Framework for Action*. Technical assistance such as translating the findings and recommendations into action plans will be provided to PACE schools upon request.

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