Accepted for Publication in *Journal of Engineering Education* to appear **July 2007**

Achieving Parity of the Sexes at the Undergraduate Level: A Study of Success

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Abstract

Most research about women in engineering focuses on reasons for their under-representation. In contrast, we capitalized on an opportunity to study success: the School of Industrial Engineering at the University of Oklahoma had organically achieved parity of the sexes at the undergraduate level. To investigate this success, we adopted an ethnographic perspective, interviewing 185 students who represented four fields and four institutions as well as 12 faculty in Industrial Engineering at the University of Oklahoma. These data pointed to a combination of aspects of the discipline and the department culture as explanatory variables. Emerging from the data was a third explanatory variable: a high number of students, disproportionately many women, who relocated into Industrial Engineering from another major, underscoring the impact of broad recruiting activities. This paper emphasizes ideas that other departments can consider adapting to their own efforts to increase diversity.

Keywords: culture, gender, success

I. Background and Context

The under-participation of women in science, technology, engineering, and mathematics (STEM) has been a topic of discussion for decades. Some fields and some departments have been more successful than others and might offer models that less successful fields and departments can adapt. The Fall 2000 roster of students majoring in Industrial Engineering (IE) at the University of Oklahoma (OU) revealed that 55% of the

undergraduate majors in IE at OU were women, indicating that this department had achieved parity of the sexes among its undergraduate majors. Furthermore, the proportion of women majoring in IE at OU had more than doubled in the space of four years, having steadily increased from 27% in 1996 (with a Fall peak at 58% in 2001). As reported in Table 1, 55% was strikingly higher than the proportion in any other engineering degree program at OU at that time (next highest 39%) and was more than twice the proportion of IE degree recipients in the then-most recent nationwide counts (25%). This climb occurred organically, meaning that the department did not set out with the goal of achieving parity and, what's more, did not have an infusion of money for that purpose. They did not offer targeted scholarships, workshops, or mentoring programs. We found these descriptive data to be compelling and set out in search of explanations for this department's success.

The most obvious candidate explanation was the unusually high proportion of female faculty in IE at OU, which at that time was four of 10 (see Table 1). However, when we looked more closely at numerical data, we found that this factor alone was unlikely to account for the success. As one counterexample, at that time on the national scene, chemical engineering (ChemE) boasted the highest proportion of female graduates, 33%, but women comprised only 8% of the faculty. At OU, the School of Chemical Engineering had proportions similar to the national ones: one of the 15 faculty (6%) was a woman and 39% of the majors were female. Thus, ChemE nationally and locally offered a counterexample in that a high proportion of female undergraduate majors can occur even with a low proportion of female faculty. As another counterexample, we

looked at computer science (CS). Nationally, at that time, women comprised 11% of the CS faculty and 24% of the bachelor's recipients. At OU, two of the 10 (20%) CS faculty were women but only 15% of the majors were. That is, CS at OU had a high proportion of women faculty but a low proportion of women majors, relative to national proportions. Both ChemE and CS countered the standard claim that there is a correlation between proportion of women faculty and proportion of women majors. Even when a department does have a high proportion of women faculty and a high proportion of women students, these data indicate only correlation, not causation [1]. Thus, we rejected proportion of women faculty, while certainly an important consideration, as the sole explanatory variable for the success of IE at OU.

	OU students[2]		students nationwide[3]	OU faculty[4]		faculty nationwide
IE	47/84	55%	25%	4/10	40%	10% [5]
ChemE[1]	126/325	39%	32%	1/15	6%	8% [5]
CS[1]	46/312	15%	24%	2/10	20%	11% [6]
ECE[1]	65/550	12%	12%	1/16	6%	7% [5]

Table notes: (1) **ChemE** is Chemical, Biological, and Materials Engineering; **CS** is Computer Science; **ECE** is Electrical and Computer Engineering; (2) *Table: Norman Campus Students By College, Major And Level Unduplicated Headcount: Fall 2000* in [2], left column is women/total; (3) *Table 257.--Bachelor's, master's, and doctor's degrees conferred by degree-granting institutions, by sex of student and field of study: 1997-98* in [3]; (4) *Table Full-Time Instructional Faculty, Tenure Status, by College and*

Department in [2] and conversations with department personnel; (5) *Appendix D: Data on Faculty Rank Comparing Georgia Tech to Benchmark Schools, 1998I in* [4]; (6) *Table 21. Gender of Current Faculty* in [5] (includes Full, Associate, and Assistant Professors in CS and computer engineering departments that grant Ph.D.s)

Table 1. Proportion of women in participating engineering fields, Fall 2000.

Having determined that the belief that women faculty beget women majors lacks sufficient explanatory power, we set out in search of an understanding of why disproportionately many women undergraduates came to IE at OU. In particular, we wanted to address the question, "What characteristics of IE at OU, as compared to less successful STEM fields/departments, attract and retain female (and male) students?" We noted that the vast majority of existing literature focused on reasons that women were underrepresented in STEM fields. In contrast, we were in a position to study a success story. Two seminal studies were particularly informative both for issues to explore and for design considerations: Seymour and Hewitt [6] and Margolis and Fisher [7]. Seymour and Hewitt [6] interviewed hundreds of undergraduates at colleges across the country to identify factors that contributed to the students' decisions about completing or switching out of a degree in science, engineering, or mathematics. Margolis and Fisher [7] also used student interviews to investigate factors affecting women students specifically in computer science.

Inspired by those two seminal studies, we designed an ethnographic research project

(NSF award GSE-0225228). Based on a review of the literature and the results of a small pilot study (Spring 2002, see [8] for details), we targeted the following six factor categories: students' backgrounds [6, 7, 9-14], aspects of the institution [15, 16], aspects of the discipline [6, 13, 17], curriculum and pedagogy [6, 13], department culture [18], and students' futures [19]. We have published a number of papers that address specific aspects of the study, which are cited in the relevant sections of this paper (see [20] for a complete list). This paper offers a synthesis of our findings. The factor categories that turned out to offer the most explanatory power were aspects of the discipline and department culture, which subsumed relevant issues from other categories, along with an emergent factor category termed *relocating*. Each of these three factor categories is discussed below.

II. METHOD

The research team consisted of faculty, staff, and students with backgrounds in Anthropology, Chemical Engineering, Chemistry, Communication, Computer Science, Education, Industrial Engineering, Mathematics, and Women's Studies. Our goal was to detect explanatory factors specific to IE at OU that could be adapted by other departments. As such, our research design involved seven departments: the School of Industrial Engineering at OU, three additional departments in the College of Engineering (CoE) at OU, and IE departments at three other institutions. We selected comparison/contrast departments at OU that varied in the proportion of women faculty and students, relative to the corresponding national proportions reported in Table 1. As

noted above, IE at OU had both a high proportion of women faculty and a high proportion of women majors. CS, on the other hand, had a relatively high proportion of women faculty and a relatively low proportion of women majors. Thus, we considered CS at OU to be a good comparison/contrast department. Similarly, ChemE at OU had a relatively low proportion of women faculty but a relatively high proportion of women students; ECE at OU had relatively low proportions of women both at the faculty level and at the undergraduate level. We included IE departments at other institutions to obtain a broader view of IE as a discipline. Seeking to hear authentic, first-person discussion of the choices students make and the factors that affect their decisions, our primary source of data was interviews with undergraduate engineering majors.

A. Participants

The study involved the following seven departments:

- the School of Industrial Engineering at the University of Oklahoma (IE at OU),
- the Department of Industrial Engineering at Arizona State University (IE at ASU),
- the Department of Industrial and Management Systems Engineering at the University of Nebraska – Lincoln (IE at UNL),
- the Department of Industrial Engineering at the University of Pittsburgh (IE at Pitt),
- the School of Chemical, Biological, and Materials Engineering at the University of Oklahoma (ChemE at OU),

- the School of Computer Science at the University of Oklahoma (CS at OU), and
- the School of Electrical and Computer Engineering at the University of Oklahoma (ECE at OU).

For each of the seven departments, we interviewed students in that major. In addition, for each student participant, we obtained a copy of their academic transcript at the time of the interview. For IE at OU, we also interviewed faculty.

Undergraduate engineering majors. The number of student participants from each of the seven participating departments is given in Table 2. We recruited student participants in a number of ways. Participating departments at OU provided lists of current majors and we contacted the students by phone and/or email. We also set up temporary information tables in strategic locations and went to relevant classes to describe the study and solicit participants. The student participants were sophomores, juniors, and seniors; we started with sophomores rather than freshmen because sophomores on average are more settled into their major, reducing the likelihood of attrition from our participant pool. We oversampled for women to ensure representation from a wide range of experiences and perspectives; we included men to investigate the relative importance of factors by sex. For added context, Table 3 shows the proportion of women majors in each participating department for the time period during which we collected student interview data in that department.

Faculty in IE at OU. To triangulate with student interview data specifically for IE at OU, we also interviewed the tenured/tenure-track faculty in IE at OU. Almost all of the 13 faculty members who were in the department at the time of data collection participated in an initial interview and about half of them participated in a second interview. These interviews included the two IE faculty members at OU who were involved with this research project. Recognizing the potential for bias, we were cautious in our use of these data, but believed that the perspectives of these two faculty were necessary for deeper, more accurate understanding of the department culture [21].

	IE at OU	IE at ASU	IE at UNL	IE at Pitt	ChemE at OU	CS at OU	ECE at OU	Total
female	28	15	15	12	13	9	3	95
male	24	6	13	7	10	14(1)	17(1)	90
total	52	21	28	19	23	23(1)	20(1)	185

Table notes: (1) One male student was double-majoring in CS and ECE and thus was counted in both departments, but only once in the male participants total.

Table 2. Number of student participants in each department.

	Fall 2002(3)		Fall 2003		Fall 2004	
IE at OU(1)	60/121	50%	54/119	45%	48/123	39%
ChemE at OU(1)			100/276	36%	98/266	37%
CS at OU(1)			41/271	15%	25/212	12%

ECE at OU[(1)]	49/418	12%	37/352	11%
IE at ASU[(2)]			70/203	34%
IE at UNL[(2)]			23/79	29%
IE at Pitt[(2)]			58/152	38%

Table notes: (1) OU data from [22-24]; (2) ASU, UNL, and Pitt data from personal communications with staff at those institutions. (3) During the grant proposal writing time period, the proportions were 55% in Fall 2000 and 58% in Fall 2001.

Table 3. Proportion of women majors in participating engineering fields during the years of data collection in those departments.

B. Data Collection, Processing, and Analysis

Some members of the engineering education community are experts in qualitative research, while others are new to the paradigm. We can not hope in the space of this one paper to offer a detailed image of the traditions, norms, strengths, weaknesses, or contributions of qualitative research. Nevertheless, we offer a few sentences of rationale for our design choices. As Leydens, Moskal, and Pavelich explained in their article published in this journal in 2004 [25],

> In general, quantitative methods are designed to provide summaries of data that support generalizations about the phenomenon under study. ... By contrast, the broad purpose of qualitative research is to understand more about human perspectives and provide a detailed description of a given

> event or phenomenon. Qualitative researchers seek to better understand social or human problems that can be examined in their natural settings. ... [T]his research provides thick description of the uniqueness of particular cases and contexts ... (p.65).

As we embarked on our research, we noted that statistical studies of large data sets had identified variables related to entry and persistence rates, but have failed to explain sufficiently the remaining gender gap [14]. Given that we want to identify factors that contributed to the success of IE at OU in attracting and retaining women (and men) in the major, we determined that (1) qualitative data were needed to provide thick, rich, descriptions that could lead to a better understanding of the factors that influence students' decisions and (2) students themselves would be the best source to describe their experiences, thoughts, and choices. To this end, we chose interviews with students as our primary data collection strategy.

Our semi-structured interview protocols were based on our review of the literature, including Seymour and Hewitt [6] and Margolis and Fisher [7], and our situated experience. Typical questions included:

- "What brought you to college?"
- "Why did you choose IE as a major?"
- "What other majors have you considered/pursued?"
- "What was your favorite (least favorite) class?"
- "What was your best (worst) experience with a faculty member?"

A template protocol is available at http://www.ou.edu/rise [20]. A graduate student with a background in chemical engineering conducted most of the interviews, including the faculty interviews, but other team members conducted some interviews as expedient. Student interviews lasted about 60-90 minutes. For a longitudinal perspective, we interviewed six students three times and another 20 students twice. Follow-up interviews were conducted at one-year intervals with those students we were able to locate and who agreed to be interviewed a second or third time. The initial faculty interview protocol, designed for a 60-minute session, was based on themes emerging from the student interview data. Protocols for the follow-up interviews, designed for 30-minute sessions, were personalized for each faculty member, based on their history.

Digital recordings of interviews were transcribed by a professional service and checked by team members for accuracy. Student interviews tended to be at least 20 pages transcribed, giving us over 4500 pages of interview transcript data. Interview transcripts were imported into the qualitative data analysis software NVivo [26], which allows passages to be marked with searchable category names. As an example, we asked students to describe their interactions with faculty. They tended to use words such as "friendly", "nice", "caring", "open", "approachable", "personable", "likeable", and "encouraging" (among many others). These words have different meanings so we were loathe to collapse them into one category to produce a tally. Instead, we coded them under a category called "interactions with faculty" (then they informed the section called *The power of personal attention and support* in the Results section below). We had 266

of such codes, falling under 59 broader categories (e.g., the "interactions with faculty" code was under the broader "department culture" category). Each transcript was coded by a team member and the coding was doubled-checked by a second person for consistency and completeness. Inter-coder reliability was determined by examining agreement on one transcript coded independently by three coders. Looking at broad categories, the three versions of the transcript agreed on 74% of the coded passages, with two agreeing 88% of the time, giving us a high degree of confidence in our consistency with coding.

Additional triangulation data were mined through official academic transcripts provided by participating institutions. Among other analyses, we mapped curricular paths to identify bottlenecks along each student's path in terms of course sequencing, retaking or deferring certain courses, and academic performance. This analysis allowed us to corroborate student experiences in classes and with professors offered through the interview process. These transcript data became a historical skeleton over which we draped the students' lived experiences collected through interviews.

As is standard with qualitative research [25, 27], data analyses began early in the project and continued throughout the entire time of data collection. Such analyses can be characterized as an iterative process of investigating conjectures that arise from being immersed in the data. Further, as our goal was to identify salient issues rather than to produce exhaustive tallies or proportions, for some analyses we employed the idea of *data saturation*, meaning that patterns emerged and that the pace of identifying new elements or nuances slowed or stopped. Having identified salient patterns from student

interviews, we incorporated triangulation data to support (or refute) the conjectures that arose from those early analyses. For example, when data from interviews with students, data from interviews with faculty, academic transcript data, and data from institutional documents pointed to related ideas, we considered those ideas to be salient and counted them as partial answers to our research questions.

III. RESULTS

In this study, we probed systemic factors that affected the proportion of women electing to major in IE at OU. As described in the Methods section, our data set was large and varied. Not all subsets of the data were relevant for all analyses. For example, to address the question of how IE majors perceived IE as a discipline, we did not use data from interviews with CS students. Accordingly, in the Results section below, different analyses are reported with different subsets of the data, leading to reports with different numbers of participants, depending on the relevance of data subsets to the particular topic and the time period in which the analysis was undertaken. Our other papers from this project have included abundant quotes from the interviews to illustrate and elucidate particular ideas. However, in the interest of conserving space in this summary paper, which is intended to provide a synthesis of the entire project, we have chosen to minimize the number of such quotes.

From our search for patterns in student comments, two categories (out of the six in our original design) rose to the top as explanations: aspects of the discipline and department

culture. In addition, as expected with qualitative research, new themes emerged. Of special salience was the movement of students into IE from other majors, termed *relocating*. Sections below present summaries related to each of these three factors.

A. Aspects of IE as a Discipline

On the national scene IE has tended to have a considerably higher proportion of bachelor's recipients who are women than most other areas of engineering ([3] and other years). In addition, at the time of data collection for this study, the proportions of women majors in all four participating IE departments were higher even than the national trends. Those who are familiar with the field might expect it to draw more women based on characteristics that distinguish IE from the other engineering fields. Thus, we asked students in all seven participating departments to describe their field and to discuss aspects that influenced their choice of and satisfaction with their major. IE majors across institutions were very comprehensive in their descriptions of IE as a discipline, more so than students in the other participating majors. Surprisingly few gender differences were noted in the descriptions of IE, although this finding may point to characteristics specific to men who are attracted to IE, which in turn could make the discipline more inviting for women [28]. Analyses identified eight distinctive characteristics that students associated with IE [29, 30]. Looking at the longitudinal student interviews, we observed that students maintained a static perception of the discipline, pointing out different areas as they took different classes, but continuing to describe the same general traits across time.

These characteristics fell along two intersecting dimensions of the field: perspectives emphasized in IE and the people who are IEs.

It was apparent that undergraduate majors viewed IE as more of an approach to thinking rather than a focus on specific sets of problems (in contrast with ChemE, for example). Most students recognized *efficiency* (77%) as a key approach of the discipline in that IEs are looking to streamline processes and activities regardless of the specific task. *Problem solving* was offered as a principle activity by 56% of the students, although this descriptor may be representative of engineering in general more than IE specifically. Perhaps more directly related to IE, about half of the students (49%) spoke to the *systems-oriented* perspective used by IEs in their approach to problem solving. Finally, a majority of the students (64%) also spoke to the consideration of *business* aspects of a problem, which tends to be emphasized in IE more than in other areas of engineering. As with other engineering students, however, it was important to the IE majors that their degree was in engineering rather than business or some non-STEM field. These phrases used by the students did not describe specific tasks, but perspectives that are integrated across all IE activities.

The other dimension of IE encompassed in the students' discussions was more about who works in IE than about what IEs do. It was striking how students talked about peers, upperclassmen, and IE professors who were passionate about the field, indicating that people who work in IE like what they do and make that transparent to students. The most commonly used descriptor was of IE as *people-oriented* (80%), meaning that IEs like to

work both with people and on issues that affect people. The literature suggested that this aspect would appeal disproportionately to women, but our data did not support this prediction [29, 31]. Similarly, about half of the student participants referred to IEs as *communicators* (51%), often people who mediate between different constituencies working on a project. A slightly smaller proportion of IE majors discussed their IE degree as an expedient vehicle for obtaining management positions (47%). This idea of *status potential* was the most substantial and persistent area of gender difference, with men more than women tending to bring it up (57% vs. 40%). The *breadth* of the discipline was described by 61% of the students across all institutions, underscoring that IE is a discipline that allows for a broad range of academic and career paths. In fact, a majority of the students across institutions chose IE not because of a particular interest in an IE sub-field, but for the variety of work available to an IE and the potential to shift among the types of work within one career. It should be noted that the curriculum at each institution provides breadth of exposure to the different aspects of industrial engineering. Faculty in IE at OU noted that they intentionally designed their curriculum to emphasize the breadth of the discipline, wanting to expose majors to an array of aspects and opportunities.

An additional characteristic of IE that showed up consistently in our interviews was what we termed *invisibility* of the field. We used this term to represent the idea that people outside of IE (faculty, students, potential employers, family members and friends) tend to be unaware of IE as a field and/or do not understand what IEs do. An aggregate 60% of the IE majors we interviewed, across institutions, brought up this issue in response to

questions about how non-IEs perceive IE. Disproportionately many men commented on it (67% vs. 54%). In interviews with the student participants across fields and across institutions, we also asked the question, "What advice would you give a freshman or high school student considering your major, or engineering in general, at your institution?" Responses from all 185 students (95 female) were analyzed as a set [32]. One of the most common pieces of advice was to choose a major based on interest in that field (23%). Yet, in order for students to determine their initial level of interest, that field must be visible to them.

B. Department Culture

Most characteristics of academic departments are not binary – either a department has the characteristic or it does not – but rather lie along a continuum. At the time of data collection, the School of Industrial Engineering at OU was unusual along a number of dimensions [33]. We discuss a few of these here, underscoring their apparent relevance to the achieved undergraduate sex parity.

Visibility of women faculty. In terms of underlying structure, IE at OU had a distinctive composition. As noted above, the most evident aspect was the relatively high proportion of women faculty: four of 10 in Fall 2001 (increasing to 13 at the time that we interviewed faculty in IE at OU). This proportion was higher than our comparison departments at other institutions at that time (at ASU 5/21 faculty were women, Pitt 3/14, UNL 2/13), as well as, more generally, higher than the national proportion for IE as a

discipline at that time (10%). It was also higher than any of our comparisons departments in the CoE at OU (ChemE, CS, ECE). However, the presence of women faculty in IE at OU went beyond being merely female bodies tallied for diversity headcounts. These women were visible in leadership positions (at the time of data collection, one was department chair and another was an associate dean), in direct contact with students through recruiting and advising activities, at department functions (e.g., the department's end-of-year banquet), and even socially (e.g., going out after the banquet). Several IE faculty at OU who were interviewed suggested that the women faculty in IE at OU had special characteristics that made an impression on students, including "sharp", "smart", "eloquent", with a "magnetic charisma". In fact, these women were described by students as "professional" and "successful", "strong, conscientious, dare I say, opinionated", all while maintaining their femininity. Male and female students alike noted the visible presence of the women faculty.

Alumni as faculty. What was also unusual about the department's composition was that the department employed three faculty who had earned their bachelor's degrees in engineering from OU, two of whom had also earned their Ph.D.s in engineering from OU. Two of these three were also two of the four women. Two of the comparison departments at OU (ChemE and ECE) employed alumni as faculty (all male, respective proportions, 1/15 and 2/16) and, of the comparison IE programs, only Pitt had this factor in their department composition (the three women faculty there all had alumni ties to the institution). Prior research (e.g., [16]) points to the level of attachment that alumni can feel toward their undergraduate institution. Faculty interviews of the two women alumnae

in IE at OU highlighted their special emotional investment in the undergraduate engineering program fueled by their attachment to the institution and their experiences as engineering majors there.

The power of personal invitation. The faculty in IE at OU described a departmental history of hiring faculty who were a good fit, meaning not only that they were productive researchers but also that they had a passion for teaching and mentoring students. This hiring strategy resulted in a department with an elevated level of collegiality among the faculty, described by one faculty member as a "team family atmosphere". Several of the faculty said that they had been invited to apply to the department, implying that the department was proactive in its recruiting for new faculty. *Proactive* may be the word that best describes the department along several dimensions.

In the late 1990s, the department began to experience an increase in the total number of majors, disproportionately women. This phenomenon coincided with a renewed departmental focus on the undergraduate program. The then department chair began a series of initiatives to recruit majors, activities based around the idea of personal invitation and attention. Comments from students, disproportionately many female, pointed to two kinds of activities: attention from the department chair and attention from IE faculty. Specifically [31]:

- The department chair called promising high school students, inviting them to consider IE as a major.

- Teams of IE faculty and students gave presentations about IE as a discipline to high school classes, Society of Women Engineers (SWE) events, freshman seminar courses, and other such venues.
- The department hired upper division IE majors to give talks about IE as a major and to participate in College of Engineering recruiting events.
- The department produced information brochures and ensured that the website was up-to-date and informative.

None of the comparison departments or institutions proactively participated in recruiting to this degree. Many departments rely on centralized college recruiting activities. For IE at OU, these activities continued, with modifications, even with a change in chair. We also note that several of the women faculty in IE at OU were active in recruiting efforts, which made them visible to prospective students.

The power of personal attention and support. As advice to freshman, 34% of the 185 student participants across disciplines and institutions (42% of the 95 women) recommended building academic and social networks of students and faculty by studying in groups, going to office hours, and participating in extra-curricular activities [32]. Most (but not all) of the students majoring in IE at OU described strong social networks [34], which extended vertically to connections with the faculty and horizontally to a high level of camaraderie among the students themselves [35]. From an analysis of the first 41 interviews with IE majors at OU, in response to questions such as "How often do you interact with other students in IE?", 44% students (52% of 23 women) offered phrases

such as "good friends" and "tight knit" or described a close friendship they had with another IE major. Furthermore, from an analysis of the longitudinal interviews, we note that two female students majoring in IE at OU specifically commented that increased interactions with classmates had over time contributed to their increased confidence.

IE majors at OU talked extensively about their relationships with the IE faculty [35-37]. They commented on classroom interactions with instructors, but they also made clear that out of classroom interactions were at least as important. Contexts beyond classroom and other course-related interactions in which students interacted with faculty included research projects, the search for internship opportunities and jobs, department events such as the annual banquet, and activities related to technical organizations. Some interactions occurred during formal office hours, but some were more spontaneous and informal. An analysis of interviews with 41 students (23 female) majoring in IE at OU [37] identified 59 spontaneous comments made about these interactions with IE faculty, 56 of which were positive (95%). This same set of students was less positive about interactions with faculty outside IE: of the 22 opinionated comments, only seven were positive (32%). This analysis also indicated that these out-of-class interactions were disproportionately important to the female students, which is consistent with the literature (e.g., [6, 38]).

Several faculty were mentioned by name so often and described so consistently by students that we gave them monikers. Because two of these faculty members were of opposite gender, we believed that the department had a mother-figure and a father-figure. This idea turned out to be true but with gender-reversed roles. Students talked about a

male faculty member with descriptions that brought us to label him *The Promoter*. One female faculty member was described as tough but caring, bringing us to refer to her as *The First Sergeant* (in the marines the first sergeant is the non-commissioned officer who, stereotypically, tends to be the one who pushes the unit to excel but who also tends to be the person that junior members trust to help them). The students talked considerably about the department chair, as a person "who watches over all her students like kids". The seniors in our study also talked about her male predecessor, who filled a similar role. In addition, students talked appreciatively about two other faculty members who were considered *Attentive VIPs*. One was a female non-IE assistant dean who taught a freshman class for women in science; she left OU during the project years. The other was a female IE faculty member who became an associate dean in CoE during the years of this study. The students were impressed at the personal attention from individual faculty, the department chair, and other faculty who were in leadership positions.

Overall the department projected a sense of community, rather than just a set of people grouped together administratively. As with recruiting, the IE faculty were proactive about the personal attention and support that made the IE majors feel at home in the department. For example, several students told stories about faculty who approached them in the hallway to say hello (rather than the more standard student-initiated contact) and who even contacted them to check in if they were having troubles. In general, students described the IE at OU faculty, male and female, as "available", "friendly", "personable", "student-centered", and "attentive", among many other such descriptors. The faculty themselves not only talked about teaching and mentoring with a striking

passion for being around students, but also, in response to questions such as, "What do you like most about interacting with students?", answered that they best like "getting to know them as people".

C. Relocators

In their seminal work about students' outflow from STEM majors, Seymour and Hewitt [6] defined terms to describe the migration of students among majors. We adopted and expanded this language to investigate the paths that students took on their way into IE as a major [39]. Specifically, we use the term *relocator* to refer to any student who changed from their original major. We sorted relocators into two subsets. We use the term *internal resettler* to describe students moving from one STEM discipline to another and the term *switcher* to refer to any student who moved into (or out of) a STEM major. In Table 4, we categorize the students' paths. Before we discuss the specifics of the table, we want to offer some suggestions for perspective. From the time of the grant proposal to the end of data collection, IE at OU tended to have 100 ± 20 declared majors; thus, each student counted for roughly 1%. In our sample of 52 students majoring in IE at OU, each student counted for roughly 2%. Thus, some differences that look substantial may occur because of only a few students; on the other hand, each student counted toward the total percent and was thus of consequence.

A majority of the 52 participants (54%) went *direct to IE*, meaning that they declared IE as their major upon matriculation to OU (either as freshmen or as transfers from another

institution) or they moved into IE from the OU category Engineering-Undecided. Slightly more than half of these students were women. The importance of relocators is seen by noticing that the remaining 46% moved into IE from another major. A full 38% migrated into IE from other majors within the College of Engineering, again with an almost even divide between the sexes. Another 8% migrated from outside of the CoE; as noted above, this 8% was only four students, but all four of these students were women, contributing directly to the proportion of women in the major, and three of them came to IE from entirely outside of STEM.

	male		female		total	
direct to IE	13	25%	15	29%	28	54%
internal resettlers – CoE	11	21%	9	17%	20	38%
internal resettlers – STM	0	0%	1	2%	1	2%
switchers (from a non-STEM field)	0	0%	3	6%	3	6%
total	24	46%	28	54%	52	100%

Table 4. Distribution of paths taken into IE as a major at OU.

In general, there are (at least) two forces at work in a student's decision to change their major, a push out of one major and a pull into another major [6], forces that different

students may experience in different proportions. The relocators who participated in our study reported pushes that fit with prior research (e.g., excessively challenging coursework, inattentive faculty, ineffective pedagogy, see [6, 7]) and pulls that are described in sections above. A third issue, more relevant for some disciplines than others, is the visibility to students of possible majors. The relocators in our study identified thirteen distinct ways they learned about IE as a possible major, with some students describing multiple vehicles. Emphasizing the importance of post-matriculation recruiting, fourteen participants (9 female) reported that they learned about IE through departmental recruiting activities, including presentations and printed media. Also especially striking was that eight relocators (4 female) said that they learned about IE as a major from IE majors who acted as unofficial emissaries, communicating passion for the field and happiness in the department. Many of the other vehicles involved face-to-face interaction, formal or informal, with one or more faculty members in IE at OU, including the department chair.

One particularly striking contrast that we were able to capture was the way that relocators talked about their original major in comparison to the descriptions of IE as a discipline and of IE at OU as a department offered above. First, 14 (8 female) of the 24 relocators described a lack of personal resonance with the perceived professional identity for their previous major; that is, they were unable to see themselves "doing that". Second, of the 24 relocators, 13 (8 female) indicated that they had experienced little if any connection to faculty in their original department; in some cases, students described interactions that they considered downright inhospitable [40]. Both of these sets of comments contrasted

noticeably with the perceptions and experiences described by students, including relocators, majoring in IE.

One concern that departments may have about recruiting, or even accepting, students who started in another major is the possibility of inheriting low quality students. An analysis of GPAs, at the semester of resettlement, indicated that this situation did not hold for IE at OU. For the 21 internal resettlers, the mean cumulative GPA was 3.03 (out of 4.00). For the men, the range of GPAs was 2.00-4.00 (mean 2.91, standard deviation .72) and, for the women, the range was 2.59-4.00 (mean 3.16, standard deviation .48). The three female switchers had an mean cumulative GPA of 3.22.

As others who have attempted research with institutional data are aware, exactly quantifying a population is difficult at best, but sometimes impossible because of inaccessible data. With this caveat in mind, we calculated that relocators comprised approximately 35% of the IE at OU enrollment at the time of our participant recruiting. Comparing this proportion to the proportion (46%) of our volunteer participants, we note that relocators are over-represented in our sample. This over-representation issue may be overshadowed by the observation that the relocators who participated in our study were a substantial proportion of the total number of majors in IE at OU at the time. Their stories were compelling and drew attention to a population of students who were in search of an academic fit and who found a home in IE at OU.

IV. SUMMARY AND DISCUSSION

Although progress has been made over the past two decades, there are still concerns about the under-participation of women in STEM professions [41]. Qualified, talented women continue to reject or abandon careers in STEM fields [10, 12]. Most studies and projects related to gender equity have sought insight about why women are under-represented in STEM fields. In contrast, we started with a program that worked and investigated why it worked. We conducted this research project to contribute to the knowledge about increasing the representation of women in engineering majors and to make recommendations for systemic efforts. One student participant gave a particularly eloquent overview of IE at OU:

> I think there is a pretty big support system. First of all, we do a lot of recruiting ... and I think we're more proactive in spreading the word and telling people about what we do. And I think having female faculty definitely helps and also having a lot of activities outside of the curriculum really helps you because I think women like to feel like they're important and they're valuable to the system and so when you have things outside of class that promote you to do well or encourage you, that really helps a lot I think in retention, in keeping girls in this major. Because I don't think I've ever heard of girls leaving IE but I've heard of girls joining the IE program. One of my friends actually last year, just switched from [another CoE major] to Industrial. (female undergraduate majoring in IE at OU)

Figure 1 depicts a summary of efforts enacted by IE at OU that differentially influenced women students and that we believe other departments can adapt.

As anticipated, most students across all seven participating departments talked about a pre-college interest in and affinity for mathematics, science, or a specific attribute of the specific field. Other comments referred to an influential person, such as a high school teacher or college professor. Furthermore, in response to questions about why they chose their particular institution, female more than the male students tended to cite proximity of home and family as a reason. These comments underscore the importance of seeing each individual student as a potential STEM major and the impact that local and persistent recruiting efforts by departments can have on potential majors, especially women. In particular, validating and informative attention from faculty can have a powerful effect on students, especially for young women who are trying to figure out where they fit [6].

STEM faculty often have opportunities to take part in recruiting and outreach activities, either in efforts to attract students to a field or in efforts to attract majors to a department. As mentioned above, *proactive* may be the word that best characterizes IE at OU, evident in the department activities intended to heighten awareness of IE as a discipline and to attract promising students to the department. Recruiting activities targeted students who might declare IE as a major upon entering OU (either as freshmen or as transfer students from other institutions) and students who had not yet settled on a major within engineering. With many STEM fields, students have a limited understanding of what careers in that discipline might look like. Recruiting activities that emphasize only a

small part of the possibilities limit their impact to students with an interest in those specific options. Emphasizing a broad range of work activities, as IE at OU did, opens doors to students who are interested in any one of the activities as well as to students who are interested in breadth itself.

It can be helpful to students to see that people like them work in the field. It has become more common for recruiting materials to include pictures of a diverse group with an emphasis on the inclusion of women and minorities. Ultimately a department's composition should reflect the diversity of the larger population along many dimensions, including different ways of thinking and living as well as sex, race, and ethnicity. Diversity should be reflected within groups as well, for example, women with families and women without families. A variety of perspectives is healthiest, as it is with any ecosystem. We believe that expanding the images available even further is important to achieving diversity. These expanded images will not all be physical, but will need the human factor of face-to-face interaction. The level of interaction between faculty and students in IE at OU enabled students (current majors and potential majors by word of mouth) to see that the discipline is home to people with a range of interest in working closely with people, a range of ability to communicate, and a range of interest in status, among other attributes. One way to make visible to students that diversity is valued is to include faculty and students of both sexes in visible department activities.

The efforts enacted by IE at OU to recruit majors (and to make IE visible as a discipline) also had a positive impact on student retention. These activities made transparent that the

department valued and actively paid attention to its undergraduate program. Not every faculty member in the department felt the same level of investment in the undergraduate program, but it was clear from our data that a critical mass of IE faculty at OU exhibited behaviors that students perceived as a high level of care for them as individuals. This personal connection tends to be disproportionately important to women. In general, the pursuits that a department values and actively pays attention to are the ones that thrive, perhaps with differential impact on certain subgroups. In the case of IE at OU, the department came together as a community that valued and paid proactive attention to its undergraduate program as a whole. This attention was not specifically directed at increasing the representation of women, but had that result.

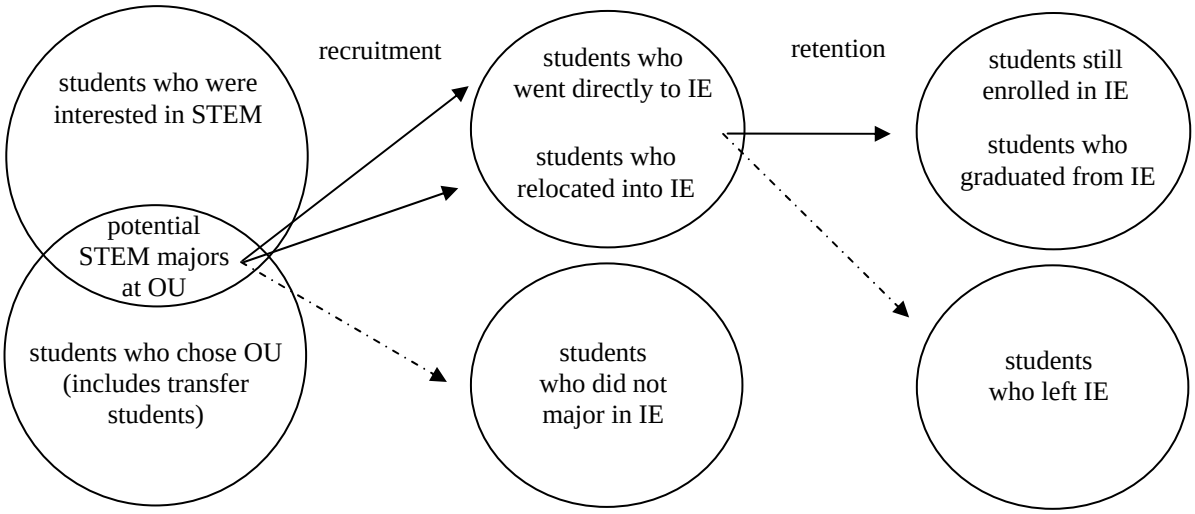
Whereas the large-scale seminal study by Seymour and Hewitt looked at STEM majors as an aggregate, Margolis and Fisher focused their discipline- and institution-specific study on computer science. They analyzed factors that lead to increased female student retention in the CS program at Carnegie Mellon University (CMU). While their findings and ours are not inconsistent, differences attributable to institutional selectivity, student demographics (e.g., high proportion of international undergraduates in CMU's CS program vs. relatively small proportion in IE at OU), disciplinary gender proportion (CS vs. IE), and departmental goals (CS at CMU sought increased gender parity, IE at OU program attained it organically) result in a different set of factors coming to the fore. For example, many female students at CMU appear to be enduring the CS program until they get past data structures, a foundational CS course, while the female students at OU in IE were thriving even early on leading them to actively recruit additional female students to

the discipline. An area of commonality between these studies is that a supportive learning community is disproportionately important to female students while also being important to male students. The differences between the results from these studies point to the probability that there will not be a one-size-fits-all solution to increasing female participation in STEM and that performing ethnographic research at different types of institutions, especially in different disciplines, is likely to produce a more layered and comprehensive understanding of the factors that lead to increased female participation.

We were sad and puzzled to note that the proportion of women majoring in IE at OU decreased substantially during the years of the project (Table 3), from a high of 58% in Fall 2001 to 39% in Fall 2004 (to 34% in Fall 2005, which is the most recent institutional data available). During this time period, the Department went through many changes (e.g., faculty, staff, students, curriculum, norms and traditions). Such changes create different effects at different times for different members of the department, making them moving targets. These effects from changes within an academic department are not realized over night; it generally requires several years to realize full impact. Some administrative processes may have a more immediate, differential impact on students. Consider cohort advising, for instance. If the advisor for a cohort has a particular influence on the advisees and another cohort experiences a different advisor with a different impact, the two cohorts may end up with radically different characteristics (e.g., noticeably different proportions of women, different preferences for areas within IE, different levels of emotional connection to the department). Similarly, if a curriculum change is implemented or a new faculty member is hired or an experienced faculty

member leaves, then there are students in the department whose impressions were formed based on the prior context, as compared to new students coming into the changed context. We suggest that tracking the effects of such changes be investigated by subsequent, longitudinal research.

During the time period of this research project, IE at OU experienced all of the changes listed in the previous paragraph. In addition, the students who were described in the faculty interviews as emissaries for the program graduated. It may be that these early emissaries had a certain charisma that helped them spread their message about IE or that they were positioned to take advantage of particular opportunities to advocate. Finally, in the section on department culture, we noted that the First Sergeant and one of the other women in IE at OU were highly visible to the students, even socially (e.g., going out after Department functions). During the grant period, one of these women gave birth to two children. While this may have made her a stronger role model for women who want to have children, it also made her less available to go out in the evenings, which in turn made both women less visible. Women who may be ideal role models lose that impact if they are not visible to the people would see them as role models. Each of these changes may seem small. However, in Gladwell's thought-provoking book, *The Tipping Point: How Little Things Can Make a Big Difference*, the author makes a convincing case that small changes can have large impact [42].



	direct-to-major recruitment	post-matriculation recruitment	retention and graduation
make visible the undergraduate degree and the breadth of the discipline (talks and printed media)	x	x	x
invite incoming freshmen to consider the major	x		
invite current freshmen to consider the major		x	
inspire current majors to be emissaries for the field		x	x
value collegiality and make that value visible to students		x	x
value diversity and make that value visible to students	x	x	x
show passion for the field and the department	x	x	x
show enthusiasm for working with students and interest in them as people	x	x	x

Figure 1. Potentially transportable efforts enacted by IE at OU and identified in this research project as having differentially influenced women students.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation's Gender in Science and Engineering (NSF GSE) program under Grant No. 0225228. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

The authors also wish to acknowledge the extensive contributions by other members of the research team: Angela Beauchamp, Kelly K. Shockley, Tyler S. Combrink, Randall W. Evans, M. Jayne Fleener, Rebecca L. Heeney, Elizabeth Kvach, Stephen M. Lancaster, Gabriel Matney, Lindsey S. McClure, Reinheld E. Meissler, Sandra Kay Moore-Furneaux, Anne Reynolds, Donna L. Shirley, Kim Warram, and Emily Weisbrook.

Furthermore, we would like to thank the reviewers and editors for their constructive and supportive comments.

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