
AC 2011-102: UNDERGRADUATE WOMEN IN CHEMICAL ENGINEERING: EXPLORING WHY THEY COME

Catherine E. Brawner, Research Triangle Educational Consultants

Catherine E. Brawner is President of Research Triangle Educational Consultants. She received her Ph.D. in Educational Research and Policy Analysis from NC State University in 1996. She specializes in evaluation and research in engineering education, computer science education, teacher education, and technology education. Dr. Brawner is a founding member and Treasurer of Research Triangle Park Evaluators, an American Evaluation Association affiliate organization. She also served as principal evaluator of the NSF-sponsored SUCCEED Coalition and is an active researcher with MIDFIELD. Address: 3504 Corin Court, Raleigh, NC, 27612-4100. Telephone: (+1) 919.782.4427. Email: recinc@bellsouth.net

Susan M. Lord, University of San Diego

Susan M. Lord received a B.S. from Cornell University and the M.S. and Ph.D. from Stanford University. She is currently Professor and Coordinator of Electrical Engineering at the University of San Diego. Her teaching and research interests include electronics, optoelectronics, materials science, first year engineering courses, feminist and liberative pedagogies, and student autonomy. Dr. Lord served as General Co-Chair of the 2006 Frontiers in Education Conference. She has been awarded NSF CAREER and ILI grants. She is currently working on a collaborative NSF-funded Gender in Science and Engineering project investigating persistence of women in engineering undergraduate programs. Dr. Lord's industrial experience includes AT&T Bell Laboratories, General Motors Laboratories, NASA Goddard Space Flight Center, and SPAWAR Systems Center. She served as the President of the IEEE Education Society in 2009 and 2010.

Matthew W. Ohland, Purdue University, West Lafayette

Matthew W. Ohland is Associate Professor of Engineering Education at Purdue University. He has degrees from Swarthmore College, Rensselaer Polytechnic Institute, and the University of Florida. His research on the longitudinal study of engineering students, team assignment, peer evaluation, and active and collaborative teaching methods has been supported by over \$11.4 million from the National Science Foundation and the Sloan Foundation and his team received the William Elgin Wickenden Award for the Best Paper in the Journal of Engineering Education in 2008 and multiple conference Best Paper awards. Dr. Ohland is Chair of ASEE's Educational Research and Methods division and an At-Large member the Administrative Committee of the IEEE Education Society. He was the 2002-2006 President of Tau Beta Pi.

Undergraduate Women in Chemical Engineering: Exploring Why They Come

That women are underrepresented in most engineering disciplines is not news to those who study engineering matriculation practices. There are, however, some disciplines within engineering that attract a higher than average percentage of women which we term “pockets of success.” One of these pockets of success is chemical engineering (ChE) which nationwide graduates 35% women compared with only 20% of all engineering graduates.^{1,2} In this paper, we address some of the reasons that women choose to major in chemical engineering. We use quantitative data from the MIDFIELD database to show the relative attractiveness of chemical engineering to women compared with other engineering fields and explore findings from two focus groups with women chemical engineering majors to shed light on why these women chose the major.

Literature Review

Extensive research has been done on students’ motivations for choosing science, technology, mathematics, and technology (STEM) majors in college.^{3,4,5} However, most studies focus on science or combining women in science and engineering and as Wentling and Camacho³ say, “experiences unique to female students of engineering need further examination.”(p. 85) There are even fewer studies that focus on subdisciplines of engineering. Here we will summarize some research on factors influencing women’s choice to study engineering and highlight research focused on women in chemical engineering. Our work seeks to contribute to the conversation by focusing on women’s motivation for choosing to major in chemical engineering.

Wentling and Camacho³ use social cognitive career theory⁶ as a conceptual framework to examine factors that assist and hinder women in pursuing and completing a degree in engineering. This framework considered four groups of factors: School factors including encouragement, information, and teaching quality; Family factors including role models, support, and advice; Personal factors including self-confidence, personal goals, and abilities; and Societal factors including fields’ public image, fields’ stereotype, and job market. Using a survey and focus groups with senior undergraduate students at a university in the Midwest U.S., they found that there were multiple factors that assisted women in choosing to pursue a degree in engineering. Important high school factors included good academic preparation in math/science/technology fields as well as excellent teachers who encouraged students in these areas. Important family factors included parental support, encouragement, and advice as well as engineering role models in the family. Personal factors that led women to choose to major in engineering included enjoying problem solving, personal satisfaction with being challenged, high aptitude and interest in engineering, and seeing engineering as providing opportunities to make a difference in society. Finally, key societal factors were that engineering as a career offered many different job opportunities, high salary, good job market, and interesting and challenging field.

Lord et al.⁷ showed that there were gender differences in major selection within engineering. Zafar’s⁸ analysis suggests that the main reasons why both men and women choose a college major are enjoying coursework, finding fulfillment in potential jobs, and gaining the approval of parents. Felder et al.⁹ conducted a detailed study of chemical engineering students’ experiences. However, they did not explore motivations for choosing chemical engineering. In a cultural

analysis, Godfrey¹⁰ showed that different engineering disciplines exhibited different cultures which impacted women's participation. Although all engineering disciplines exhibited a masculine culture, chemical engineering had a less "macho" culture that allowed for different forms of masculinity and was more welcoming to women. The author also suggests that women might be drawn to this major because "a reliance on prior practical knowledge or tinkering experience did not seem as essential."

Lyon¹¹ studied 19 women engineering students at a research university for a year. During that year, women were asked participate in interviews and focus groups, to be observed, and to keep a journal of their feelings about being in the major. Students were all undergraduates, first year through senior, and three were chemical engineering majors. The purpose of the study was to explore how the women's undergraduate experiences relate to their anticipatory socialization into the engineering profession and ultimately what they needed from their programs to succeed. She found among other things, that to succeed, the women needed a supportive father and strong internal motivation, ambition, and commitment.

Hartman, Hartman, and Kadlowec¹² and Hartman and Hartman¹³ examined differences in women's attraction to various engineering majors and the differences between men and women in various engineering majors. They compared first year students in electrical/computer and mechanical engineering (ECE/Mech) with those in chemical and civil/environmental engineering, the former disciplines having fewer women (< 12%) and the latter having more (17.9% and 15.4%, respectively). Their participants included 83 women (29 chemical engineers) and 545 men (133 chemical engineers) enrolled in a public institution from 2000-2005. They found no differences between men and women in academic and family backgrounds, general academic self-confidence, and attributions of success to their own competency. Overall, men and women did not differ significantly in their expectations from the engineering degree. The highest responses from all majors and both genders were that an engineering degree would result in a well-paying job. However, chemical engineering women were statistically more likely to expect a challenging job and respect by others and less likely to expect time for outside interests compared to their male counterparts.

In one of the few studies to critically examine sex segregation across engineering majors, Litzler¹⁴ combined data from the Engineering Workforce Commission (EWC) and the Project to Assess Climate in Engineering (PACE) survey to explore both individual and institutional factors that might explain why certain engineering majors have relatively higher or lower percentages of women compared with the representation of women overall in engineering. The EWC data contains information from all of the schools of engineering in the U.S. while the PACE data includes 21 generally large, public, research intensive universities. Litzler's analysis included the implications of human capital theory (which would allow easy exit and re-entry into the field), status beliefs related to the socialization students receive about the discipline, and discrimination and hostile climate. She examined nine engineering majors that were common to most of the PACE schools, including chemical engineering.

At the individual level, Litzler¹⁴ found that prior experience with engineering pulls students toward highly male-dominated fields such as electrical, computer, and mechanical engineering. A positive climate generally pulls students into majors with a higher proportion of women. Similarly, she found a higher proportion of women in majors that were perceived to be family-

friendly with greater support from faculty. The proportion of women in the major, however, was not the defining characteristic for women's choice of major. Rather, individual-level characteristics were more important than institutional variation in women's major selection overall and particularly for chemical engineering.

The research suggests that chemical engineering is attractive to women because the environment is somewhat more welcoming of women than more male-dominated disciplines like electrical and mechanical engineering. Although most engineering students expect a high paying job at graduation, there is also evidence that women in chemical engineering are more likely to expect a challenging job and respect from others than their male counterparts. The purpose of this paper is to explore more in depth why women choose to major in chemical engineering. We do so by examining the major selection patterns in engineering of 10 cohorts of students from eight universities and talking with currently enrolled women from two of those universities about why they chose to major in chemical engineering.

Methods

This study is an explanatory research study. Our primary goal is to learn why women choose to major in chemical engineering and we do so through focus groups with women at two institutions. Using focus groups allows us to develop a more complete understanding women's motivation for selecting chemical engineering and we describe experiences using their voices. To provide context, we show student major selection data from MIDFIELD, described below, which allows for generalizability to large public institutions. This mixed methods design combines quantitative and qualitative research to learn about the systemic issues that cause a relatively high percentage of women to choose to be chemical engineering majors.

Quantitative Data

This study uses the Multiple-Institution Database for Investigating Engineering Longitudinal Development,^{15,16} a data set with more than 79,000 students matriculating in engineering at nine southeastern United States institutions that awarded 1/12 of all U.S. engineering bachelor's degrees from 1987 to 2004. Included in MIDFIELD are two Historically Black Colleges and Universities (HBCUs). Because we are studying only chemical engineering in this research, we excluded from this study the one MIDFIELD school that does not offer a ChE degree. This resulted in approximately 3,000 students being deleted. We focus on first-time-in-college U.S. citizens and permanent residents. Since we have whole population data, inference is unnecessary—all reported differences are valid for these institutions and are likely generalizable for similar institutions. In this paper, we consider first-time-in-college students who matriculated from 1988-1998. We did not include any transfer students.

Two institutions in this data set have first-year engineering (FYE) programs. Thus, students at these institutions cannot matriculate directly into any specific engineering major including ChE. To include these students, we report numbers of students enrolled in ChE at matriculation (Semester 1) and Semester 3 when first-year engineering students are expected to have chosen a major. There are over 12,000 engineering students who have not declared a major by Semester 3. They may be undecided or still in an FYE program.¹⁷ Some might ultimately become chemical

engineering majors but they are not accounted for here. We count only enrolled semesters to Semester 3 to ensure that we measure actual educational progress.

Focus Groups

We held focus groups with a total of 10 women undergraduates majoring in chemical engineering at two MIDFIELD institutions during the 2009-2010 academic year. Students were invited to participate in the groups by a person on each campus who had access to lists of women majoring in chemical engineering. Each student received \$20 for her participation. Students ranged in age from 20 to 25 and were juniors and seniors. One group had four students and the other had six. Seven of the students were African-American and three were White. Five were transfer students and three were first generation immigrants to the U.S. Four of the 10 students reported having family members who were engineers.

The purpose of the focus groups was to answer three research questions: 1) Why did these women choose to major in chemical engineering? 2) Why do they stay in chemical engineering? and 3) Why is chemical engineering more popular with women than most other engineering majors? This paper focuses on the first of these questions.

The richness of the descriptions of the experiences shared by the students is one of the key advantages of focus group research. We use direct quotations but edited them to eliminate verbal crutches such as “uh,” “er,” “you know,” and excessive repetition to enhance readability. Some personal details have been obscured to protect the privacy of the participants. Unrelated digressions have also been removed and are represented by ellipses (...). Words in square brackets [] are added for context and words in parentheses () indicate verbal cue such as “others laugh.” Moderator prompts are preceded by “Moderator” and are italicized. Respondents are identified by school (A or B) and seat number.

In this article, we report themes common to the two schools. We report institution-specific elements in the findings only where they had a great bearing on students’ decisions at that institution and are consistent with the literature. With that exception, the purpose of this article is to report on findings common to chemical engineering in a variety of settings. The Institutional Research Board at each institution approved our study and each student signed a consent form. Students were assured confidentiality in published articles to the extent possible with a focus group.

Findings and Analysis

Choosing Chemical Engineering

Women in the MIDFIELD data set choose chemical engineering at the highest rates and chemical engineering is a more popular choice among women than among men. Table 1 shows the numbers of students in various engineering majors at matriculation and Semester 3 disaggregated by sex in order of the percentage of women at matriculation. For women, chemical engineering is the most popular major in terms of raw numbers and percentage of women in the major at matriculation at those schools where students can matriculate directly into a major and also at Semester 3 for all institutions, including those with FYE programs. For men, mechanical

is the most popular major at matriculation and Semester 3. Chemical engineering is the 4th most popular out of the 8 majors shown for men at matriculation and 5th at Semester 3.

Table 1 *Students in Various Engineering Majors at Matriculation and Semester 3*

Engineering Major	Matriculation			Semester 3		
	Female	Male	% female	Female	Male	% female
Chemical	2030	3171	39%	2281	3718	38%
Industrial & Systems	939	1561	38%	1788	2883	38%
Engineering, Other	566	1237	31%	685	1512	31%
Materials	296	765	28%	498	1422	26%
Civil	1165	3861	23%	1534	4904	24%
Electrical	1348	7327	16%	1532	8609	15%
Mechanical	1583	9210	15%	1842	11321	14%
Computer	498	3003	14%	511	3965	11%
Grand Total	8425	30135		10671	38334	

Source: MIDFIELD, 1988-1998; First time in college matriculants.

Qualitative Findings

It is important to note that the reasons that people choose a particular discipline are multi-faceted and interrelated. A variety of factors influencing students choice of a specific major, including high school teachers and counselors, extracurricular activities, family members, faculty members, and peers. Programmatic factors (including systematic interventions) and self-exploration were found to be the largest influences on students' decision-making process.¹⁸ At schools with a first-year engineering program, there is evidence that only 25-30% remain in the major they most favor at matriculation^{18,19} while the remaining engineering students make their decision during the first year or later.

The qualitative responses of the students in this study are consistent with this previous research, with each student identifying a few important reasons that they chose chemical engineering and other things that they feel distinguish chemical engineering from other engineering majors to support their decision. In fact, when coding the student responses, many of their comments could be easily coded into multiple categories (e.g., flexibility of the discipline, job opportunities and family influence) so it is important to note that all of these factors in combination yielded the women's choice to major in chemical engineering. Fundamentally, their decisions were influenced by two overriding factors: flexibility and job opportunities and to a lesser extent by the prestige of the discipline and respected influencers (family or from the university).

Flexibility. All 10 participants identified the breadth of the field and the flexibility of career options as a key attraction of the chemical engineering major. Flexibility has been identified as a motivation for women in choosing engineering in general.³ The women in our study commented on this for chemical engineering.

I always loved chemistry, but it came down to what chemical engineering had to offer me as a degree, such as the flexibility. I can go to law school, I can go to med school. It's just so many things I could do, so I just tied it all together and chose chemical. (A3)

Chemical engineering is considered by these students to be broader and provide more career opportunities with a bachelor's degree than a chemistry or biology degree, which are seen as attractive degrees for medical school, but otherwise renders holders unqualified for the job market without further study.

Well, with premed it's pretty much a chemistry degree, and engineering just added on like a bigger aspect, ... like you could go to grad school, but if you decided not to and you just wanted to go out into the workforce, chemical engineering offers a whole lot more opportunities than just a chemistry degree. Because I think with chemistry degrees, you could work a little, you could teach, it's kind of more narrow, your opportunities with just a chemistry degree. So, chemical engineering, you could work within pharmaceuticals, you can do a plant, you could do make-up...there's just so many different things you could do. So that pretty much swayed me a lot, too. I would have a bigger opportunity. (A2)

[The] key reason for choosing chemical engineering is you don't necessarily have to go to grad school to get a job. And chemical engineering is extremely diverse. [W]e can go into pharmaceuticals, we can go into teaching, we can go into manufacturing operations, we can even do consulting with a ChE degree. So it was like, whatever we chose to do or whatever, I could do once I graduated. I have infinite opportunities to find work, and that's what I was looking for in a major. (A1)

When I was younger, when I wasn't really sure of what I wanted to do, I wanted to be in the medical field. But by the time I got to high school, I knew that I didn't want to major in biology because ... I pretty much knew that if I majored in biology and I didn't get in to medical school [or] decided not to go, I would have to go back for more school, and that was not an option. (B2)

The medical school factor. Five of our participants had actively considered the possibility of going to medical school and chose ChE both because it provides good preparation for medical school and keeps their options open in case medical school does not work out.

I originally was set on med school all through my younger years because I loved math and science – that's pretty much what I loved. But then I said I couldn't do the biology. ... And then I realized I didn't want to live in a hospital. So I said I like math and science, I'm gonna go to engineering. I came here to [Institution B] undeclared engineering. ... And so I was convinced I wanted chemical, pretty much because it was one particular mentor I had. And it was also broad enough to where, you could do paper, you could do petroleum, you can do vaccines. So I liked the range of what this major covered, because you could do so many things. And now I'm actually thinking, maybe one day I'll go back and maybe do med school. Who knows? (B4)

I've wanted to do medical school or pharmacy school from day one. But I wanted to also have a terminal professional degree once I get out in four years. I mean anyone who goes and takes a biology degree or chemistry degree, if they don't get in to medical school or they decide that it's not for them, they don't have anything to fall back in where they're considered professional in that degree. They have to continue on to get more education. And that was very attractive to me for chemical engineering. (B5)

Some considered chemical engineering to be both good preparation for medical school and an acceptable alternative in the eyes of their family members. Others were advised to hedge their bets by pursuing a degree that would allow a range of career possibilities in the event that they were not accepted to medical school or changed their minds or simply delayed their decision to apply for a few years.

I was raised in Africa before my family moved to [the U.S.]. And my dad had died and everybody in my family was like, you need to be a medical doctor. So I grew up learning that I had to be a medical doctor. So when I got to the United States I looked at the lifestyle of medical doctors. I'm like, no, I cannot do this. I know everybody still asks, are you gonna go to medical school? I don't think so, but the closest discipline to math and science I could think of was engineering. ... And I thought probably chemical would suit me more because of the different ranges and the options they have. ... So I decided to get a degree in chemical engineering so if one day I have to go back to med school, I would go. (B1)

I originally wanted to do premed, but then, my uncle who's an engineer kinda talked me out of it. He was like, well, what if you don't get into medical school your first year? What are you gonna do? And he was like, if you come to engineering, you'll get all the credentials that you need in order to go into medicine, but you'll also have a fallback if you decide that's not what you want to do, or ...if you want to take a break, or something like that. So, he kinda persuaded me. *Moderator – And are you still planning to go to med school?* I'm thinking I want to take a break. It's kinda hard and takes a lot of time, so I think I want to work in chemical engineering for a little bit and then eventually go back. (A2)

“A better alternative.” Six of the women had considered or even sampled other disciplines through prior majors or work opportunities. After this period of exploration, they chose chemical engineering, again because the breadth of the course of study and job opportunities allowed them to meet their life and career goals with the chemical engineering degree rather than the other course of study that they considered.

My first choice was environmental engineering. And I was preparing for that degree. But at the very last minute, when I was about to go and actually get into that program, I talked to some person, and they told me that chemical is much broader. Plus, a lot of environmental engineers come from [a] chemical engineering background. (B6)

I started off with biomedical engineering, because I wanted to make prosthetics. And so I started off with biomedical engineering, thinking it would be a good marriage between

science well, specifically biology and math. And I got there, and it was a lot of mechanical engineering, and I found myself struggling through material that I absolutely hated and didn't understand, and getting nowhere. ... So my mentor was a chemical engineer, ... and she suggested that I should just talk to Dr. X. ... I'd actually been thinking about chemical engineering prior to that. And I spoke with Dr. X and found out all the different opportunities that were available in chemical engineering, even as far as the classes are concerned. And I felt like that was a perfect fit because it's biology and it's math and it's chemistry. But if you want to focus heavy on chemistry and math, then you can go a different route. Or if not, you can go biotechnology. And that's just what I prefer – it's what I like, so I went that way. (B2)

When I went to [my first college], I had a plan that I was gonna be in nuclear engineering because I really thought that I could. At that time I wanted to be a doctor and do some kind of oncology or something related. ... But then I was just looking through the website of [Institution B] and it was actually the first semester that the biomanufacturing [concentration] had been offered. ... And I realized that it was just a little bit more of what I wanted to do because the nuclear program here is more about like maintaining and construction of fire reactors, than having anything really to do with any kind of medicine or on that kind of scale. So it just worked a little bit better. And then I also could get out in four years with a lot of summer school, instead taking that fifth year, so that's kinda what I decided. (B5)

But at first it wasn't me being an engineer, because I was really good at reading, so I was looking more toward law. But just doing research, and just trying to figure out myself, I chose engineering because, especially chemical, because it's really flexible, so I can do a lot with that. (A3)

Similar to (A3), one of the women in Lyon's¹¹ study chose chemical engineering to better position herself to get into a prestigious law school. She believed that succeeding in such a rigorous discipline would enhance her chances.

Job opportunities. Many of the comments related to the flexibility of the discipline are also related to the job opportunities available to graduates. Good job prospects for engineering in general have been found to be more important for women than men.²⁰ These women were attracted to the fact that they believe that they will always be able to find good employment when they graduate as well as internships while still in school. However, there were other elements of the workplace that these women also found attractive including the incongruity of high starting salaries and an opportunity to work in a field that involves doing something good for society beyond simply making a lot of money.

Even if it's like a mechanical industry, even if it's like an electrical industry, they still were hiring chemical engineers, so you've got the greatest chance of job security when you graduate college for sure with this major, because you know, even at [Company Name] they hire like 40 percent mechanical engineers and 60 percent chemical engineers. But they'll tell you we prefer the ChE's because they can do everything our mechanicals can do and they can zone in on the reaction that's going on in the process. So you know,

it's good job security. It's not that the other ones don't have it, but right now, I feel good graduating with that more so than the others. (B4)

I'm trying to find an internship right now. And I'm trying to look in all of the areas, and it's really easy with chemical engineering. ... You can do a lot of things, really. You can do, pharmaceutical, you can do construction; you can do anything pretty much. And that's why I chose chemical – because it's so broad. (B6)

Salary considerations. A few students identified the starting salaries for chemical engineers as a key reason for choosing the major, if not for themselves, then for others who are considering the major. However, most acknowledged that it was not the only or even primary reason. “One of the things that caught my attention was the starting salaries. That didn't hurt either (A2).” These students felt it was important to do something they found interesting. These echo the sentiments reported in Wentling and Camacho's³ study of women in a variety of engineering disciplines.

I think salary, basically, it was going to put me where I wanted to be when I got out of school. Like it was going to put me in a good place. I could take care of myself. I could be doing something I've thought I would have a interest in, it would just place me well within society I think, was a major reason. (B3)

I think the salary, when people look at engineering and look for different disciplines, the first thing they do is they go through and look at the starting salary. So then it's like, oh, well, I like chemistry, and that salary's talkin' to me. But then it's like, yeah, it talks to you, but you gotta work for it, so, and if you don't want to work hard then it's not for you, but that's what draws people to a department. It's just up to the person whether or not they're gonna stick with it, and they're gonna have much more than the salary just talking to them about the degree. (A1)

Opportunity to give back. The opportunity to give back to their communities by example or choice of employment was very important for two students.

I stayed in engineering, it would be a huge accomplishment to me, but not just me. I'll be the second one. My mom was the only one to go to college in my family, and it's a long distance between me and her. And ever since I've been to college, I've gotten cousins into college, and back home, most people when they graduate high school they just stick around. They don't do anything. And so when I go back home, I want to be a good influence to other people. And for somebody to say I got out of this situation, that's another reason I do stay in. Because a lot of people where I come from they don't go to college, or if they do they don't finish, so, that's another reason I try to stay in. (A3)

When I switched to chemical engineering I just felt like that helps me do more, coming from [Africa]. I mean I didn't live in a village or a remote area, but knowing people who lived in remote areas and how, just little things that we take for granted here, changes their lives back there, I wanted to be able to kinda do something similar in that area. And so I decided to be an engineer. Chem-E. (B2)

B2 later clarified how, of all of the careers that are available to her, she wanted to find one that fit with her life goal of helping people in her home country or other impoverished areas.

Like I don't want to make [potato] chips, y'know? ... So that's why you go to things that aren't promoted like this international health career fair. And you go and you find ways to use your degree, [and] yes – get paid because I don't wanna do it for free. But you still feel as though you're making some kind of impact, but other than being in the lab, being on a line, producing something for a guy who's already filthy rich, and you're just making him richer. ... I just want to be part of something that's greater, but I do feel as though chemical engineering, and the side of chemical engineering that I know, will allow me to do that, rather than making more products. (B2)

These ideas are found in several studies where women chose engineering for the “opportunities to make a difference in society”³, or express a desire to work in field where they feel they are making a difference.²¹ However, Hartman, Hartman, and Kadlowec¹² found no statistically significant differences between men and women or among women in Chemical, Civil/Environmental or ECE/Mech in expectations of making an important contribution to society. The National Academy of Engineering showed that to attract today's young people, more effective marketing is needed to show the connections between engineering and helping society.²²

Respected Influencers. These women were influenced in their decision by both family members and a campus mentor who was particularly influential at Institution B.

Family. Half of the women were influenced significantly by members of their families to become engineers. In our study, family members who were engineers showed these women the breadth of the discipline, the job security and the ability to reach career and personal goals.

My uncle's an engineer, a chemical and a mechanical engineer, and if I graduate out of this program, I'll be the first female chemical engineer in my family, and I think that's really exciting for me. (A2)

I thought about mechanical. I didn't see myself mechanical. I thought about the other disciplines. My older sister, she's a chemical engineer. My older brother is an electrical engineer. And I thought probably chemical would suit me more because of the different ranges and the options they have. (B1)

Anderson-Rowland²³ showed that having a family member in engineering had a large effect on women's choices to major in engineering. Forty-five percent of the women engineering students in her study had a family member who was an engineer. “One of the best ways to influence a student to choose engineering as their major field is for them to have a family member or know a friend who is or was an engineer” (p. 373). Women were found to be more likely than men to identify the influence of parents as strong motivation for choosing engineering.²⁰ An overwhelming majority (17/19) of the women in Lyon's¹¹ study were positively influenced by family members to choose an engineering major. Three of the women had fathers who were engineers who encouraged them to pursue engineering.

Other students who lacked such role models were the first in their family to go to college or to get an engineering degree and were motivated by a desire to make their family proud.

I'm coming from a family none of us ever had a high education. And now I'm pretty much first in line, and I just thought that that's great opportunity for me to move up. (B6)

[My most important reason for staying in the major] is because I'll be the first person within my family to have an engineering degree, and to be a female and to have the engineering degree, it will make me feel really good. (A4)

Campus mentor. At Institution B, a female ChE faculty member with administrative responsibility for undergraduates, had a particular influence on many of the women's choice to major in chemical engineering.

So my mentor was a chemical engineer...and she suggested that I should just talk to Dr. X. And obviously anybody who's had Dr. X knows, if you're in any other major and you talk to Dr. X, you're switching. (Others all laugh). Like, there's no way you're gonna remain in that major. (B2)

I give tours a lot. ... And [Dr. X is] always there waiting, and she introduces herself to every single person. And every time I go and give a tour, I talk about how she's just a best advisor, best person to run this department ever. And she's a big reason why I find it that this department's so successful. And I always end up talking about her during the tour saying when you come here, she will know you by name. And you will live in her office. Any problem you ever encounter, she's there to help you with it. And so I end up always saying something about her in the tour, even though I don't intend to talk about how great Dr. X is. It just always seems to come up. (B5)

And it took me like a month to get drafted in with the head of the department here, because she's one of my biggest role models. And so I was convinced I wanted chemical, pretty much because it was one particular mentor I had. (B4)

Institution A has a relatively small chemical engineering department, enrolling approximately one fifth as many undergraduates as Institution B. In this environment, students and faculty all know each other. There, the prospect of mentor relationships was not important so much for choosing the major as the institution, but confirmed the women's choice to remain in chemical engineering.

And one of the things that I liked about chemical engineering at [Institution A] was it was a small department. So, you'll get to have that one-on-one interaction with your teachers and get to see them in your office hours and they would know your name and not be like, are you sure you're in my class? And I don't know many chemical engineers that skip class, but should they, the teacher cares enough to send you an email or ask the class, have you seen, [that student]? Where is she? Is she okay? And they actually care about

their students in seeing them succeed, so that's one of the things I really liked about [Institution A] is the amount that they cared. (A2)

For the most part, I think the faculty members make me want to stay in the major, because if I ever had, any issues with any of my classes, even though they aren't teaching my class, they will help me with my work. So that's important to me though, to be able to go to a teacher, and for them to be able to help me with work that wasn't even like part of their class, like as long as it was something that they were knowledgeable about, then they were willing to help me. So that's really helped since I've been here. (A1)

Not only are they willing to mentor you as far as academia-wise, they're also willing to help you get the internship, to get that experience, as well as helping you, figure out the right schedule for you, and, pushing you to do more outside of class as well. A lot of them are chairpersons for a lot of the organizations that we're in, and they're always trying to get you involved in that as well. It's like they're trying to make us a well-rounded chemical engineer. (A4)

Lyon¹¹ found that all 19 women in her study “could identify at least one person who supported them academically” (p. 95). All of the women found someone who provided support in an advisory role, whether from an administrator, faculty member from another discipline, or professional staff.

Prestige. Three students identified the prestige of succeeding in such a challenging major as one of the key reasons for choosing it. For others, including all four students at institution A, it was a key reason to remain in the major, though not so much for choosing it.

For me it was the challenge that I liked the most, because I decided – well, I'm already what? 25? – I need to decide on something that would really show my abilities. Sort of move me forward. ... And chemical engineering was a very good option, and I just enjoy the challenge the most. That's what was my intent. To try myself in something that's really hard. (B6)

I mean when you hear someone say, what degree are you in right now? When I go to work, and people are always checking in on me and say, oh, my chemistry degree's going okay. Okay, she's in chemistry. That's great. I say chemical engineering and everyone's like, WHOA, WHOA, WHOA! It's just a completely different status! I mean it's just kind of a little different. You know, you pushed yourself, and you really worked hard. (B5)

I think it's a really big accomplishment to actually graduate out of chemical engineering, and to know when you come in with your initial class [that] a lot of people switch into different disciplines and stuff like that. So when you actually come to the point where you know you're graduating and you're in your senior classes, you're like where did everybody go? And so I think it's really cool the ones that actually stick it out and graduate in it. (A2)

If it seems that the themes of “ChE is hard or challenging” and “ChE students get more respect / prestige / status” are concomitant, that is not surprising. Engineering has been found to operate as a meritocracy of difficulty,²⁴ so if ChE is perceived as more difficult, it would naturally be ascribed higher status within the cultural context of engineering’s hierarchical, and socially constructed, meritocracy. The hierarchy of the various engineering disciplines is a microcosm of a larger hierarchy that is commonly assumed, and has been voiced in scholarly literature.^{25,26,27}

Conclusions

The reasons that these women chose to major in chemical engineering are not as isolated as the categories here make them appear. They can be summarized succinctly into the broad categories of flexibility and career opportunity but there is considerable nuance and overlap as can be seen in the quotations. Flexibility of the major and career was more important for students as they chose the major, with job opportunities becoming more relevant as they advanced in their studies. For all of the students, their reasons were multi-faceted with a host of complementary influences. At Institution B, an advisor in the department was critical to many of the women’s choice to become chemical engineers while at Institution A, that type of influence was absent. Conversely, at Institution A, a feeling of being welcome in the department was influential. Godfrey (2007) notes that women who are qualified in math and science and who choose to study engineering, choose the particular discipline through an apparently random process “often swayed by a personable lecturer, perceptions of career potential or even a process of elimination.” The women in our study seem to have been somewhat more deliberate in choosing chemical engineering, but many did so after carefully considering other options that they hoped would meet their career and personal goals and finding those options lacking.

Litzler¹⁴ notes that prestige, starting salary and critical mass (>30% women in a discipline) do not explain sex segregation in engineering majors. If they did, chemical engineering with its high prestige and starting salary would be dominated by men in the same way that electrical and mechanical are. Indeed, while these constructs were important to some of the women in our focus groups, they were not the dominant themes in our discussions by far.

While the presence of transfer students introduces other (possibly unknown) factors into the interpretation of the focus group data, there is benefit to their perspective as well. Individuals “on the margin of a group” sometimes have the clearest perspective in defining the group’s core culture.^{28,29} That is, by including students who chose to transfer into ChE at the institutions studied, the sample may include students who were acutely aware of the benefits of majoring in ChE at these institutions.

In summary, we find that the key feature of chemical engineering that makes it attractive to the women we interviewed is its flexibility. With a chemical engineering degree, women can enter the workforce in a high paying and prestigious field, seemingly of their choice. They can also go directly to medical or graduate school or work for a while before pursuing graduate study.

Limitations and Future Work

The analysis presented here is part of a larger ongoing study. As such, it has several limitations. Although we asked our campus contacts to recruit sophomores, juniors and seniors in their programs, no sophomores chose to participate. Half of the students in our focus groups were transfers, however at this time we are unable to present data from MIDFIELD about transfer students. Our focus groups also included a disproportionate number of Black students relative to their participation in chemical engineering in general. This was not intentional oversampling, but also has potential benefits. Considering the intersectionality of race and gender is important for future work. To more fully understand the reasons why women choose chemical engineering, more qualitative data is needed from more institutions. This could also be used to explore the impact of mentoring and faculty demographics. Ongoing and future work includes more quantitative analysis of data from MIDFIELD including retention in chemical engineering through graduation and qualitative analysis of focus group data on why students are retained in the major.

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