DISSERTATION

CULTURE MATTERS:
FACTORS AFFECTING THE PERSISTENCE OF EUROPEAN AMERICAN AND ASIAN WOMEN IN TWO U.S. ENGINEERING DOCTORAL PROGRAMS

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY STEFANIE AKI HOSOI ENTITLED CULTURE MATTERS: FACTORS AFFECTING THE PERSISTENCE OF EUROPEAN AMERICAN AND ASIAN WOMEN IN TWO U.S. ENGINEERING DOCTORAL PROGRAMS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

CULTURE MATTERS:

FACTORS AFFECTING THE PERSISTENCE OF EUROPEAN AMERICAN AND ASIAN WOMEN IN TWO U.S. ENGINEERING DOCTORAL PROGRAMS

Over 50% of the students enrolled in engineering doctoral programs in the U.S. are foreign nationals, with the majority of these students coming from Asian countries (primarily China, Korea, India, and Taiwan). The present study was designed to better understand the factors that affect the persistence of women in engineering doctoral programs in the U.S., while explicitly examining how differences in students' cultural backgrounds might influence the factors they perceive as important to their educational persistence. Individual interviews lasting 62 to 98 min were conducted with 16 participants enrolled in two U.S. universities. Ten of these participants were U.S. citizens of European American descent, and six were foreign nationals from five Asian countries (China, Korea, India, Taiwan, and Singapore). All interviews were recorded and transcribed verbatim, and then analyzed by team of trained coders using Ethnographic Content Analysis (ECA) as a qualitative framework. The results are discussed in two chapters. The first chapter focuses on the perceived challenges described by the 16 study participants, and shows that social contexts and psychological responses to these contexts interact to create challenges to persistence on an engineering educational career path. In the second chapter, factors that participants perceived as

promoting their persistence on an engineering educational and career path are described, including both external support structures and psychological factors that motivate persistence. Similarities and differences between the themes that emerged from interviews with U.S. and Asian participants are discussed in both chapters, highlighting the implications of these themes for the development of interventions aimed at increasing women's representation in doctoral level engineering careers. This paper concludes with a General Discussion, in which I provide an additional theoretical structure to these findings by examines the themes that emerged from the interviews in the context of Social Cognitive Career Theory (SCCT), and discuss the limitations of this research.

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Culture Matters: Factors Affecting the Persistence of European American and Asian Women in Two U.S. Engineering Doctoral Programs

This dissertation was designed to gain a more in-depth understanding of the supports and challenges that affect the persistence of women from the U.S. and Asia who are enrolled in U.S. doctoral-level engineering programs. The study is based on theory and research indicating that understanding the potential impact and intersection of gender and culture on the pursuit of an engineering career is critical to understanding women's under-representation in higher level engineering education and careers. In this introductory section, I briefly review previous research on women's under-representation in engineering, and discuss why nationality cannot be ignored when studying women in doctoral level engineering programs. I also introduce the research questions and purpose of the two chapters that comprise this dissertation.

Factors Impacting Women's Under-representation in Engineering

In 2008, women represented 21% of doctoral degree recipients in the U.S. (ASEE, 2009). Although the reasons for this persistent under-representation remain ambiguous, decades of research on women in the U.S. and other countries have shown that socialization and learning strongly influence women's science and engineering performance, and the foundations for their interests and future career choices begin to be set in childhood (Baenninger & Newcombe, 1989; Ceci, Williams, & Barnett, 2009; Halpern & Collaer, 2005; Halpern & Tan, 2001; Hyde & Mertz, 2009; Levine, Vasilyeva,

Lourenco, Newcombe, & Huttenlocher, 2005; Newcombe, Mathason, & Terlicki, 2002; Nosek et al., 2009; Wraga, Helt, Jacobs, & Sullivan, 2006). These studies therefore offer compelling reason to further examine the sociocultural context in which educational and career choices are made.

Differences in how girls and boys are treated with respect to their scientific and technological abilities emerge at an early age (Spelke & Grace, 2007). Several studies in the U.S. have indicated that parents interact with their children differently when engaged in scientific activities, with parents offering more scientific explanations to boys than girls, thus helping boys to develop the type of reasoning that is critical to success in scientific fields (Crowley, Callanan, Tenenbaum, & Allen, 2001; Hyde, 2007). Differences in self-confidence and attitudes also develop at an early age, and can have important consequences for later choices and successes. For example, there is evidence that observed gender differences in performance in scientific and technical arenas may be due at least in part to a gender difference in how boys and girls learn to cope with setbacks, rather than a true difference in aptitude (Dweck, 2007). Stereotype threat, i.e., the decrease in academic performance caused by awareness of a negative stereotype about one's group, may also affect females' scores on tests that serve as important stepping stones to engineering education (Steele, 1997). Several studies have shown that women perform more poorly on math tests under stereotype threat conditions (Davies & Spencer, 2005; Hyde, 2007), and that introducing positive messages about women and math can improve women's performance, just as negative stereotypes can harm it (Wraga et al., 2006). Finally, early social influences encouraging girls to engage in nurturing play and boys to interact with blocks and machines are also believed to contribute to observed

patterns of career choice, with girls favoring careers that involve people or other living things, while boys are more likely to show a preference for careers involving objects (Lubinski & Benbow, 2007).

As girls grow into adolescents and then women, certain social pressures increase in salience. The years after women earn their engineering undergraduate degrees and decide to begin entry level careers or continue on into graduate school represent a key transition period in their intellectual development. Many students get their first experience exploring specialized areas of interest within the engineering field during this time period, and the focus of engineering may shift from classroom-based academic learning to practical skills and applications. For many women, this is also a time of relational transition, when they may enter into more committed romantic relationships and think about starting families of their own. The educational and career choices women make in this time period may therefore be heavily influenced by women's expectations about how these decisions will impact their other life priorities, and the social expectation that women be family caretakers, leading women to seek out careers that are both nurturing and flexible enough to allow them time to tend to these additional responsibilities (Frome, Alfeld, Eccles, & Barber, 2006; Halpern, 2007; Lubinski & Benbow, 2007; Morse, 1995).

Unfortunately, most research on female engineering students has focused on women at the undergraduate level, when such conflicts may be just beginning to arise. Very little is therefore known about how women negotiate these conflicts in the years following completion of an undergraduate engineering degree, and how the intellectual and personal transitions that frequently occur during this time affect their persistence on

an engineering education path. Graduate school may be a time period that is particularly challenging for women to negotiate because science and engineering careers tend to be demanding, and the timing of the "typical" career path through graduate school and beyond is based on a traditional male norm in which most family caretaking responsibilities are assumed by the female. This norm does not allow for the competing demands of being the primary caregiver for a family, which may place women may be at a disadvantage in this system (Grant, Kennelly, & Ward, 2000). However, if career demands were the only obstacle to pursuing engineering higher education, then one would also expect women to be under-represented in other highly demanding professions such as medicine or nursing where they are well-represented (Bell, Di Fabio, & Frehill, 2006), nor would one expect to see the cultural differences in women's representation that will be described in the following section.

Intersections Between Gender and Culture

As the previous section illustrates, the social context surrounding an individual has profound impacts on her educational and career choices. The potential impact of such social influences at an international level is illustrated by a cross-national comparison of the proportion of women earning doctoral degrees in engineering in 2000-2001. This comparison showed huge differences between countries in the proportion of women earning degrees: Taiwan had the lowest proportion of women earning doctoral degrees in engineering (2.3%) and Italy the highest (35.0%), with the U.S. falling in the middle of this range (16.9%) (Babco & Bell, 2004). Similar international variation has also been found for childhood performance on tests of math and science, with comparisons of test scores in different countries showing 1) varied effect sizes and directionality for gender

differences, 2) very small gender differences in most countries, and 3) performance differences between countries that are much larger than gender differences within any single country, and 4) correlations between gender differences in testing performance and culturally mediated national differences in gender inequality as measured by economic participation and opportunity, educational attainment, political empowerment, and indicators of implicit gender-science stereotyping (Beller & Gafni, 1996; Else-Quest, Hyde, & Linn, 2010; Guiso, Monte, Sapienza, & Zingales, 2008; Hyde, 2007; Hyde & Mertz, 2009; Lummis & Stevenson, 1990; Mullis, Martin, & Foy, 2005; Nosek et al., 2009). Research also indicates that women's representation in science and engineering careers may often reflect the pay and prestige of these careers, with women more strongly represented in science and engineering careers in cultures in which these careers are not highly valued, and only women born into the upper class allowed to pursue these careers in cultures where wealthy women have higher status than poor men (Barinaga, 1994).

Unfortunately, despite such strong evidence that cultural differences affect women's representation in science and engineering, women in engineering programs in the U.S. tend to be studied as if they are a homogeneous group, without regard to their country of origin or other cultural identifiers. This helps to perpetuate the misleading assumption that we can generalize about the experiences of culturally distinct women based on the experiences of women of European descent who grew up in U.S. (Thom, 2001). This tendency to make broad generalizations about women in engineering is particularly misleading for women enrolled in engineering doctoral programs, because over 50% of engineering doctoral students are foreign nationals (Bell et al., 2006). In order to understand the factors that contribute to the challenges and successes of women

in higher engineering education, it is therefore critical to examine how gender and other culturally relevant factors intersect in influencing these women's experiences.

Purpose

The goal of this dissertation is to generate information about women's persistence on an engineering educational path after the initial choice to pursue a major in engineering has been made, while taking into account differences in the cultural backgrounds of study participants. The two chapters that comprise this dissertation are designed to identify and explore the factors that have challenged and supported the educational persistence of female doctoral engineering students. Specifically, the first chapter addresses the perceived challenges or barriers to persistence described by women in doctoral engineering programs. The second chapter examines the factors that these students identify as supporting their persistence on an engineering career path. This second chapter takes a strength-based approach, highlighting factors that support educational and career persistence among female doctoral-level engineering students. To my knowledge, this dissertation is unique among studies examining women's under-representation in engineering careers in that it focuses on two culturally distinct samples of students, female doctoral students of European American descent and female doctoral students who are Asian foreign nationals, and examines the impact of such cultural differences in the context of the questions listed above. Thus, this study is designed to explicitly acknowledge the context of the cultural diversity that is so prevalent in engineering doctoral programs. Such attention to the diversity of cultural experiences is essential, if we are to understand and address the social inequalities that continue to exist within this field (Else-Quest et al., 2010).

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CHAPTER 1

European American and Asian Female Engineering Doctoral Students' Perceptions of Past and Current Challenges to Their Persistence

Women's proportionate representation in most career fields has increased dramatically over the past few decades, with women now making up almost 50% of the U.S. labor force (Bell, Di Fabio, & Frehill, 2006). However, increases in women's representation in doctoral level engineering fields have been disproportionately small, with women earning only 17 to 21% of doctoral degrees in engineering between 2003 and 2008 (ASEE, 2009; Bell et al., 2006; Snyder, Dillow, & Hoffman, 2007). It is therefore important to better understand the challenges that may prevent women from earning doctoral degrees in this field, both from a social justice perspective and because the changing demographics of the U.S. labor force make women's participation in the engineering field critical if this country is to maintain its status as a world leader in science and technology (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007).

Previous Research on Challenges to Women in Engineering

Numerous studies have sought to understand the challenges that contribute to the continued under-representation of women among engineering degree recipients, with the majority of studies examining women's persistence in engineering only to the point of undergraduate degree completion. These studies have found that undergraduate female

engineering majors reported difficulties related to a perceived lack of inclusion or support (Marra, Rodgers, Shen, & Bogue, 2009; Wentling & Camacho, 2008), a sense of isolation (Brainard & Carlin, 1998), and a lack of female professors and classmates (Wentling & Camacho, 2008). There is also evidence that undergraduate women's self-confidence or science and engineering-related self-efficacy beliefs 1) predict their future plans to persist on an engineering educational and career path (Marra et al., 2009), 2) decline as they move through their engineering programs (Brainard & Carlin, 1998; Felder, Felder, Mauney, Hamrin, & Dietz, 1995; Hutchinson-Green, Follman, & Bodner, 2008), and 3) are generally lower than those of men (Felder et al., 1995; Hutchinson-Green et al., 2008; Vogt, Hocevar, & Hagedorn, 2007). Furthermore, undergraduate women may experience conflict between social expectations of how they should behave as women and how they should act in order to be perceived as competent engineers (Powell, Bagihole, & Dainty, 2009).

There is relatively little research examining the challenges women face after completion of an undergraduate engineering degree. One recent quantitative study found that enrollment into graduate programs in science, math and engineering was negatively correlated with women's desire to create social change, indicating that a lack of information about humanitarian applications of engineering graduate degrees could be a barrier to women's persistence in engineering (Sax, 2001). Additionally, there is some evidence women who have children or place a high priority on raising a family are less likely to pursue an engineering graduate degree, indicating that perceptions of the incompatibility of graduate-level science and engineer careers and motherhood may create barriers to engineering educational and career persistence (Sax, 2001; Xie &

Shauman, 2003). The latter challenge might be predicted to become even more salient for women after they enter graduate school, because graduate students are often at an age where marriage and family become increasingly important concerns, resulting in conflicting demands between career and the socialized pressures of child rearing and caring for a partner (Crawford & Unger, 2004; Stevens, Kiger, & Riley, 2001). However, this does not explain why women are well-represented in other highly demanding careers such as medicine or nursing. The existing quantitative studies also have been able to explain only a small proportion of the variance in women's enrollment in science, math and engineering graduate programs by using the above cited factors as predictors (Sax, 2001). Thus, the lack of information on women's experiences in engineering graduate programs and the inability of current theory to account for women's continued under-representation in this field indicate that new research approaches are needed. In particular, exploratory qualitative studies are needed to closely examine the experiences of female engineering students and identify additional challenges that have not been previously considered, particularly at the doctoral level where women are most under-represented (Bell et al., 2006).

An Overlooked Factor: Cultural Differences

In recent years, increasing attention has also focused on research that attends to the unique experiences of different cultural groups, based on the recognition that all problems occur in a sociocultural context, and understanding social issues therefore requires an understanding of how this context influences individual perspectives and decisions (Stead & Young, 2007). Attention to cultural diversity is particularly crucial with respect to doctoral students in engineering because foreign nationals represent only

7% of U.S. engineering degree recipients at the undergraduate level, but over 60% of engineering doctoral recipients in the U.S. (Bell et al., 2006). The majority of these individuals are from Asian countries, with China, India, Korea, and Taiwan comprising four of the five countries that are most commonly represented among engineering foreign national doctoral students in the U.S. (Hoffer et al., 2004). However, despite the fact that foreign nationals constitute a majority of engineering doctoral students, to date there have been no published studies that separately examine the challenges faced by female doctoral students from different nationalities or cultural groups.

Study Objectives

The purpose of the present study is to help fill these gaps in our understanding of the challenges faced by women in engineering. It is an exploratory study, designed to generate new information on the under-representation of women among engineering doctoral degree recipients. Specifically, this study examines the perceived challenges to persistence that emerged from narrative descriptions of the educational paths of sixteen women from two U.S. universities, who had successfully completed the first few years of a doctoral engineering program. Participants were recruited from two universities to incorporate a wider range of academic environments and potential challenges, thus increasing the range of challenges that could potentially be captured through our exploratory analysis. This study also begins to address the cultural diversity that is present among doctoral women in engineering by explicitly examining and comparing the challenges described by two groups of women: U.S. citizens of European American descent and Asian foreign nationals from five countries: China, India, Korea, Taiwan and Singapore.

Because the goal of this exploratory study was to generate information on the range of challenges and barriers to persistence faced by groups of women in engineering that have not been the focus of previous research, we used a broad definition of "persistence." This definition did not restrict persistence to a particular choice point; rather, it encompassed a woman's continued commitment to an engineering educational path at any time following her initial decision to pursue this path. Challenges to persistence were defined as any factors that might cause a woman to question this commitment or consider changing to a different educational or career path. Qualitative analysis of interviews was used to address two questions: 1) What are the factors that U.S. and Asian female doctoral students identify as challenges or barriers to their persistence on an engineering educational and career path, and 2) How are the challenges described by U.S. and Asian participants similar or different?

METHOD

Participants

The interview participants for this study consisted of 16 female doctoral students in engineering. Participants were recruited from two universities that differed in terms of their prestige, location, and funding source (public versus private), in order to broaden the range of experiences that would be represented in participant interviews. Six participants were students at a state land grant university (SLGU), and the remaining ten were students at a prestigious private science and technology university (PSTU). The students were also recruited from a range of different engineering departments including Civil/Environmental/Geological (N=5), Biological (N=2), Mechanical (N=5), Electrical/Computer (N=3), and Material Science and Engineering (N=1), in order to

maximize the breadth of experiences represented in this exploratory study. Our sample was evenly split between two subfields which have historically had the lowest representation of female doctoral students (Mechanical and Electrical engineering, where women earned 12.4-12.8% of engineering doctorates in 2005) and the remaining subfields, in which women's representation ranges from 22.3-32.1% of engineering doctorates earned (Bell et al., 2006).

Ten of the participants identified as U.S. citizens coming from a European American background. The average age of these ten participants was 27.5 years. Two of these students identified as "single," three as "in a committed relationship," and five as "married." Two of these students had children or reported that they were actively trying to start a family. On average, they had completed 4.4 years of graduate school at the time of the interview, including time spent earning a prior master's degree, where applicable.

The remaining six students were foreign nationals from five Asian countries (China, India, Korea, Taiwan, and Singapore). This distribution of countries reflects the representation of Asian foreign national students in doctoral engineering programs, with most students coming from China, India, Korea, and Taiwan, and a smaller proportion of students coming from other Asian countries (Hoffer et al., 2004). The average age of these six students was 27.0 years. Two identified as "single," two as "in a committed relationship," and two as "married." Again, two of these six students had children or reported that they were actively trying to start a family. On average, they had completed 3.8 years of graduate school at the time of the interview, including time spent earning a prior master's degree, where applicable.

Procedures

Study participants were recruited via email and word of mouth, with the assistance of campus groups for female graduate students and women in science, engineering professors, advisors, and other staff at SLGU and PSTU. Prior to each interview, the participants were sent a demographic questionnaire that included questions related to their educational history, nationality/ethnicity, and relationship status (Appendix A). Each participant also filled out a consent form for participation (Appendix B). In person, semi-structured interviews were carried out by the primary researcher in a private room on the campus of the university attended by each participant, between October 2007 and December 2008. Interview questions related to the challenges encountered by participants on their educational paths were used to structure the interview, with follow up questions providing flexibility to explore emergent themes (Shah & Corley, 2006). Interviews were tape recorded and then transcribed verbatim into a text document by a team of research assistants. Each interview transcript was also reviewed and edited by the lead researcher prior to coding, to ensure accuracy of the transcription.

Data Analysis

Ethnographic Content Analysis (ECA) was the qualitative framework used in this study. ECA is a qualitative methodology in which documents are examined for thematic categories using the constant comparative method of analysis to inductively identify thematic categories (Altheide, 1987; Boeije, 2002; Willig, 2001) . Coding was completed by a six member coding team, consisting of three graduate students, two undergraduate research assistants, and a recent college graduate. Following the constant comparative

method, analysis involved identifying areas of text that were of relevance to the research questions, assigning these segments of text to specific categories based on shared themes, condensing the themes by combining them into broader categories, examining the themes in the context of what the data mean with respect to the research questions, and writing narrative descriptions of these themes (Boeije, 2002; Krippendorff, 2004).

More specifically, training of the coding team began with all coding team members analyzing the same interview transcript independently, and assigning labels that were one to three words in length to segments of text that they judged to be significantly related to the research questions. Emerging codes were discussed at team meetings, where each team member discussed the codes she had created to represent the data and her rationale for this coding; through examination and reexamination of the data and its interpretation, we arrived at a consensus on which codes most accurately represented the emerging themes when there was disagreement among team members. During these meetings, we also began grouping codes into broader categories, based on shared characteristics (Boeije, 2002; Krippendorff, 2004). This individual process of line-by-line coding of a transcript followed by team discussion of the resultant codes was then repeated for a second transcript, to ensure that all team members had a good understanding of the emerging codes.

Once a coding structure was determined through detailed discussion of the first two transcripts, the remaining transcripts from U.S. participants were coded by pairs of team members, using the coding structure developed at the previous team meetings. Each member of the pair coded her assigned transcript independently before meeting with the other pair member to compare coding, and to reexamine and discuss any areas of

disagreement. Any coding that did not seem clear after this was discussed at the biweekly team meeting, where revisions were made to the coding structure as new information emerged from the data (e.g., adding new codes or rearranging existing codes). These team meetings were also periodically visited by an outside auditor, who reviewed our emerging coding structure and requested justification of coding choices (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005; Lincoln & Guba, 1985).

The same procedure was followed for coding transcripts of interviews with Asian participants, with each team member individually coding each of the first two interview transcripts and then reviewing all segments and category labels as a team, before the remaining Asian interviews were analyzed in coding pairs. Because the interviews of U.S. and Asian students were both based on the same initial set of structured interview questions, codes that had been developed during coding of the U.S. interviews were often also appropriate for describing sections of text in these interviews. Rather than artificially re-creating these codes for the Asian interviews, we continued to develop a single coding structure for both U.S. and Asian interview participants, adding new codes as needed. However, Asian and U.S. interviews were analyzed separately during the final two steps of analysis (see below), to allow the research team to look for similarities and differences between the thematic structures emerging from interviews with the two groups of students, and to revise codes as needed for each group.

After all 16 interview transcripts had been coded following the procedure described above, we separated the data from U.S. and Asian interviews using NVivo 8 software (QSR International). Team members again worked in pairs, carefully examined the sections of text from Asian or U.S. interviews that were assigned the same category

label or code, and wrote a brief description of the characteristics that defined that code and its relationship to the research questions. At this stage, additional distinctions could be made between codes derived from U.S. versus Asian interviews, if sections of text that had been assigned the same label were found to include subtle differences in content between the two groups. Some codes were combined with other codes or subsumed under broader categories as patterns in the data were clarified during this process (Boeije, 2002). The research team then met again to discuss their written descriptions of themes, and to expand upon these themes as needed to accurately describe the data. This narrative description of coding themes, in combination with the use of quotations from the transcripts that illustrate these codes, provided the final explanation of our research findings (Krippendorff, 2004).

Data Trustworthiness

This study used Lincoln and Guba's (1985) methods of establishing credibility, transferability, dependability, and confirmability, to minimize value bias and ensure methodological rigor. Credibility is a measure of how accurately the findings reflect the intentions of the study participants; in the present study, this was established by repeatedly referring to interview transcripts to ensure that any interpretations accurately reflect the original meaning conveyed in the interview, and by clarifying any ambiguous material during the interview. Credibility was also achieved by supporting coding categories with direct and specific quotations from interview subjects, and using a consensus coding method that required coding categories to constantly be evaluated and defended (Brantlinger et al., 2005). The requirement of transferability, which refers to the researchers' responsibility to provide information that will allow future researchers to

determine to what extent study findings can be generalized to their own population of interest, was met through collection of extensive demographic information on all study participants. Transferability was also addressed by establishing an audit trail including memos taken throughout the coding process and observational notes taken immediately after each interview to create additional transparency about the interview process (Lincoln & Guba, 1985). Finally, dependability and confirmability replace the quantitative measures of reliability of objectivity. In some ways the idea of replication runs counter to the fundamental assumptions of qualitative inquiry, in that one of the strengths of such inquiry is its flexibility in allowing for changes in design as the researcher gains understanding of the subjects. Thus, the goals of dependability of confirmability are to establish the accountability necessary to develop a meaningful data categorization scheme, while maintaining this flexibility. In the present study, these requirements were met by following a rigorous methodology in which all data were coded by a culturally diverse coding team including individuals of both European American and Asian American backgrounds. Coding was also periodically reviewed by the primary researcher's dissertation advisor as the outside auditor (Brantlinger et al., 2005). The role of the coding team was to provide a broad array of viewpoints when making coding decisions, and to ask challenging and thoughtful questions about the data analysis and interpretation of all team members. By constantly engaging in a process of discussion and feedback on coding decisions with the end goal of reaching consensual validation, this team approach to coding ensured that all coding decisions were challenged and defended, and the coding structure we developed was supported by the interview data. The primary researcher also kept written notes of coding changes made at

coding team meetings and the rationale for these changes, to further build an audit trail (Creswell, 1998).

RESULTS

For this study, factors challenging persistence were defined as any factors that influenced participants to consider abandoning their engineering education or to change career ambitions (i.e., to move away from a plan to pursue a full time career that was directly related to engineering), *after* their initial decision to pursue a career in engineering. These challenges clustered into two major categories. The first category consisted of challenges that were directly related to the contextual framework (i.e., the social and academic context) in which these women made their educational and career decisions. The second category consisted of participant's psychological struggles with respect to their self-appraisals and internal reactions to experiences. This second category is closely linked to the first, in that the social environment these women inhabit has broad consequences in terms of how it impacts their perceptions of themselves and the choices they make. The major themes that emerged from the interviews in each of the two categories are summarized in Table 1, and all themes are described in detail in the sections that follow.

Contextual Framework

The contextual framework described by study participants can be separated into themes related to 1) social gender biases and 2) academic challenges. Together, these themes describe the sociocultural norms and expectations that have presented challenges to participants' engineering educational and career persistence, as well as the more practical difficulties they have encountered with respect to their engineering programs.

Social Gender Biases

The broad category of social gender biases emerged in response to women's descriptions of social contexts in which they perceived a difference in how women and men were treated. The specific themes related to social gender biases that were described by both U.S. and Asian participants included social stigma, professional gender biases, social isolation, and negotiating gender expectations, as described below.

Social Stigma

Both U.S. and Asian students talked about a social stigma related to negative stereotypes of women in engineering, which led others to react as if their personal appeal as women was lessened when they revealed their professional identities in social situations. U.S. participants from PSTU described shocked reactions and social distancing from acquaintances after they learned that the participants attended this prestigious engineering program, as well as an assumption that engineers could not also be fashionable or attractive. For example, one participant described the reaction she got from two men she had been socializing with after she told them she attended PSTU:

> And we're all looking at the water, and they're kind of sitting down there in front of us. And the two guys actually turn around and look at me and like…*look* at me. And I'm like, "What? Did you think I looked differently than I did five minutes ago?" Like, I haven't suddenly turned into a big green slimy monster.

Asian students also spoke about the negative stereotypes of engineers, noting that people often needed time to "adjust" to the information that they were engineers in social interactions, and describing a perception of engineers as "geeky" and poorly dressed.

This social stigma sometimes left participants in a double bind, as they found themselves in situations where the professional benefits of their behavioral and educational choices (e.g., pursuing a career in engineering, being in a position of power,

being assertive) were counterbalanced by the stigma of making these choices as women. As one U.S. participant described it:

> …as you move up and you get older, you kind of realize that there are things that people are comfortable with and things that people aren't really comfortable with, and it's definitely not the same thing that you were told. So then there's like this point of confusion…So I think the culture seems to be okay with women being in positions of power, up to a point, and then after that they're really not ok with it.

Similarly, one Asian participant provided the following simple summary when asked whether engineering was considered a prestigious career in her home country. "To be an engineer is prestigious, but a woman engineer, I'm not quite sure."

Professional Gender Biases

Many U.S. and Asian participants also discussed gender biases in how they were treated in their professional roles as engineers. For the U.S. participants, these included being excluded or ignored by professors and peers, and difficulty earning respect or having to "prove themselves" in ways their male colleagues did not. Most frequently, they reported differences in interaction style and tone of voice when others were interacting with them as compared to their male colleagues, and an assumption that they would not be as smart or capable as a male engineer. One participant noted that her advisor would make "relatively degrading comments" disguised as humor and explained, "So that type of behavior I was not finding helpful, especially when it seemed like he meant it to be an insult and not a joke."

Asian participants brought up similar themes of being excluded or treated in a condescending way by peers or employers; as one woman put it, "I learned that a woman in engineering or in academia, you have to – especially at the beginning – you have to somehow prove yourself." Another Asian woman described how at a former job she was

asked to perform menial tasks that were normally performed by the female administrative office staff, who were the only other women working in her department:

> I think they have this mixed value for me because they wanted you to work as an engineer but they also wanted you to work that, [as one of] those female people… Sometimes when she's not in they ask you to bring coffee or something when I'm working hard. And, well maybe it's not that much deal, but…it gets depressing…Even after I was promoted, I have to do some of those kind of works, so. You have to do like both parts of that work and still try be a good engineer, so. That's not easy, I guess.

In some cases, the more overt professional gender biases described by Asian participants were described as culturally expected and normative in their home countries. These included hiring biases because of expectations that women would leave the work force after they married or had children. As one interviewee described it:

> …they [employers] think, "Males are more capable and they can," and for females, "Oh you, you have to be pregnant and you'll have rest for one year…it will not be good for our company."

Social Isolation

Both U.S. and Asian students described a general feeling of alienation and loneliness in their professional lives. This sense of social isolation was described in connection with limited role models by both U.S. and Asian participants. Additionally, U.S. students talked about value differences that separated them from many of their peers and colleagues, and Asian students discussed acculturation challenges.

Limited role models. The lack of female role models in engineering was extensively discussed as a challenge by U.S. participants, and was also brought up by one Asian interviewee who talked about her wish for "a mentor that was a female." Although some students reported that they did not experience the lack of female role models as a problem because they were able to connect with male role models, one student talked

about the difficulty of having male role models because of the possibility of romantic attraction. Others expressed frustration at their inability to find women whose lives they wished to emulate. As one participant described it:

> …one of the reasons I quit my job at [company name] was when I realized that my vision of myself at 50 was male…I just did not have any female role models at that level that I looked up to, and that was terrifying and concerning.

Other U.S. participants stated that they felt like they had no one in their family they could talk to about being in a Ph.D. program, and that when they were young they were not aware that women could be engineers. As one woman explained, "...nurses, maybe high school teachers is about what you see in my community and my culture." Additionally, one U.S. participant also talked about the shift that occurred in her need for female role models after she had a child:

> …now the realities of being a mom and trying to be a grad student and all of that have really hit hard. So I think that the need has really come clear to me to have role models as people I can say, "Alright you're doing it." And up until now other men have been okay as role models, and now the gender differences and what it means to be a parent just are really strong right now. And, I think in five years…if we don't have another kid, that'll change back. But, right now, the toll on your body as a woman and the impact being a mother has is different than being a father.

In some cases, the general lack of women who could serve as role models was exacerbated because participants reported that the few women they knew in engineering appeared to be struggling or disliked their jobs. For example, one student stated that she would not enter academia because she saw the huge sacrifices a faculty member had made to gain tenure.

Value differences. U.S participants also reported a sense of social isolation that was created because they had different values than their colleagues in their graduate

programs, such as not sharing interests in sports, wanting more personal connections with faculty, having less ambition or valuing money less, or feeling that others did not believe their specific research interests constituted "real" engineering. For example, as one U.S. student explained:

> I think there is also a "jock-ish" culture in mechanical engineers, in particular for the men. And that's not who I am or who I see myself as. And so, there is just a lack of common values and interests that makes it tough.

Acculturation challenges. Asian students also talked about challenges related to acculturation or difficulties adjusting to the culture of the U.S. This included communication challenges (in terms of both language and communication style), having a hard time getting to know people well, feeling homesick and isolated, and having to learn to take care of oneself. As one participant described this transition, "…it was tough for me. I guess I keep thinking about the fact that I'm foreign and I'm an international student and I'm so different from everyone else."

Negotiating Gender Expectations

All participants in this study described a constant process of having to negotiate between conflicting demands, particularly in the context of socially normative expectations of women. Both U.S. and Asian students talked about the challenge of achieving work-life balance, and the struggle to negotiate between the different responsibilities they tried to meet in their lives (i.e., as students, parents, daughters, wives, and girlfriends). In particular, participants spoke in detail about challenges related to family expectations, negotiating relational responsibilities, and negotiating career priorities.

Family expectations. Both U.S. and Asian students reported feeling torn at various stages in their educational paths because others had different priorities and expectations for them than they did for themselves. As one U.S. participant described it, "...my parents are finally doing better with it, but I think they had trouble because they had envisioned one path for my life and it's not the one I chose." Additionally, participants talked about family members who would like them to have a family, or felt that being an engineer impeded getting married or having a family.

Negotiating relational responsibilities. This theme was primarily brought up as a challenge by U.S. and Asian participants who currently identified as married or in a committed relationship, and who struggled to balance their identities as students and developing professionals with socially normative expectations related to women's caregiving responsibilities. More specifically, both U.S. and Asian students reported difficulties negotiating with partners about who would tend to household tasks. This difficulty was described as a "cultural thing" by one Korean participant, who explained that men and their parents in Korea, "just expect the women to do the housework." One married U.S. participant also described feeling that her partner was gradually contributing less towards household responsibilities as his job responsibilities increased:

> I see it changing already. So that worries me. 'Cause it seems that he chipped in a lot more when I was making all the money and he was going to school. So I don't know if he felt like that was more important and now it's kind of diminishing. But his demands with his position right now are even higher than when he was in school, so. I don't know. I'm a little bit nervous of how it might equal out.

Participants also discussed challenges related to negotiating relational responsibilities with respect to parenting. In particular, the two study participants who had children discussed the constant tension between the time demands of graduate work

and motherhood. Both of these participants described ways in which their partners tried to assist with parenting tasks but acknowledged an imbalance that followed traditional expectations of women, as described by one participant who explained, "We try to be fair. It doesn't work and it's definitely classic; I fall into the caretaker role more."

Negotiating career priorities. Both U.S. and Asian students also reported challenges related to reconciling career demands in dual career partnerships. Most frequently, these challenges were related to geographic conflicts between jobs or to decisions about career compromise in the context of parenting. In some cases, there appeared to be little room for compromise, as described by one Asian participant who explained, "...once I finished my master's at [school name] I got job offers, but they were near New York, New Jersey, that area. And my husband had got a job here. So we came here." Even when both partners were willing to compromise with respect to geography, some participants talked about the difficulty of negotiating which partner would sacrifice and move to support the other's career or educational path, as described by this U.S. participant:

> And there may be challenges in trying to find -- since there's my fiancée and I, the two-body-problem of, like, if he finds something he really wants to do then balancing out, "Well how do we-, what do I do then?" 'Cause up until recently I've sort of had the attitude of like, "Yeah, so if he finds a professorship someplace then I'll just find something to do in the area. It's not a big deal to me." And so this last month has been the first time where it's kind of like, "Well, but maybe there are things that I want to do."

This negotiation process could be further complicated by timing issues such as which partner graduated first, the income potential of each individual, and a need to find places to live that were close to childcare services or family who could help with child care.

With respect to parenting, both U.S. and Asian participants talked about their expectations of themselves and of their partners in the context of current and future career compromises. One participant talked about how it was important to her in theory that her partner be willing to be a stay-at-home dad, but in practice she believed that she would give up her career after having children. Another participant emphasized the shift in her priorities that had occurred after having a child:

> It wasn't clear how severely my priorities would change and how clear it would be that this kid is the number one thing in my life and, you know, all that. Anything else can change and that is fine. And I'll do what it takes to keep that relationship good and strong. Like, right now I basically, I feel like I'm an awesome mother and, like, really mediocre grad student. And feeling okay being a mediocre grad student is very new and kind of crazy.

Even the students who did not have children were already concerned about how they were going to navigate between career demands and their future role as mothers, particularly those students who were considering time intensive careers such as tenure track professorships. Several participants shared a willingness to give up opportunities for career advancement and settle for less demanding, more stable, or part time jobs to allow for more time to spend with their children or increased life balance, as explained by this Asian student:

> …for example, without a child I can work ten hours a day but if I have a child I can just work eight hours for the company. And I think I will lose some opportunities for promotions. But that's ok…I want a happy family and if my career's not so bad it's ok. I can endure that.

Academic Challenges

The socially-based expectations, assumptions and judgments described above provide a broad context that affected the experiences of all the women we interviewed.

Within this broad context, participants also faced challenges within a narrower academic realm. Both U.S. and Asian participants talked about academic challenges including research difficulties, academic requirements, lack of academic preparation, and limited resources. It is possible that some of these challenges would be shared by male engineering students, but it is important to consider how women may respond differently to these challenges, given the additional context provided by the social gender biases they constantly faced.

Research Difficulties

Research difficulties were discussed only at the graduate level. U.S. students talked about the challenge of completing independent research projects, including not knowing what research to pursue or choosing a research direction that was not productive. They also discussed difficulties with advisors (i.e., advisor not getting tenure, tension with an advisor, or lack of good advising), as well as simultaneously balancing the demands of many projects and adjusting to being a more independent researcher (i.e., learning to be more self-motivated, and making decisions about research with minimal input from advisor). The Asian students talked about the same set of research challenges, though none of these participants reported problems with their academic advisors.

Academic Requirements

Both U.S. and Asian students talked about the challenge of fulfilling academic requirements. Specifically, U.S. participants talked about having to take certain classes that were difficult or that they did not enjoy in order to complete the engineering major, and the challenge of passing qualifying exams in order to advance to Ph.D. candidacy. Asian students also talked about the challenge of having to take specific classes that they

did not enjoy along their educational path towards becoming an engineer, but had the additional challenge of having to get high scores on difficult national exams in order to be admitted into engineering school at the undergraduate level. For example, one participant described her undergraduate experience as follows:

> My first year in Bachelor's degree in India, it was really tough. It was quite different from what we were doing till then, and I had no idea what I am doing…And so I really thought I wouldn't get an engineering degree at that time. Really thought I would go -- I would not pass any of those exams.

Lack of Preparation

Although most participants felt prepared for their engineering graduate programs, some U.S. and Asian students talked about facing additional challenges because they had missed out on some educational aspects during their high school or undergraduate education, or because they felt they had less experience with hands-on or mechanical work. For example, one U.S. student talked about how she realized that she learned differently than the men in her class, and explained this by telling herself, "Well yeah, if I had taken apart lots of cars growing up maybe I'd have a better intuitive sense for this, and I don't have an intuitive sense and so now it's like trying to get intuition from nowhere." Similarly, one Asian student commented on her lack of practical experience compared to her classmates saying:

> I did pretty good in all the classes, but then again I didn't have that much of experience like them -- like in doing experiments, or working on the field, practical, that kind of stuff. So. And I kind of feel like I'm weak in that part.

Limited Resources

Both U.S. and Asian participants described difficulty getting access to financial and informational resources that they needed to receive in order to continue their

engineering education. Additionally, Asian students talked about challenges related to their visa status that created uncertainty about their ability to continue as students in U.S. engineering doctoral programs.

Financial. U.S. students talked about the challenge of securing funding to support their research and education, the uncertainty of not knowing whether they would have the financial support they needed to complete their education, and the debt they accrued throughout this process. One U.S. student described the effect this had on her long-term career plans, including plans for caregiving once she and her husband had children:

> …when he was in school it was a little bit different. You know, initially he was like, "Yeah, maybe I'll stay home for a while," and whatever else. But then once the reality came down to it that we were going to have all this debt and he was going to make more money than I would, you know. Then -- so that's kind of where the economic comes back in too.

Asian students talked about the same challenges, as well as the high cost of education in the U.S. compared to their home countries and differences in the financial aid available to international versus U.S. students. As one student described it, "I always wanted to come to the U.S. but the financial aspect was a huge consideration."

Informational. In terms of informational resources, some U.S. students talked about how they would have benefited from more engineering-related informational resources in various forms, including information about departmental resources, the benefit of getting a Ph.D., less traditional engineering fields, and engineering graduate programs in specific fields. As on participant who was interested in engineering careers with a humanitarian focus put it:

> …as an undergraduate there were no resources. And there were no models that I found. Certainly if I'd known how to look better and the internet was more

> advanced at that point, I would've been more aware of it. But, there was nothing and so basically that dream died. And then I fought to bring it back.

This theme was only identified by one Asian participant, who reported not knowing what engineers do on a day to day basis in areas outside of academia, and noted that she was aware of a much narrower range of career options before coming to the U.S.

Visa. The limited availability of student visas for study in the U.S. was described as a major challenge by several Asian students. These students described a range of challenges related to obtaining and maintaining the proper visa status, including coping with the uncertainty of not knowing whether a visa application or renewal would be approved, having to think carefully about timing in order to navigate the complicated system and ensure that they always had the proper visa, and dealing with delays related to visa complications. Depending on the country they were from, getting approval for a visa posed huge challenges to some students, as described by this participant from India:

> And grad school, the thing that becomes an issue is your research. They want to make sure it's not like terrorist…So it's kind of interesting 'cause you have to prove to them that you're not doing anything terrorist-related, and you have to prove to them that you're going to come back [to India], at the same time prove to them that you're not going to come back and use what you learned against the U.S. So it's just...so I got stuck with that last year when I went to renew my visa…So despite getting admissions, despite everything being done, I always had like a backup second plan that in case I don't [get a] visa, what am I going to do.

Psychological Struggles

The themes in this category represent psychological challenges that are likely to be the internalized reflection of the gender biased social messages these women have received, as described in the *Social Gender Biases* section. The emergence of these themes is important as it reflects how deeply these women have been impacted by the

sociocultural context that constantly surrounds them; that is, their challenges to persistence were not only external, but were generated by internalized messages and self-doubts as well. Two major themes emerged: 1) internalized gender biases and 2) defining personal expectations.

Internalized Gender Biases

Internalized gender expectations include those themes that appear to reflect participants' internalization of dominant beliefs, expectations, and biases about the responsibilities and abilities of women in general and women in engineering in particular. This internalization of gender expectations is illustrated in the following statement by a U.S. student:

> I want everyone to be okay. I want people to think that I'm doing a good job, but not only at my job. I want to be a good wife. I want to take care of the house. And so my biggest challenge is: don't quit school. Don't quit and let the stress get to you.

As this statement illustrates, women's internalized expectations of what they should be able to accomplish can create difficulties when they find themselves struggling to balance all of these competing demands. More specifically, these internalized beliefs most often emerged in women's discussion of three themes: low self-efficacy, self-silencing, and guilt.

Low Self-efficacy

U.S. and Asian students reported struggling with low self-efficacy beliefs that made them question whether they could be successful as students and engineers. In particular, they reported being unsure of their abilities, wondering if they deserved to be in their programs, and being unsure about passing graduate qualifying exams. For example, one U.S. student talked about a discussion with her undergraduate advisor after

he pointed out the steady improvement in her work and recommended that she pursue a graduate degree:

> And I was like, "Yeah, that's true but I'm very average. They're not going to let me into grad school. They don't let average people into grad school." And, he was like, "You're not average." And I was like, "I think I'm average."

Asian students reported similar concerns, as well as doubts about their abilities to pass rigorous national exams before the graduate level. The internalization of social beliefs about the lower engineering abilities of women was poignantly described by one U.S. participant, who noted that after years of interacting primarily with other male engineers she even found herself feeling some prejudice against female engineers:

> I feel like in some ways -- okay this is a little bit bizarre, and I can't believe it didn't come up before but -- I got kind of misogynistic when I came to [school name]. And I'm still struggling with it and it's actually something that my female friends here have noticed too…I can hear it kind of in the back of my brain…I notice women and I'm skeptical of them in some ways. Now that maybe I'm not around as many of them. Um…that's weird.

Self-Silencing

Another internalized struggle described by both U.S. and Asian students was a tendency towards self-silencing, which included difficulty discussing needs or accomplishments. Both U.S. and Asian students talked about difficulty asking for engineering help, as well as difficulty asserting themselves in personal contexts relevant to their persistence. For some students, this difficulty was specifically related to gender expectations. For example, one U.S. participant talked about how difficult it was for her to discuss her ideas about possible future career plans with her partner, because she was concerned about constraining his future choices:

> …I feel like I always want to be careful, you know, like, women are pushy, right? Bad women or bad girlfriends are pushy and they're always making you do stuff

> you don't want to do. And so I feel like a lot of women are very conscious to try to not be pushy and demanding about things.

Guilt

In addition to having difficulty asserting their own needs, a few U.S. and Asian students reported feeling guilty because they were not taking care of others properly. This psychological struggle was closely tied to the previously described negotiation of gender expectations with respect to relational responsibilities. In particular, a few women talked about how the difficulty of trying to manage multiple time demands was compounded by an internal sense of guilt at being unable to meet these demands according to their own internal standards. As one Asian participant described:

> There is no time for anything or everything. Weekends are busier than weekdays kind of thing…So my house is never clean. So that is kind of -- you feel so bad that it's never clean, kind of…And then you worry that it's the lack of cleanliness that is causing sickness or something.

Defining Personal Expectations

The themes related to defining personal expectations that emerged from the interviews reflect U.S. and Asian participant's struggles to define themselves and their personal and professional roles. Although more abstract than the other themes described by participants, this struggle for self-definition was of primary concern for several U.S. participants, who identified it as the most significant challenge to engineering persistence that they had faced.

Career Uncertainty

Both U.S. and Asian students reported feelings of career uncertainty or ambivalence as they tried to define their academic or career paths, research interests, and professional priorities. As described by one U.S. participant who was thinking of

switching career paths after completing her engineering doctoral degree, "I don't know that I'm really changing careers as much as I feel like I never really knew where I was going to begin with and that I was kind of on this default path." For many participants, addressing this question of professional priorities and goals was an ongoing process, as explained by this Asian participant:

> …my career choices is not as explicit…You know, I don't have something specific in mind. I know of peers who [are] like, "I'm gonna be the next president or researcher," or they know exactly what they want and they're going for that. But I don't think I have that in mind yet.

Identity Confusion

U.S. participants also described struggling with the process of self definition in a broader sense. That is, in addition to the previously described challenge of uncertainty related to their career goals, some U.S. students described struggling with a more existential type of self discovery, revolving around the central question, "Who am I?" More specifically, U.S. participants discussed challenges related to defining their roles in life and finding meaning in what they do, as well as discovering how their personal identities fit with social and family expectations. As one U.S. participant described her struggle to persist in her engineering doctoral program:

> …really for me it was kind of a major identity issue. And…it seems to be the case for my female friends who are in this field. Most of what the struggle is, is identity struggles.

Similarly, other U.S. participants described struggling with questions such as "How am I going to define my graduate experience?" and "Why am I here?"

Readjusting Expectations

Finally, a few U.S. participants talked about having to modify some of their learned professional expectations in response to their lived experiences. This included accepting that many people are not actually comfortable with women as engineers despite being told that women can "do anything," finding research to be tedious despite an expectation that it would be "glorious," and feeling disappointed in themselves for not feeling passionate about their work. As one participant described it:

> …so for me the biggest thing about graduate school was the rupturing of the kind of intellectual passion myth that I feel like I grew up with, which is that successful people have an intellectual passion…and we all thought that. This is what comes out of every conversation I have with women grad students who hate what they're doing and feel incredibly disappointed with themselves. It's 'cause we thought we had intellectual passion. And we came to grad school and we hated it and then it was like, "Well what's the point? What is the point of me, I am a failure."

As this participant went on to describe, the challenge to persistence for these women was not just in recognizing the discrepancy between what they had believed and the reality that they experienced, but also in finding a way to adjust to this discrepancy without feeling so disillusioned that they abandoned an engineering career path altogether:

> But realizing that there is maybe no such thing [as intellectual passion] necessarily, for me…so now my new role models are these people who kind of realize that, and who allow themselves to be in careers that, you know, satisfy maybe nine of their ten criteria. Or seven of their ten. And the other three they just get over and they kind of fill out the rest of their lives.

In other words, this process of self-definition may require participants to internally recreate a more realistic professional image that is both personally acceptable and consistent with the world that they experience as students and engineers.

DISCUSSION

The challenges described by female doctoral students in the present study are consistent with previous research on undergraduate women in engineering. Thus, our results extend these findings to a sample of female doctoral students, showing that they faced similar challenges on their engineering educational paths despite their persistence to the doctoral level. For example, consistent with our findings, past studies have shown that female undergraduates experienced gender biases in their social environment that included a sense of isolation or lack of support (Brainard & Carlin, 1998; Marra et al., 2009; Wentling & Camacho, 2008). There is also evidence that undergraduate women often struggle to maintain a sense of engineering self-efficacy (Brainard & Carlin, 1998; Felder et al., 1995; Hutchinson-Green et al., 2008; Vogt et al., 2007), and to define their identity as women in a male-dominated environment (Powell et al., 2009). Additionally, previous research has shown that a lack of information about humanitarian applications of engineering education, as well as perceptions of the incompatibility of graduate-level science and engineer careers and motherhood, may be barriers to engineering educational persistence (Sax, 2001; Xie & Shauman, 2003).

This study expands on past findings not only by showing that these challenges also apply to women at the doctoral level, but also by showing that any of these challenges in isolation may not be sufficient to deter a women from persisting on an engineering educational path. That is, the women in this study all had successfully completed the first few years of a doctoral program, and yet as a group they described encountering all the challenges that previous literature has identified as possible explanations for women's under-representation in engineering higher education. Given

the resiliency these women demonstrated in the face of challenges, it seems possible that the critical question is not, "What challenges are missing from the literature?" but "How can we understand the variable impact of these challenges?"

In answer to this question, the results of the present study indicate that challenges occur at multiple levels, with no single challenge or combination of challenges evoking the same reaction in any given individual. Many previous studies have focused on only a limited subset of challenges women face, or have focused on either the social context or the internal consequences of this context in terms of women's attributions. It is not surprising that such studies have found that, although women often are significantly impacted by the challenges that are any given study's focus, these challenges provide only a partial explanation for their persistence or attrition. It may be necessary to take a more holistic approach to understanding women's under-representation in engineering, that is, an approach that integrates challenges from many different sources and emphasizes the importance of considering these factors as a complex, interacting system.

As part of taking a more holistic approach to understanding women's under-representation in doctoral level engineering programs and careers, the present study included a comparison of U.S. and Asian participants. Such comparisons are important to better understanding how participants' intersecting identities as women and members of a given culture may influence the factors they identify as important challenges or barriers to their persistence. The themes that emerged from interviews with the 16 participants in the present study indicate that there is a large degree of overlap in the challenges faced by U.S. and Asian doctoral students in engineering. More specifically, all the themes identified in this study were described by both U.S. and Asian participants, with the

exception of the themes of *Value Differences*, *Identity Confusion*, and *Readjusting Expectations*, which were only discussed by U.S. participants, and the themes of *Acculturation Challenges* and *Visa Challenges*, which were only discussed by Asian participants. These differences are discussed in more detail below. However, these differences do not reflect the full impact of cultural influences on our study participants. Importantly, one of the major themes identified by both U.S. and Asian participants was *Social Gender Biases*. These culturally mediated biases varied in terms of how they were experienced (e.g., Asian students spoke more about overtly gender-based hiring biases), but reflected the same broad themes (i.e., *Social Stigma*, *Professional Gender Biases*, *Social Isolation*, and *Negotiating Gender Expectations*). Thus, there were broad challenges that were shared across cultures by the participants in the present study, but understanding the exact nature and impact of these challenges requires closer attention to the intersections of identity that characterize each individual. The following sections provide a more in depth exploration of the challenges that were shared across cultures, as well as the complex intersections of identities that affected the impact of these challenges.

Contextual Framework I: Social Gender Biases

"To be an engineer is prestigious, but a woman engineer, I'm not quite sure."

Overall, the themes that emerged from the present study paint a picture of a society that is generally not overtly hostile towards women in engineering, and may on the surface even be vocal in encouraging women's participation in this field. However, many of the stories of the women in this study contradict this apparent acceptance of women into the engineering field, by describing how women are invited to be engineers *if*

they can comfortably exist an environment where they are often still perceived as outsiders and *if* they can take on these professional responsibilities while still gracefully fulfilling unrealistic social expectations accompanying their roles as women, daughters, wives, and mothers. These women are therefore left struggling with the discrepancy between the visible encouragement of women in engineering and the biases they encounter in their lived experiences, often assuming that if they are unable to find success it must be a reflection of their personal shortcomings.

The results of the present study also indicate that this pattern is not unique to women who grew up in the U.S., as the narratives of both Asian foreign national participants and U.S. participants of European American descent included themes related to social gender biases. This is supported by a recent study of female science and engineering doctoral students in India, which found that these women were disadvantaged due to negative gender stereotypes about women in science. That study's author further argued that culturally based gender norms related to the historical position of women in Indian society created challenges that were distinct from the challenges faced by women in Western cultures (Gupta, 2007). Thus, understanding the challenges faced by female engineering doctoral students in the U.S. requires careful attention to such cultural differences, while acknowledging that some challenges may be shared by women regardless of their national background.

For example, previous studies on science and engineering undergraduates have identified social isolation as a challenge to persistence (Brainard & Carlin, 1998; Marra et al., 2009; Wentling & Camacho, 2008). Given the socially pervasive negative stereotypes and perceived lack of acceptance described by female doctoral students in the present

study, it is not surprising that our study participants also described feeling socially isolated from their professors and peers. Both U.S. and Asian students identified a lack of female role models that made it difficult to envision the future they wanted for themselves. However, results also highlighted a difference between U.S. and Asian participants, in that U.S. participants perceived a difference between their life values and those of the people they commonly interacted with in their professional lives that was not discussed by Asian participants, while some Asian participants discussed acculturation challenges that made it more difficult for them to connect with professors and peers. Consistent with the report of this latter subset of students, a recent study of Asian international students enrolled in graduate programs at universities in the U.S. found that they struggled with communication and social connection with European American peers (Sato & Hodge, 2009). Thus, interventions aimed at increasing access to role models may be beneficial to both U.S. and Asian doctoral students; however, U.S. students might additionally benefit from interventions aimed at identifying and connecting them with other female students and professors who may be more likely to share their values, while some Asian students might benefit from interventions designed to improve communication skills and increase social connection with U.S. peers.

The narratives of the women in the present study also provide clues as to why women in engineering continue to be so strongly under-represented, in contrast with women in other demanding scientific professional roles such as nursing and medicine (Bell et al., 2006). The themes that emerged from these interviews revealed how pursuing an educational and career path in engineering requires constant renegotiation of socially derived expectations related to participants' roles and responsibilities as women, as well

as an ability to tolerate an environment in which they may feel stigmatized, isolated, and discriminated against. Thus, it seems possible that women in engineering doctoral programs face many of the same challenges as women in other demanding professional positions with respect to renegotiating their professional and family responsibilities, but these professional demands may be more likely to lead to career change because they are overlaid upon an additional level of challenges related to the male-dominated culture of engineering. Further research is needed to explore this possibility and to explore how multiple challenges may interact for women in engineering as compared to women in other demanding professions.

Contextual Framework II: Academic Challenges

"*My project...sometimes gets to me so much that I just want to quit.*"

On a more narrowly focused scale, the stories shared by the participants in the present study also create a contextual framework for their inner experiences by highlighting academic difficulties that have directly challenged their ability to continue on their educational path. The actual impact of these challenges is likely to be minimized in this study sample, given that it consists of students who already completed several years of an engineering doctoral program. As such, the academic difficulties described by both U.S. and Asian study participants focused primarily on academic challenges that they had successfully overcome earlier in their academic careers. Given the lack of previous research on female doctoral students' persistence, it is impossible to estimate the impact these challenges may have on women who do not persist to this level. However, it possible that the impact of these academic challenges could be much larger for students who have fewer support structures to counteract their influences.

Similarly, the students in the present study cited financial challenges but did not describe these as serious threats to persistence. However, it is interesting to note that every student in this study sample self-identified as middle class, and many described an awareness of the privilege associated with their backgrounds. Future research should incorporate participants from a broader range of socioeconomic backgrounds, to examine how this impacts persistence. It is likely that students from a lower socioeconomic level might experience more significant challenges due to a lack of economic and informational resources (Foor, Walden, & Trytten, 2007), and the visa challenges described by Asian participants in our study might be insurmountable for students who do not have the financial backing to support a U.S. student visa application. The impact of socioeconomic status may also be culturally driven. For example, female science and engineering doctoral students in India have been found to come from a higher socioeconomic background than their male counterparts, which may be because more economically advantaged families are more willing or able to provide their daughters with higher education in science and engineering (Gupta, 2007).

Psychological Struggles I: Internalized Gender Biases

"Am I supposed to be here? Did I deserve to get in?"

The internalized struggles described by participants in the present study are easily understood when they are examined within this complex contextual framework. For example, given our participants' descriptions of a sociocultural environment in which their competence and sense of belonging in engineering are frequently challenged, it is not surprising that previous studies of female engineering undergraduates have found that they often struggle with low self-efficacy with respect to their ability to succeed on an

engineering educational path (Besterfield-Sacre, Moreno, Shuman, & Atman, 2001; Brainard & Carlin, 1998; Felder et al., 1995; Hutchinson-Green et al., 2008; Marra et al., 2009; Vogt et al., 2007). Consistent with these studies, both U.S. and Asian participants in the current study discussed low self-efficacy beliefs related to engineering that had challenged their persistence at some points along their educational paths, though many of the doctoral candidates in this study had eventually overcome these academic self-doubts.

Additionally, both U.S. and Asian participants in the present study discussed feelings of guilt that challenged their persistence on an engineering educational and career path. This guilt was described in contexts in which the women found themselves caught in a double bind, unable to simultaneously attend to the demands of graduate school and family to a degree that they considered acceptable. Participants also described a tendency towards self-silencing, which may be related to another double bind, in which women find themselves in positions of power that require them to assert themselves, but they are disliked and labeled as aggressive and not feminine when they do so (Crawford & Unger, 2004). In short, many of the psychological struggles described by our study participants appear to be connected with social expectations that they have internalized as women in a given cultural context.

Internalized Struggles II: Defining Personal Expectations

"*Most of what the struggle is, is identity struggles.*"

Many of our study participants emphasized an ongoing struggle to define their career goals. It was not uncommon for U.S. participants to have considered a career shift or discontinuation of further education at some point during their engineering education, and several participants were still considering or planning to pursue a career that was

only tangentially related to engineering after completing their engineering doctoral degree. The undergraduate educational structure described by most Asian participants afforded fewer opportunities for career change, but even these participants described struggling to define their professional identities and considering fields outside of engineering. Again, such ambivalence must be considered in the culturally mediated social context described previously, in which pursuing an engineering career may involve defying culturally normative expectations about women's roles and responsibilities.

For the U.S. women, this process of defining their personal expectations not only involved exploration of what career they wanted to pursue professionally, but also focused on a more personal search for professional meaning. Similar identity-related struggles have been previously described for undergraduate and professional women in the U.S. and Australia, who felt caught between conflicting roles as professionals in a "masculine" profession and as women (Gill, Mills, Franzway, & Sharp, 2008; Powell et al., 2009). The women in the present study struggled to negotiate a balance between social expectations and personal priorities, and to reconcile the encouragement they had received to pursue an engineering career with the subtle discouragement that was often part of their lived realities. With few role models to guide them, the identity challenge they described was the challenge of inventing a version of themselves that could move between multiple roles and environments, and of coming to terms with the limitations this imposed on their ability immerse themselves fully in any given role.

Implications and Conclusion

The narratives of the 16 women in this study illustrate the complexity of the challenges faced by women who pursue doctoral-level engineering careers. The stories

are specific to each individual, yet the study participants were deliberately selected to represent some of the diversity that is present in this population: Asian and U.S. students, students from a prestigious private school and students from a state land grant university, married students with children and students who were not in a committed relationship. This methodology allowed us to capitalize on the rich understanding of participants' experiences that can only be obtained through qualitative analysis, while simultaneously capturing the breadth of experiences that is essential for an exploratory study like this one.

This study highlights the importance of considering the social context within which women encounter specific challenges, and the degree to which they have internalized the values and expectations associated with this contextual framework. It is possible that previous quantitative studies have been unable to fully explain women's under-representation in engineering because they did not capture the complex web of interactions that determine the impact of any given challenge. Quantitative studies may be too limited in the number of variables and interactions that they can realistically assess, while qualitative studies create opportunities for the discovery of new and more complex variables and permit a richer exploration of women's lived experiences (Sax, 2001). For example, academic challenges that may seem trivial in the abstract could have a more significant impact when they are presented in a context in which women already feel isolated, stigmatized, uncertain of their abilities, and guilty about failing to live up to external or internalized expectations in other life arenas. The exact nature of the societal messages each individual receives will also vary depending on the intersections of identity associated with each individual. By using qualitative methodologies to explore

the impact of specific challenges in the context of different cultural identities, as in the comparison of U.S. and Asian participants that was a focus of this study, we can begin to build a better picture of how these factors interact, which can inform future interventions.

The results of this study indicate that interventions to encourage the persistence of women in engineering should be targeted at multiple levels, while attending to cultural differences that may be salient at each level. On the level of social gender biases, the lack of available female role models was discussed as an important concern for both U.S. and Asian participants in the present study. One possible intervention to help address this problem was highlighted by the narrative of one Indian study participant, who talked about the important role the media in her country played in sharing inspirational success stories highlighting the accomplishments of women in certain career fields. Academic challenges may present the easiest opening for interventions, both by providing additional financial resources and by providing opportunities for students to receive information on key areas that our study participants identified as important (e.g., humanitarian job opportunities, balancing work and family, academic communication skills for foreign nationals). Finally, the internalized struggles that women in engineering often face should be acknowledged and resources should be provided to help address these struggles, both in the form of opportunities to build social connections with other women who may face similar struggles, and by normalizing and providing information on professional counseling resources that students can turn to for support outside of their academic community. It is our hope that by simultaneously targeting interventions at multiple levels, educators can more effectively reduce the challenges these women face.

Ultimately, however, women are likely to continue to experience difficulties until the social biases that underlie so many of their struggles are challenged and addressed.

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Table 1

Summary of Descriptive Themes for Factors Challenging Persistence

	Contextual Framework
Social Gender Biases	
	Social Stigma
	Professional Gender Biases
	Social Isolation
	Limited Role Models
	Value Differences (U.S. ONLY)
	Acculturation Challenges (ASIAN ONLY)
	Negotiating Gender Expectations
	Family Expectations
	Negotiating Relational Responsibilities
	Negotiating Career Priorities
Academic Challenges	
	Research Difficulties
	Academic Requirements
	Lack of Preparation
	Limited Resources
	Financial
	Informational
	Visa (ASIAN ONLY)
	Psychological Struggles
Internalized Gender Biases	
	Low Self-Efficacy
	Self-Silencing
	Guilt
Defining Personal Expectations	
	Career Uncertainty
	Identity Confusion (U.S. ONLY)
	Readjusting Expectations (U.S. ONLY)

CHAPTER 2

Understanding Women's Persistence in Engineering: European American and Asian Foreign National Doctoral Students Explain Their Educational Commitment

An examination of long-term trends in the proportionate representation of women among engineering students indicates that their representation tends to remain stable or even increase slightly from the bachelor's to the master's level, but then decreases again among students earning doctorates (ASEE, 2009; Bell, Di Fabio, & Frehill, 2006). In 2008, women earned only 21.1% of doctoral degrees in engineering (ASEE, 2009). Given that women currently represent almost 50% of the overall labor force in the U.S. (Bell et al., 2006) and science and engineering degree production has failed to keep up with job growth in these fields over the past five decades (National Science Board, 2006), there is a growing need to address the under-representation of women in this field, particularly at the doctoral level where they are most under-represented.

Previous Research on Women's Engineering Persistence

Persistence to a doctoral level of engineering education involves a series of decision points that occur after the initial choice to pursue engineering education. A student can make the decision to leave an engineering educational path at any time, though losses tend to be higher at certain key transition points. For example, studies have shown that a substantial proportion of both women and men decide not to pursue a career

in science or engineering, let alone pursue higher engineering education, following completion of their undergraduate science or engineering degrees (Lichtenstein et al., 2009; Sax, 2001). Additionally, attrition rates from doctoral programs after enrollment can be quite high, with one study indicating that attrition rates around 50% are not uncommon for women and men in science and engineering doctoral programs (Hollenshead, Wenzel, Lazarus, & Nair, 1996). Furthermore, even in studies showing similar persistence rates for men and women at the transition from undergraduate to graduate engineering programs (Sax, 2001) or the period from graduate engineering enrollment to commencement (Hosoi, 2006), there is some evidence that the factors influencing persistence differ for women and men. Some researchers have argued that the organizational culture of engineering is inhospitable to women, because there is a cultural assumption that engineering is a profession that is better suited to "masculine" individuals (de Pillis & de Pillis, 2008). The women who manage to persist and succeed in this culture may therefore possess unique protective factors, and understanding these factors is important to developing more effective programming to support women in engineering.

Previous studies on factors supporting women's persistence following their choice to major in engineering have focused primarily on undergraduates. A recent qualitative study of undergraduate students identified involvement in campus student organizations, professors' dedication to their classes and students, enjoyment of engineering classes, good performance in engineering classes, and peer support as key support factors for undergraduate women in engineering (Wentling & Camacho, 2008). Additionally, relational supports such as mentors and role models have been shown to be

developmentally important for undergraduates (Downing, Crosby, & Blake-Beard, 2005). Other important influences on undergraduate women's persistence that have been identified in past studies include aptitude and self-efficacy (Jackson, 2004; Sax, 2001; Schaefers, Epperson, & Nauta, 1997; Wentling & Camacho, 2008), with individuals who persist in engineering being more likely to attribute their academic successes to their own efforts than individuals who leave engineering majors (Nauta, Epperson, & Waggoner, 1999). It remains unclear, however, to what degree these factors or other factors impact women at higher levels of educational attainment.

Very few studies have examined gender-specific factors influencing women's persistence in engineering programs beyond the undergraduate level. One exception was a quantitative survey analysis of undergraduate science, math, and engineering (SME) majors, which found that the factors supporting pursuit of SME graduate degrees by both men and women included good grades, spending time with faculty, a sense of commitment to making a theoretical contribution to science, and the positive effects of having a peer group that valued science, with the last factor influencing women much more strongly than men (Sax, 2001). However, this study did not separate out graduate programs in engineering from other science programs or explore persistence after graduate enrollment. Furthermore, the researchers highlighted the fact that using quantitative methods they were only able to account for 20% of the variance in graduate enrollment. Qualitative interview research is important to filling this gap in our understanding because it allows researchers to inductively identify factors supporting persistence based on participants' own perceptions of their experiences, rather than forcing participants to choose from a set of options identified by the researchers (Willig,

2001). This promotes exploration of factors that may not have been previously considered as potentially impacting persistence, which therefore would not be captured using quantitative survey methodologies.

Diversity Among Doctoral Level Engineering Students

The field of engineering is diverse in terms of the national and ethnic backgrounds of doctoral level engineers. In 2003-4, 57.2% of engineering doctoral recipients in the U.S. were foreign nationals with temporary visas (Babco & Bell, 2004). The large influx of foreign national students into doctoral engineering programs in the U.S. provides a rich opportunity to explore how differences in cultural background may impact engineering persistence. This cultural diversity has been largely overlooked in the literature on women's under-representation in higher level engineering education (for exceptions see Barinaga, 1994; Gupta, Kemelgor, Fuchs, & Etzkowitz, 2005; Sharma, 1994), with most previous studies implicitly assuming that the factors promoting the persistence of women in engineering are culturally invariable. This is a highly questionable assumption, because it is becoming increasingly clear that the experiences of women in science and engineering take place within a historical and sociocultural context, which includes variables such as the status of women in science and society, and the status of engineering as a career field within a given country (Barinaga, 1994; Gupta, 2007). This context does not become irrelevant when an individual currently is attending a U.S. university. In fact, a recent study found that over half of the variation in the size of the gender gap in employment observed among first generation immigrants in the U.S. was accounted for by labor force participation rates in their home countries (Antecol, 2000). This indicates that cultural values continue to have an important influence on

immigrant women's career trajectories, even after they have physically relocated to the U.S.

One recent study combining quantitative and qualitative methodologies did focus on the intersection of gender and ethnicity among female engineering students at the undergraduate level. This study found that the Asian, Hispanic, European American, and African American students all shared a sense of belonging and a perception that they had a strong social support system, but there were differences between groups in some of the factors motivating their persistence. The major observed difference between Asian and European American students was that Asian students reported a culturally-based expectation that they pursue a professional career such as engineering, though differences in levels of parental education and expectations were observed between different Asian subcultures (Trenor, Yu, Waight, Zerda, & Sha, 2008). It might be expected that differences in motivation and support structures would be even more pronounced between European American students from the U.S. and Asian students who were foreign nationals because of the larger cultural differences between these groups, but no studies to date have made this comparison.

Research Questions

The present study was designed to address these gaps in our understanding of women's under-representation in engineering through exploratory analysis of interviews in which participants provided narrative descriptions of factors supporting their educational persistence to the doctoral level. In contrast to quantitative studies, in which a theoretical framework is critical in the early identification of hypotheses and experimental design, this study adopted an inductive approach to data analysis. This

approach required that such theoretical frameworks were only examined after data analysis, to allow for the possible identification of new phenomena and insights from a fresh perspective (Borrego, Douglas, & Amelink, 2009).

The study sample included participants from two geographic regions and two U.S. universities, in order to increase the potential range of experiences described in interviews and thus, the potential to capture themes that might not be observed in a more homogeneous group of individuals. The Asian countries represented in our sample included China, India, Korea, Taiwan and Singapore, with the first four of these countries being the countries that are most heavily represented among Asian foreign nationals in doctoral engineering programs in the U.S. (Hoffer et al., 2004). This exploratory study examined the factors that contributed to persistence on an engineering educational path, defining "persistence" as beginning after the initial selection of this discipline and continuing to the present (i.e., several years into a doctoral program for the participants in this study). Interviews were analyzed with respect to two research questions: 1) What are the factors that female doctoral students in engineering identify as promoting their persistence on an engineering career path and 2) how are these factors similar and/or different for U.S. students of European American descent versus Asian foreign nationals?

METHODS

Participants

The interview participants for this study consisted of 10 female students enrolled in engineering doctoral programs at a Private Science and Technology University (PSTU) and six female students enrolled in engineering doctoral programs at a State Land Grant University (SLGU). Ten participants were U.S. citizens with a European American

background, and six participants were foreign nationals from five Asian countries (Korea, China, India, Taiwan, and Singapore). The departments of Civil, Environmental and Geological Engineering; Biological Engineering; Mechanical Engineering; and Electrical and Computer Engineering were represented in both the U.S. and Asian groups. The U.S. group also included one student from the department of Material Science and Engineering. U.S. and Asian participants were similar in terms of other demographic measures. The average age of the U.S. students was 27.5 years, compared to 27.0 years for the Asian students. Two of the U.S. students identified as "single," three as "in a committed relationship," and five as "married." Similarly, two of the Asian students identified as "single," two as "in a committed relationship," and two as "married." Among the married students, two U.S. students and two Asian students either had a child or reported that they were actively trying to have a child. At the time of the interview, the U.S. and Asian students had completed 4.4 and 3.8 years of graduate school, respectively, including time spent earning a prior master's degree, where applicable.

Procedures

Before beginning participant recruitment, approval for the study was obtained through the human research review boards at PSTU and SLGU. Participants were recruited with the assistance of campus groups that provided support for female graduate students and women in science, as well as engineering professors, advisors, and staff who informed students of this research via email and word of mouth. Each individual who agreed to participate in the study was sent a demographic form which included questions about her educational history, national background, ethnicity, and romantic relationships

(Appendix A). To allow the participants to maintain anonymity, each participant was also assigned a random number for identification purposes.

All interviews were conducted in a private room on the campus of SLGU or PSTU, between October 2007 and December 2008. Interviews were tape recorded with participant consent, and lasted from 62 to 98 min (mean = 78 min) with an additional 30 minutes preceding the interview to complete a consent form for participation (Appendix B) and review demographic paperwork. All interviews followed a semi-structured protocol to explore the factors that the study participants identified as important to their persistence on an engineering educational path. This format was chosen to ensure that all participants were given the opportunity to address key research questions, while allowing the interviewer ample flexibility to ask follow up questions in order to explore emergent themes (Shah & Corley, 2006). Each interview began with a grand tour question (Fetterman, 1989), "What are the events in your life that led you to where you are now in your education and on your career path?" that was designed to gain a broad perspective on the participant's decision to pursue an advanced degree in engineering. This was followed by more specific questions, with follow-up questions guided by the participants' responses (Appendix C).

Data Analysis

Each interview was transcribed verbatim into a text document by a team of research assistants; transcripts were reviewed and edited by the lead researcher prior to coding, to compare the written document to the recording and ensure accuracy of the transcription. Ethnographic Content Analysis (ECA) was used as the framework for this study. This qualitative methodology uses the constant comparative method of analysis

and is ideal for an exploratory study like this one, in which documents are examined for thematic categories through a process of inductive analysis (Altheide, 1987; Willig, 2001).

Coding was completed by a six member female coding team, with the lead researcher's female dissertation advisor serving as the outside auditor and periodically attending team meetings to review the emerging coding structure and request justification of coding choices. Coding consisted of a multi-step process, in which team members identified segments of text that were of interest for analysis because they related to the research questions, assigned segments of text to specific categories based on shared themes, condensed these themes by combining them into broader categories, and created narrative explanations of these themes (Boeije, 2002; Krippendorff, 2004; Willig, 2001).

More specifically, all coding team members analyzed the first two transcripts of U.S. interviews individually. Each coder independently identified segments of text that they judged to be significantly related to the research questions, and created labels that were one to three words in length to categorize these segments. All categorized text segments were then compared and discussed at team meetings, until the team arrived at a consensus on categorical labels that most accurately represented the relevant text. During these meetings, the coding team also began grouping these emerging themes into broader categories based on shared characteristics, to form a preliminary coding structure (Boeije, 2002).

Pairs of team members then coded the remaining transcripts from U.S. participants, using the coding structure developed at the previous team meetings. As before, each member of the pair coded her assigned transcript independently before

meeting with the other pair member to compare coding and discuss any areas of disagreement. Any coding disagreements that were not easily resolved were discussed at meetings with the entire team. In these meetings, all team members also discussed any proposals to add new codes or rearrange existing codes based on new information that emerged from the data (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005).

The team followed a similar coding process for coding of all transcripts of Asian participants (i.e., each team member individually coded each of the first two interview transcripts and all coding decisions were reviewed as a team, before the remaining Asian interviews were analyzed in coding pairs). Rather than artificially creating new labels for themes that had already been identified in interviews with U.S. students, we continued to develop a single coding structure for both U.S. and Asian interview participants, adding new codes as needed. However, since a goal of this study was to examine similarities and differences in the factors promoting persistence in U.S. and Asian students, interviews from the two groups were analyzed separately during the final stages of analysis (see below). This allowed us to separately reexamine the thematic structure and labels we had created for each of the two groups, and revise the coding structure for each group as needed.

For the final stage of analysis, we used NVivo 8 software (QSR International) to separate the coded sections of text from U.S. versus Asian interviews. Pairs of team members reviewed the sections of text that supported each coding category, comparing sections of text from Asian versus U.S. interviews that were assigned the same category label or code. Each code was then defined by a sentence or two describing the characteristics that defined that theme and its relationship to the research questions; this

description could be the same for the Asian and U.S. interviews, or could elucidate aspects of the category that were unique to one of these two groups. The research team then met again to discuss the narrative descriptions they had created, and finalize any last changes to the coding structure as patterns in the data were clarified. This finalized set of themes, along with the narrative description of these themes and supporting quotations from the interview transcripts, comprise our research findings (Krippendorff, 2004).

Data Trustworthiness

Data trustworthiness was established through the use of analysis methodologies that demonstrated credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). Specifically, credibility was established by developing and supporting coding categories with direct reference to specific interview quotations. Transferability, which refers to the researchers' responsibility to provide information that will allow other researchers to determine to what extent study findings can be generalized, was addressed by providing detailed descriptions of the demographic parameters defining the data and by creating a detailed audit trail. This audit trail included a reflexive journal containing methodological notes, as well as observational notes taken immediately after each interview to create additional transparency about the interview process (Lincoln & Guba, 1985). Finally, dependability and confirmability were established through investigator triangulation, in which all coding was performed following a method that 1) involved independent coding of all transcripts by multiple researchers and 2) required all coding decisions to constantly be evaluated and defended at team meetings through direct reference to the interview data, with the end goal of reaching consensual validation on all coding decisions (Brantlinger et al., 2005; Creswell, 1998; Lincoln & Guba, 1985).

Additionally, researcher reflexivity was established through open discussion of the backgrounds and potential biases that all members of this culturally diverse coding team (Asian American, Italian, and European American) brought to the coding (Brantlinger et al., 2005).

RESULTS

The factors identified as promoting persistence on an engineering educational path fell into two broad categories: 1) external support of persistence and 2) internal motivations for persistence. External supports were people, experiences, or social structures that the participants described as directly supporting their persistence in engineering. In contrast, internal motivations for persistence were thoughts, beliefs, values, or personal characteristics that provided psychological support for persistence, by motivating a participant to continue on an engineering educational path. These two broad categories overlapped to some degree, that is, students were both directly supported by external factors and indirectly affected by how their experience with these support factors influenced them psychologically, by increasing their motivation to continue on their path to an engineering doctorate. Thus, though the categories are presented separately below for the sake of clarity, it is important to acknowledge that persistence in engineering was the result of a constant interplay between external factors and the psychological impact of these factors on the participants' internal motivation.

External Support of Persistence

Asian and U.S. participants discussed five major external factors that supported their persistence on an educational or career path related to engineering: inspirational contact, relational support, organizational resources, sociocultural advantages, and

chance. Table 1 summarizes these themes and their related subcategories, which are described in detail in the remainder of this section.

Inspirational Contact

Both U.S. and Asian women talked about contact with people and experiences that inspired them to persist on an engineering educational path in two contexts: 1) situations in which the participant had a positive experience in a professional role and 2) situations in which the participant observed others in a role they perceived as desirable.

Experiencing Desired Role

In terms of positive experiences with a desired professional role, U.S. participants explained that through teaching opportunities and experiences working in the field or laboratory they developed a passion for careers related to teaching or research in engineering. As one U.S. participant described her first teaching experience:

> …it was just so exciting to show them these things that I always thought were kind of cool, and then *they* would get excited. "Oh, this is amazing! This must be why people teach!"

Similarly, one Asian student talked about how a research position got her interested in returning to graduate school:

> Well, in between undergrad and grad school I did work for three years in the government…So, I guess those three years of work there exposed me to more on what research is about and all of that…and sort of what attracted me to go back to grad school, so.

Role Models

Although many participants discussed struggling to find role models in the engineering field, others identified specific inspirational individuals who influenced their persistence both through their exemplary actions in a given role and because they

demonstrated the success and life balance female engineers could achieve. For example, as one U.S. participant described:

> ...I think it is really important to have seen my old boss and how she runs things and how she balances things...I think it's good to see people who are actually, like, succeeding in having the balance between family and work and doing really good science and things like that.

Another Asian student described how women's participation in certain career fields was encouraged by the government and media in her country, by highlighting the accomplishments of certain women who could serve as role models:

> And every year our government will select excellent women in every field, like sciences, like policeman, in every field, ok? Oh, we will see, ah she's so good in that position. I think most of the role models is from the government selection and from media. And the T.V. I think the T.V. has great influence in our life.

Relational Support

Both U.S. and Asian participants also talked extensively about the importance of relationships with others in supporting their persistence. The four types of relational support that emerged from the interviews included: 1) emotional connection, 2) advice, 3) accommodating partnerships, and 4) social networks. Unlike the role models described above as part of the inspirational contact theme, relational support was based on direct interaction between individuals, rather than simple observation (though a relationship described by an individual could be coded under both themes, if it was described as important both in providing inspiration through observation and support through direct relational interactions). Because relational interactions are so pervasive and can take so many different forms, relational support was also the most complex and multifaceted of the major support themes that emerged from the interviews.

Emotional Connection

The theme of emotional connection was brought up by both U.S. and Asian participants, who talked about the importance of feeling supported and valued as an engineer, and being able to connect with others at a level that was not just professional but also personal. Participants described the importance of knowing people in the department and outside of school who were enjoyable to spend time with and who could relate to their educational experiences. They also talked about the importance of knowing people who they could communicate with honestly, and who would notice when they were struggling and provide assistance. This general sense of emotional connectedness was often more narrowly defined in terms of three ways of establishing this connection: shared values, shared experiences, or encouragement.

Both U. S. and Asian participants who described emotional connection through shared values talked about the support they experienced from having partners, friends, or mentors who understood them because they shared common viewpoints and priorities, or had similar interests and goals. For example, one U.S. participant described how she was affected by a difference she had observed between certain male professors who just wanted to "move people through the system" and the personal connection she felt with her female professors:

> And I don't know what it is but I guess just when I'm around those female professors I pay attention better too. Because it's like there's a caring, so if they care about me then I will actually care and listen to what they have to say.

Both U.S. and Asian participants also talked about a sense of emotional connection that was achieved by getting support from individuals who had experienced

similar things and could therefore relate to what they were going through. For example, one Asian participant spoke about her experience during her first year in graduate school:

> Well, there are two or three common courses that everyone has to take, so when you are admitted into that department all first year students take the same class the first semester, so everyone gets to know one another, like this is my batch, ya know, my year…so I think that helps to form friendships and working relationships.

Finally, several U.S. participants and one Asian participant also talked about the importance of being connected to individuals who provided encouragement of their engineering paths. This included showing faith in the participants' ability to succeed on these paths, and listening and providing non-judgmental empathic support when the participants were struggling. For example, one U.S. participant provided the following description of her parents:

> …they always told me I could do whatever I wanted and they really meant it and they really did celebrate, like, when I got an A in literature that was just as cool as an A in physics. But I did feel like my dad had a little bit of extra pride about the A in physics…and I could kinda sense that. But generally it was similar across the board…it was just this constant stream of, "Good job, keep up the good work."

Advice

The second major form of relational support that emerged from interviews with both Asian and U.S. participants was receiving direct advice from friends and mentors, primarily with respect to academics and life balance. Topics of academic advice included getting help with a particular research question, receiving advice on how to publish a paper or give a research presentation, getting suggestions on how to communicate effectively with mentors or peers, and making decisions related to graduate school. Academic communication issues appeared to be particularly salient for the Asian

participants. For example, one Asian participant described what she had learned about academic communication from a seminar offered by one of her professors:

> …communication is very important, so never assume that your professor wants this or that…Even for the thesis proposal some professors want it to be very long, some professor doesn't really care. And so it's good to always ask, ask directly. So, I think that's how I learn.

Interview participants also talked about academic advice they received in which they experienced pressure to pursue their education in engineering by others who did not want for them to quit. This pressure was described by both U.S. and Asian participants, for example, one U.S. participant laughingly recounted the story of how her advisor convinced her not to leave graduate school after earning her master's degree:

> ...he started prodding me, you know, like, "You should really get a Ph.D. It would be a *waste* for you not to get a Ph.D." You know, poke poke poke about how I should consider it…the way he put it was, "If you don't have a Ph.D. you'll always, someone else will always be your boss. And if you have a Ph.D. then everyone has to listen to you, 'cause that's what it means is that you know what you're doing."

Similar pressure to persist also came from individuals outside of academia, for example, one married Indian student described how extended family had impacted her educational persistence explaining, "My husband's family also has a very important say in [my studies]. Luckily I have a mother-in-law who likes everybody to study."

In addition to receiving academic advice on their career pathways, both U.S. and Asian participants talked about receiving advice from family, mentors, and friends on life balance, particularly on how to balance family and career. For example, one U.S. participant talked about receiving advice from a female relative who was a professor on when to have children:

> So I talked to her about that and she had had a lot of graduate students that had children while they were in school, and she said that would be a better time to do it than when you're on a tenure track position. 'Cause at least then by the time you're on a tenure track position your kids are a little bit older and, and things like that, so. And I had heard that from other people also, that that's kind of the better time to do it.

Accommodating Partnerships

For U.S. and Asian participants who were in committed relationships, their educational persistence was also supported by having partners who were accommodating of their needs and open minded in their attitudes towards traditional gender-based roles and priorities. This desire to be accommodating could be evident in the partner's attitudes towards his own career, or in the division of household tasks. In terms of career, some U.S. and Asian participants talked about how it had been helpful to have a partner whose career afforded him opportunities for geographic mobility, and who was willing to readjust his life for the sake of the participant's career. For example, one Asian participant described her husband's participation in completing household chores as well as his support of her career decisions as follows:

> I mean, it helps to have someone share a meal with you and share the chores with you at home…he's definitely very supportive, and I'm glad that he's here with me. I don't think he has hampered my graduate school work nature in any way. I don't think he influences my career decision as much, he pretty much leaves it to me, and then, you know, just tells me, "Whatever you want to do, you know, I support you and go along with it."

This theme of having an accommodating partnership was not described by all participants who identified as married or in another type of committed relationship. In fact, there were U.S. and Asian participants who clearly considered their careers to be secondary to the

careers of their partners. Nonetheless, when such flexibility was present in a relationship, it provided important support for the career persistence of the female participants.

Social Networks

Both U.S. and Asian participants described having a social network of individuals who could help them to move towards their goals. For example, one U.S. student talked about getting a job in a laboratory through a friend who was able to vouch for her ability to learn quickly despite not having a background in that area. Family was a key resource for two Asian students, one of whom talked about having the option of turning to her extended family to get assistance with child care after returning to her home country, while the other described a time when her engineer mother helped her to learn difficult course material, thereby preventing her from having to discontinue her studies in that particular engineering field.

Organizational Resources

Both U.S. and Asian students described benefiting from resources that were provided by their universities or other organizations, such as private companies or national organizations supporting women in science and engineering. This organized support helped participants to persist in their engineering education both because of the tangible benefits it provided and by helping them to understand their options and connect with others.

Concrete Support

U.S. and Asian students reported receiving scholarships, assistantships, funding for groups supporting women in engineering, and maternity leave. In some cases, funding

had a significant influence on an individual's decision to persist, as described by this U.S. student:

> And then in my second year of grad school we got a company to sign on to sponsor a Ph.D. so they could have priority on the patent. So that's given me funding all the way through. And I wasn't planning to stay for the Ph.D. but at that junction when I was finishing the master's everything came into place, and there was funding for a Ph.D....Like, everything was there, so it was like, "Unless you are certain you don't want this then do it." So that's what I did.

Although U.S. funding opportunities were somewhat more restricted for international students, most of the students interviewed talked about receiving some form of financial support from their schools or outside sources. For example, one Asian student noted that a partial scholarship from her undergraduate university made it possible for her to study in the U.S., while another talked about a generous government-funded scholarship from her country of origin that funded both her undergraduate and graduate studies.

Informational Support

U.S. and Asian students also mentioned multiple informational and networking resources at their universities that helped them persist on their engineering career paths, including social networks that helped them to meet people and directed them towards departmental workshops on engineering careers and academia. Many of these resources were specifically targeted towards women in engineering, and one U.S. participant explicitly commented that, "as much as I found that gender has not been an issue in kind of the choices that are available to me, all of the really kind of useful...information dumps that I've been a part of have been women-targeted." Such resources were described as particularly important to students early in their graduate studies, when they provided them with important information in preparation for graduate school and served as a social

networking opportunity. However, they were also described as a useful source of information by women as they approached graduation from their doctoral programs.

Sociocultural Environment

U.S. and Asian students also described numerous privileges or benefits that they thought they derived from their sociocultural environment. These perceived advantages fell into the following categories: ethnicity and nationality, economic background, women's minority status, educational background, and culturally-based values. Again, it is important to recognize that these advantages were not shared by all participants, but they helped encourage persistence among some of the participants in this study.

Ethnicity and Nationality

Ethnicity and nationality were discussed as advantages by several U.S. women, who spoke about the benefits of being "white" and U.S. citizens. One woman spoke about her ability to apply for certain national grants that foreign students could not receive, while another described how her education has been affected by her ethnic identity, stating concisely, "It's been easy. I hate to say this but…we're white skinned." Such advantages were not cited by Asian students, although one woman spoke about the advantage of growing up in Singapore, because English is the first language there and this made the transition to education in the U.S. easier.

Economic Background

A number of U.S. and Asian students described their economic backgrounds as a benefit, either because of the direct benefits of having a family who would provide them with financial assistance or because of the informational resources and professional expectations that accompanied this background. As one U.S. student described:

> ...being middle or upper-middle class in the U.S. there is an expectation that I would go to college. So I did. And an expectation that I would pursue a high-powered career, probably come back to grad school, like, all those things have just been in the expectation set and so I'm following through, basically.

Both U.S. and Asian students also talked about how they were helped by having parents who put a high priority on education and saved money to help them pay for college, sometimes despite having limited resources themselves. These students frequently expressed both a sense of gratitude for this privilege, and a connected sense of obligation not to waste their parents' investment. In the words of one Asian participant:

> You know my parents are doing everything they can to send me here and, I mean, I never really felt bad about it, but it was something always there bearing in my mind consciously that I have to keep track of.

Other students did not have parents who were financially able to support them, but described a sense of financial security stemming from other sources. For example, one married U.S. student talked about the advantage of having a partner who provided some degree of financial stability. As she explained:

> ...just having someone that...is supportive emotionally but also, you know, there is some financial stability, which I think has -- I probably don't recognize it as much, but I think it's been very important. Just not having to worry so much about, you know, like when I couldn't have my tuition paid for.

Women's Minority Status

Several U.S. women perceived being a woman as an advantage, because of the rarity of female engineers in the U.S. Specifically, they talked about standing out more, being more in demand because of their minority status, and having had mentors who wanted to help them because they felt that there was "a lot to make up for" with respect

to women in science. For example, one U.S. participant described her experiences as a woman in engineering as follows:

> …it's been really bankable so far. Like, I feel like I've had a lot of doors open to me. In fact, I feel like I've never had a door close, and I feel like a lot of that comes from the fact that I'm a girl in engineering. And I'm a very special flower because of that. And so it makes me hirable and interesting.

In contrast, the Asian participants in this study did not have the perception that being a woman made them more employable in their home countries; in fact, several thought that being a woman was an obstacle to finding employment. However, they shared the view that because they were rare they would stand out more if they were able to perform engineering-related tasks well when they were offered an opportunity. As one Asian student described it:

> I think it's like two edges of the sword. On one side they will think, "Ah, you can't design things faster than boys," and they won't give you much opportunities to do some tough jobs. But I think, you know, opportunities can always come. But if opportunities can come, you did very excellent job, they will think, "Oh it's very good," and I think because you are a woman you will be more distinct than others. Ah, they will think you are so outstanding.

Educational Background

U.S. and Asian students also talked about advantages connected to their background and training. U.S. students from PSTU often talked about the advantages of undergraduate and graduate education at this prestigious university. Most commonly, these students talked about the many opportunities that were available to them there and the sense of security they derived from being associated with PSTU's reputation. As one student put it, "That's one of the good things about [PSTU]. I'm not worried that I'm not gonna have choices. I'm always gonna have good choices. That's really liberating." Asian students also talked about the advantages of the education they received in their

home countries, including a rigorous preparation for college entrance exams and a strong grounding in engineering fundamentals, as described below:

> My high school education was sooo good. Like, I didn't do anything new 'til like junior year of college. And I was doing advanced classes … So I think the high school education really helped me in a way here.

Culturally-based Values

The values or beliefs that participants described as supporting their persistence in engineering differed by culture, though both U.S. and Asian students talked about the social value of an engineering career because it brought them some degree of prestige and respect. One U.S. student explained how enjoyment of this prestige helped prevent her from leaving the field:

> …like, part of me enjoys the whole, "Oh you must be smart, it must be really hard." … And so the idea of leaving engineering made that-, losing that was concerning. I think that's one of the reasons that I stuck in there, was that image.

Similarly, one Asian student stated simply, "How would you say, like, oh I like to say that I'm an engineer," while another talked about why she wanted to prioritize her engineering career above romantic relationships:

> Because actually you know, in my eye, career is more important than that partnership. Yeah. It can bring me confidence and it can bring me the social status and many things that make me very satisfied.

Asian participants also cited more culturally specific beliefs, for example, one discussed her family's faith in astrological predictions that foretold her future success in engineering and how this provided important reassurance that helped her to persist in the face of challenges.

Chance

The four major themes outlined above (inspirational contact, relational support, organizational resources, and sociocultural advantages) all provide examples of specific forms of external support identified by participants. However, both U.S. and Asian students also pointed to key junctures on their educational pathways when they believed that chance played a major role in their experiences and persistence. For example, some students talked about how they stumbled upon important resources or social networks without looking for them. There were also several cases in which U.S. participants attributed events that contributed to their persistence to "luck," even when other factors may have played a more important role. For example, one U.S. participant described her acceptance into her current graduate program as follows:

> …so I really didn't feel like I got here necessarily because I was that great. It was sort of a combination of, like, I got lucky and then, like, I had people that liked me, as opposed to, you know, I was really the *best* choice.

Such examples were included in the "chance" thematic category because this is the theme that emerged most directly from the interview participant's words. It is important, however, also to consider how the participants' choices of attributions may be influenced by cultural norms and past experiences.

Internal Motivations for Persistence

Ultimately, the decision to persist on a path towards an engineering doctorate is dependent on internal thought processes and perceptions that affect a participant's internal motivation to persist. These internal motivating factors were grouped into three major themes that emerged from the interviews: 1) professional priorities, 2) personal characteristics, and 3) perceived limitations.

Professional Priorities

Both U.S. and Asian participants talked about being influenced to persist on their engineering educational and career paths because of the importance they ascribed to certain professional goals. The professional priorities that emerged from the interviews reflected the following four themes: educational commitment, career ambitions, practical applications, and social conscience.

Educational Commitment

Some U.S. students described being motivated to persist to completion of an engineering doctoral degree by an internal commitment to complete a Ph.D., independent of any practical benefit this degree conferred. The reasons that degree completion was a high priority for them included a sense of responsibility to an advisor or funding source, a belief that they should to take advantage of opportunities others had not had, a desire to bring joy to family members who would take pride in this accomplishments, and a desire to prove to themselves and others that they could earn a degree in a challenging technical field. For example, one U.S. student explained her commitment to completing her doctoral degree as follows:

> One thing that has helped me through some of the times when it's just like, "Ah, what am I doing?" -- there is sort of a commitment, like, we made a contract with the company and then I don't want to just quit on my advisor or on the company. I would like to finish.

Asian students also talked about being motivated to complete their engineering doctoral degrees by a sense of commitment to this goal. For example, when asked if she had ever considered switching majors or careers, one Asian student simply replied, "Oh no, no. I always want to be Ph.D.," while another talked about needing to complete her degree because of a sense of obligation to the government that funded her education.

Career Ambitions

Both U.S. and Asian participants talked being motivated to continue on their path towards an engineering doctorate by the value they placed on certain professional roles or the benefits that accompanied these professional roles. These participants were driven to persist by a desire to achieve specific future career ambitions for which a Ph.D. was required or would enhance opportunities (e.g., teaching engineering at a university level, and becoming a Principal Investigator). For example, one U.S. participant described the process she went through before deciding to go to graduate school as follows:

> …I didn't go on to grad school right away. I looked for jobs and all of the things that I was really interested in required a Ph.D. So -- which were mostly research positions. And so I worked for a couple of years and then decided that I would really like to go back to get a Ph.D., so that I could do the jobs that I was interested in.

Teaching was the professional goal that was most frequently cited by the U.S. interview participants. One participant described her first teaching experience as a "defining moment of: okay, I need the Ph.D. because I want to teach at a really high level and I want to really get students excited about what I'm doing." Participants also talked about how the skills gained through graduate education would help them to achieve their future career ambitions, particularly with respect to hands-on experience. Additionally, Asian students discussed the increased standard of living they could expect with a graduate degree in engineering in their home countries, the difficulty of getting jobs in the U.S. as an international student without a Ph.D., and expected future growth in the engineering field in their home countries. As one Chinese student described the advantages of a career in civil engineering:

> They can live the higher rank life. Civil engineer's salaries are very good too now because China now launched many infrastructure constructions, so it provides lots of opportunities.

Practical Applications

Both Asian and U.S. students also talked about being motivated to persist on their engineering career paths because they placed a high priority on having careers that allowed them to have a direct visible impact. One U.S. participant explained, "I want something where I could work on something and really feel a connection with what the results were going to be." Similarly, one Asian participant described how she was drawn to her current research because, "I find that seeing small things with electron microscopes or various different microscopes really help me. Because you make something and you can actually see it."

Social Conscience

Even more commonly, both U.S. and Asian participants described being motivated to persist on their path to an engineering doctoral degree by a strong social conscience that guided the work they hoped to do using their engineering training. More specifically, they talked about wanting to make the world a better place, and seeking out projects with a humanitarian or environmental benefit. For example, one U.S. participant talked about asking herself, "What is the greater good that you want to do?" while another simply explained, "I love engineering. I like being able to make things better." U.S. students typically described these values as primarily learned from their families of origin, as illustrated by this participant's description of why she has sought out engineering projects that are atypical in their humanitarian focus:

> I mean, I think that's just the values that were instilled in me from more my mom's side. It's just the doing good in the world and trying to make a difference

> and that's just something that from a very young age has been an expectation and important to me.

For the Asian students, these values often came from directly witnessing the potential and struggles of their home countries. This is illustrated by one participant's description of how she had become involved with projects aimed at helping developing countries:

> I think it's been very gradual, but the fact that I come from a developing country that has so much potential. I mean, I don't know, it just makes me feel as though we can do so much more there…I mean, a lot of people talk about everything, but no one does anything. And I feel as if someone has to do something to, I don't know, elevate it.

Several Asian students also spoke movingly of their awareness of the opportunities they had and a desire to give back something in return. As one participant explained:

> …my husband and I will talk like, "What do we want to do with our lives, like, how do we give back to society, how-, what do we, [*pause*] have I contributed more than I have taken, since I've been born?" … I do worry about those things … I mean, I don't want to just do a Ph.D. and just, you know, live happy, like, for myself. I mean, I want to make sure that I'm contributing too with what I learn and what I know, I guess.

Engineering Compatibility

A sense of compatibility with the engineering discipline emerged from many of the interviews with both U.S. and Asian participants. More specifically, these participants described personal characteristics that they perceived as compatible with a future career in engineering, including personal enjoyment, personality-career fit, and aptitude.

Personal Enjoyment

Both U.S. and Asian participants talked about liking undergraduate or graduate engineering classes, being interested in the questions that engineering approaches could

help solve, and enjoying research and teaching experiences in engineering. As one U.S. student put it:

> I do like my engineering, and I think it's just so fun and fascinating and it explains so much of, like, what I interact with in the world and all that. I just think it's really cool. So I wouldn't change.

Participants also discussed specifically enjoying certain topics within the broad field of engineering, for example, one Asian student described the passion she felt for her field of engineering stating, "I have studied bridge engineering for almost six years. And I have emotions, ah, great emotions in that major…"

Personality-Career Fit

U.S. and Asian participants sometimes highlighted the fit between their personality traits and engineering careers, both by explicitly pointing out ways their personalities were well-suited to engineering, and by more indirectly indicating that they had certain personality traits that helped them to persist in this field. For example one Asian participant described the importance of being persistent as a woman in engineering "because this road is not very smooth," the importance of being honest and careful, "because for engineering your calculation is related to actual projects," and the importance of being able to work collaboratively, "because if you want to be engineer it's not like in studies, you can't just calculate it by yourself."

One personality trait that was less explicitly discussed as necessary for an engineering career but that both U.S. and Asian participants clearly indicated had been important to their success and persistence on an engineering career path was self acceptance. Specifically, U.S. and Asian participants talked about accepting or learning to accept themselves, often despite resistance from other individuals. For example, one

U.S. participant talked about how she initially "thought that I needed to tone down who I was" in order to gain respect from others in the department, but eventually reached the point where she was able to say, "I'm very comfortable now and I'm not afraid to be who I am," noting that her educational pathway became easier after that.

Two additional personality traits were only described by U.S. students: desire for challenge, and enjoyment of being unique. The theme of desire for challenge emerged from interviews with two students from the U.S., who talked about how having a challenging career was important to them. As one of these participants explained, "I mean I've always been ambitious, I've always wanted to do things that were gonna be hard and, you know, cool, and impress *me* at least." Many of the U.S. participants also appeared to possess an independent spirit that led them to enjoy feeling unique or different. In contrast to other participants who expressed discomfort at the surprised responses they often elicited when they disclosed that they were engineers, these participants derived some satisfaction from defying stereotypes. As one participant put it:

> And I guess that I want to, I want to be different. I'm still striving to do something a little novel. And I do kind of delight in telling people that I'm an engineer at [school name], and having them, you know, after them guessing that I'm a communications major at [humanities-oriented school]. You know, like, it's-, I kind of love that a little bit. And I kind of think it's fun to defy the stereotypes that people have.

Engineering Self-Efficacy

Both U.S. and Asian participants also discussed a high level of engineering self-efficacy, based on strong past performance in academic programs related to math, science or engineering. In general, most students estimated that their academic performance in their current graduate program was at least average compared to their peers, and several

identified their performance as above average in some respect. Some participants described this self-efficacy as something that had developed gradually based on accumulated successes. For example, one U.S. participant described her initial doubts about her engineering abilities, and how she finally overcame her belief that she did not deserve to be in her graduate program:

> And that I don't think went away until I took my qualifying exams. I feel like that was a really big turning point especially for self-confidence because it's pretty numeric, right? ... And I was just, like, that was the point where I was like, "I DO deserve to be here, 'cause this is a hundred percent me." Like, I studied. I did all the work and then I went up there and I defended it all myself. And I was like, "Ok. I think I can get a Ph.D. now. And feel like I'm getting it because I deserve it, as opposed to because somebody bent the rules or let me in."

For other students, this sense of self-efficacy appeared to have been present from the beginning of graduate school. For example, one Asian student spoke about how she was at the top of her class when she graduated from her undergraduate university. This student had a clear awareness of the challenges she could face as a woman in engineering in her home country, but also expressed a strong sense of confidence that she could still be professionally successful in the future stating, "I could be better than others, so…to be a female is a weak point but other point will be very strong. Yeah. So no problem."

Interestingly, several participants made a point of attributing their academic successes to hard work. One Asian participant explained her status at the top of her class in China by observing that in comparison with her classmates "I will do much more work than them." Another U.S. student provided the following candid self-reflection:

> …based on the statistics that I saw, and based on talking to other females, I know that I have performed better in terms of grades than other women in my department. And I don't know why that is, and I wouldn't say that it's because I'm more intelligent…I always fall back on the idea that I just work harder…I don't know if that's just my personal perceptions or whether that's actually true.

Additionally, for U.S. students this sense of self-efficacy often focused on communication strengths that contributed to their success in an engineering graduate program. In particular, these participants described how their communication skills had placed them in leadership roles that made use of their abilities to make interpersonal connections and negotiate conflict. As one U.S. participant explained:

> …I feel like I can organize things well and I hope I can communicate well and I can run different events… But I feel like also that's another benefit a lot of women have is that -- because, from the time we're little, we're kind of schooled to have all these little social things that we're good at and, you know, maybe carry on a conversation better, whatever, be more sympathetic to people, or listen better -- that we sort of get an advantage in that. Whereas, there's some guy engineers who are not the best communicators or the most sensitive in discussing topics, or coming to consensus.

This emphasis on communication ability as an advantage was not mentioned by the Asian students in the study, who sometimes struggled with academic communication because of cultural differences in communication styles and the challenge of communicating in another language.

Perceived Limitations

The choice to persist in engineering was not always described as an active choice process based on internal strengths and supports. Both U.S. and Asian students talked about persisting on an engineering educational path because they were not aware of other viable options. For both U.S. and Asian students, these perceived limitations were often based on difficulty identifying alternative careers that interested them. Additionally, Asian students saw themselves as limited in their ability to change career tracks after their initial choice of engineering because of the educational structures in their countries of origin.

Undefined Career Alternatives

Some U.S. and Asian students talked about persisting in engineering because they did not have a clear idea or plan for what else they would do instead. For example, when asked if she would consider switching away from engineering, one U.S. student replied, "No. I don't know what else I would be good at." Another U.S. student who was considering a career switch after completing her Ph.D. provided the following explanation for why she had not left her graduate program:

> I'm gonna complete my degree. I mean there is no good reason not to do that at the moment and I don't really know where I want to go anyways so even if I tried to switch right now, I don't know where I would end up.

This lack of awareness of other options could be considered a disadvantage from the perspective of allowing an individual to pursue the career that will bring them the most enjoyment and fulfillment, but it nonetheless can result in an increase in the likelihood of engineering persistence, if other options are not recognized in an individual's world of possibilities.

Track Inflexibility

A few Asian students also talked about a perceived inability to leave the engineering field that focused on having limited flexibility to change to a different field in their country once they were on an engineering career track. In the words of one Indian participant:

> I don't think you can have any other option in India. Like, you know, once you choose a field, you can't go back. Well, engineering is one of the better ones you know. You can at least go to the business management one. But if you were to become a doctor you don't have any other choice, you have to stay a doctor.

Again, this could be perceived as a disadvantage to an individual who is unhappy with their initial choice, but from a persistence perspective it also functions to encourage individuals to continue on an engineering educational path, even in the face of challenges.

DISCUSSION

This study provides an initial exploratory overview of the range of factors that contribute to women's persistence in engineering education to the doctoral level, by carefully examining the narratives of women at two very different universities, who come from a broad range of life experiences in terms of educational background and relational status. This study is one of the first to directly address the intersection of cultural and female identity in the educational and career choices of female doctoral students in engineering. Given the international diversity of doctoral engineering programs in the U.S., it is important that cultural identities be explicitly acknowledged in studies examining engineering education at the doctoral level. By separately examining the factors identified by U.S. and Asian participants, the present study allows us to better understand how the intersection between their cultural backgrounds and identities as women affected their perceptions of the factors that supported and motivated their persistence to the doctoral level, thus broadening our understanding of how to positively impact women in each of these groups.

As described in more detail in the sections that follow, the themes that emerged from the present study are highly consistent with support factors identified in previous studies that examined factors supporting women's persistence in engineering, which focused primarily on undergraduate populations. Thus, the present study expands the

relevance of these themes to a group of female doctoral students. Although this study differs from many previous studies in the complexity of the support factors described by participants, there are no single factors that stand out as surprisingly novel. Rather, what emerges from this study in an awareness of the richness of each individual's experience, and the multiple levels of interacting factors whose impact may accumulate over time in supporting their persistence.

The present study also builds on the existing literature by explicitly comparing the factors described by U.S. and Asian participants as supporting and motivating their persistence. Interestingly, the themes that emerged from the U.S. and Asian interviews overlapped completely, aside from the theme of *Track Inflexibility*, i.e., the assertion by some Asian participants that it was very difficult to switch to a different career field once the initial educational commitment to engineering was made, because of the educational structure in their home countries. However, as the following sections will illustrate, despite this broad overlap in themes there were many differences between U.S. and Asian participants in the precise nature or impact of support factors, as well as differences between individuals within either of these groups. This is consistent with the view that simplified comparisons between groups are inadequate to fully understand women's persistence in engineering. Instead, the decision to persist on an engineering educational and career path must be conceptualized as a complex and multi-dimensional process. Understanding this process requires simultaneous consideration of multiple layers of past and present support factors in the context of the challenges, needs, and priorities created by an individual's many intersecting identities. The impact of some of these intersecting identities is discussed in the sections that follow.

Factors Providing External Support

Inspirational Contact and Relational Support

The results of this study indicate that is important for women to be exposed to inspirational individuals whose careers they may wish to emulate ("*inspirational contact*"), and to receive direct emotional and professional support from mentors and loved ones ("*relational support*"). These findings are consistent with previous studies on female undergraduate students, showing that role models are important to women's persistence in science (Downing et al., 2005; Wentling & Camacho, 2008), as are support and encouragement from professors and family, good guidance from advisors, study help and encouragement from classmates or friends, and having a sense of belonging (Trenor et al., 2008; Wentling & Camacho, 2008). This type of support may be particularly important for women who are entering "non-traditional" fields such as engineering, because they may often face significant challenges with little concrete reassurance that they can overcome these challenges and achieve success in this field.

By using a qualitative framework and including both U.S. and Asian participants, the present study allowed a closer examination of the context surrounding these supports and the meaning they had for the study participants. Such examination shows that the types of inspirational contact described by individuals varied widely depending on the opportunities provided by each individual's developmental history, and the intersections of identity that defined this history (e.g., family background, nationality, economic status). For example, some Asian countries may do a better job than the U.S. of using national media to provide women with role models and to promote women in careers such as engineering. Further research is needed to explore how specific countries

encourage women's participation in engineering through governmental or socially mediated encouragement. Similarly, although the same general themes characterized the relational supports important to our U.S. and Asian participants, the relevance of these supports depended again on an understanding of their intersecting identities. For example, partner flexibility became of primary importance to participants whose identities including a role as a mother or committed partner, and the impact of advice from individuals in different roles was strongly affected by cultural identity and associated norms and traditions. In future research, it will important to more closely examine the impact of each of these intersecting identities, and to begin to separate out national identities rather than combining multiple countries into one "Asian" group as was necessary for this exploratory study.

Organizational Resources

Both concrete and informational types of organizational resources were also described as important in promoting persistence by both groups of graduate women in this study. This is consistent with previous studies showing that women who persist in undergraduate engineering programs are more likely to make use of support services, particularly campus organizations supporting women in engineering, than women who transfer to another major (Brainard & Carlin, 1998; Jackson, Gardner, & Sullivan, 1993; Wentling & Camacho, 2008). Many U.S. and Asian students in the present study were actively involved in such organizations, with several of the women holding leadership positions within these organizations. However, it is possible that this finding partially reflects a bias of our sample, in that participation in this study was voluntary and the women who participated may therefore represent a subsample of students who were

exceptionally willing to provide volunteer services or were particularly active within the campus community. This possibility should be explored in future studies, to determine whether there may be groups of individuals who benefit less from these organizational resources than others.

Sociocultural Environment

The present study also provides evidence that sociocultural advantages may have a profound effect on women's persistence in engineering to the doctoral level. Previous research at the undergraduate level has shown that a woman's success on an engineering career path may be affected by an her socioeconomic status, and by the implications of this status in terms of social capital (i.e., resources based on social networks), cultural capital (i.e., knowledge or skills acquired by growing up within a given environment), or symbolic capital (i.e., prestige based on the accumulation of cultural capital) (Foor, Walden, & Trytten, 2007). Women in engineering are likely to enter the field with lower cultural capital than men, that is, most women enter the male-dominated world of engineering as relative outsiders and have to learn to adapt to this unfamiliar environment. Because of this, one might predict that women would be particularly affected by having or lacking other sociocultural resources. In the present study, both U.S. and Asian students talked about the importance of having economic support during their undergraduate and graduate education, and all study participants described themselves as middle class. This relatively privileged socioeconomic status may have been particularly important to Asian study participants, who described the high cost of education in the U.S. as compared to their home countries, the difficulty of getting financial support here, and the importance of proving financial security in order to obtain

a visa to study in this country. Thus, foreign students who lack these financial resources are less likely to be able to pursue higher education in the U.S.

Similarly, some of the cultural values that participants discussed as supporting their persistence can be viewed as a type of cultural capital. In a recent study of undergraduate female engineering students of different ethnic backgrounds, Asian participants talked about a cultural expectation that they pursue one of a limited number of professional career fields, including engineering, and reported that their parents supported their decision to pursue an engineering degree (Trenor et al., 2008). This is consistent with the support and encouragement Asian students in our study reported receiving for their career choice from family members, as well as the prestige associated with an engineering career that was reported by both Asian and U.S. participants.

Many women in our study were also convinced that being female was an advantage that had given them access to important support structures throughout their educational paths, and that would continue to help them in the future. The articulation of this belief by the women we interviewed is concerning, as it reflects an apparent internalization of the assumption that the social disadvantages responsible for the under-representation of women in engineering have already been fully addressed, despite strong evidence that the measures that have been taken to encourage women's participation in this field are insufficient to compensate for the additional challenges they face (Hersh, 2000). This was particularly true for the U.S. women in our study, who perceived being a woman as an advantage in terms of future career opportunities, in contrast to several of the Asian women who talked about culturally normative gender biases against hiring women in their countries of origin.

Consistent with the results of the present study, female engineering undergraduate participants in a recent longitudinal interview study also shared a belief that gender made them more employable (Powell, Bagihole, & Dainty, 2009). However, the benefit of standing out must be balanced against the social isolation of this unique status, in which being visible can also make women more likely to be targets of hostility or exclusion (Watts, 2009). The misperception that their gender gives women an unfair advantage is particularly dangerous, because it may gradually erode their confidence that the successes they achieve are based on their own merits, while simultaneously supporting a social environment in which women's successes in engineering are sometimes questioned or considered less valid than those of their male peers.

Chance

The role of "chance" or "luck" that several participants described as supporting their persistence has not been previously discussed in the literature, perhaps because there is a tacit understanding that chance inevitably plays some role in the vast collection of events and choices that result in an individual's life path. It is meaningful, however, to examine this theme because of the significance it was given by participants. For example, one student attributed her successes to luck so frequently that the interviewer commented, "You've been lucky a lot," to which she happily replied, "I *have* been lucky a lot. Isn't it good?" Such comments may reflect a genuine appreciation for opportunities and supports that women who do not persist in engineering may lack; however, they might also indicate an unconscious tendency to attribute successes to external causes, rather than to the participants' own talents and efforts. This has important implications, as research

indicates that students who persist in engineering are more likely to attribute their successes to their efforts (Nauta et al., 1999).

Internal Motivations for Persistence

Although external support factors clearly play a critical role in providing the context within which the decision to persist on an engineering career path is made, ultimately persistence also depends on how a participant internalizes this context, and interprets it with respect to her own needs and priorities. The findings of the present study indicate that participants were primarily motivated by perceptions related to: 1) the fit between their own professional priorities and their perception of the responsibilities and benefits of an engineering education and career ("*professional priorities*"), 2) their personal characteristics and their perception of the personal characteristics that were compatible with a career in engineering ("*engineering compatibility*"), and 3) their perception of external or internal barriers to pursuing alternative careers ("*perceived limitations*").

Professional Priorities

The results of the present study are consistent with past research indicating that the decision to pursue a Ph.D. in engineering is often motivated by an individual's specific career ambitions, i.e., an interest in jobs that require a Ph.D. such as teaching or research (Abadie, Christy, Jones, Wang, & Lima, 2009). For both U.S. and Asian participants in our study, these career ambitions were strongly influenced by their perceptions of the social impact they could have. Findings from previous studies have been somewhat mixed with respect to the relationship between social motivations and women's engineering career persistence. In one study of professional engineers,

participants shared their enjoyment of the practical applications of their work, and emphasized their desire to engage in work that was socially beneficial (Gill, Mills, Franzway, & Sharp, 2008). However, another study of engineering undergraduates found that while several female ethnic minority students expressed a desire to provide mentorship or to "give back" through their engineering work, none of the European American participants expressed such interests or motivations (Trenor et al., 2008). Furthermore, another recent study found that women were less likely to pursue graduate degrees in science, math, and engineering if making "a contribution to society" was an important component of their career decision (Sax, 2001). These findings seem contrary to the results of the present study, in which the educational persistence of both European American and Asian female doctoral students appeared to be strongly motivated by their desire to pursue a career where they could make a social contribution, whether through teaching, mentoring, or research with environmental and other practical applications. Taken as a whole, what these results seem to indicate is that women at the undergraduate level may be dissuaded from pursuing a graduate degree in engineering by a lack of information about the potential humanitarian applications of work in this field, but that women who do have the information or motivation to continue on to the graduate level may find satisfaction in the socially beneficial aspects of their work. Education about such options may therefore be a key component of attracting women to engineering careers.

Engineering Compatibility

Our findings indicated that personal characteristics played a significant role in our study participant's persistence on an engineering career path in three ways: 1) in terms of

their interest in and enjoyment of engineering-related tasks, 2) in terms of the fit between participants' personality traits and some of the personal attributes that are helpful in achieving success in this field, and 3) in terms of their perceived level of engineering self-efficacy. Several studies on undergraduate women have found that their enjoyment of the coursework or tasks related to an engineering major helped support their persistence in this major (Brainard & Carlin, 1998; Trenor et al., 2008; Wentling & Camacho, 2008). However, it has also been argued that lack of interest is an important contributor to women's underrepresentation in engineering, with the largest difference between men and women being men's attraction towards careers oriented towards things while women are more attracted to careers oriented towards people (Su, Rounds, & Armstrong, 2009). Although the results of the present study provide no information about the proportion of women in the general population who would find engineering to be rewarding and interesting, they do indicate that those women who dedicate themselves to careers in this area often genuinely enjoy the work they do. Moreover, many of the women in the present study enjoyed this work despite clearly being "people-oriented" themselves, and were able to reconcile this interest with their science interest by focusing on teaching, mentorship, or engineering research that was humanitarian in nature.

Finally, findings from the present study are consistent with the results of previous studies on undergraduates showing that math/science self-efficacy and aptitude are strongly associated with engineering persistence (Jackson et al., 1993; Sax, 2001; Schaefers et al., 1997; Wentling & Camacho, 2008). Our findings are unique, however, in that some of the U.S. participants in the present study also discussed their engineering self-efficacy in terms of their strong interpersonal communication skills. These

participants discussed how these communication skills had brought them leadership positions in their engineering programs, a privilege which could also be considered a double edged sword in some ways. That is, U.S. participants spoke about serving a mediating role in their labs, providing mentorship, and organizing social events because of their skills in these areas. This was a source of satisfaction for them, and their involvement in these activities may have helped them build relational support networks; however, it also required a time commitment that pulled them away from research or academic responsibilities. Future research should further explore this connection between communication skills and engineering educational and career success; for example, it is possible that strong skills in this area might lead women to pursue more managerial roles within an engineering context. In contrast, Asian participants did not talk about communication skills as an asset, probably due in part to the fact that communication in English was a significant challenge for some of these students.

Perceived Limitations

Finally, a few of the participants in the present study indicated that their persistence in engineering was driven in part by a perception that they did not have other good career options. For the U.S. participants, this was based primarily on a belief that they did not have skills that would apply to other career fields, while the Asian participants focused more on the relatively inflexible educational structure in their home countries, which made it difficult to switch career paths once they had chosen to pursue education in engineering. Asian participants also talked about the relatively narrow range of options they had considered as possible careers, and contrasted this with the huge array of very specific career possibilities that U.S. students explored. Interestingly, all of the

Asian participants in the present study planned to pursue a career in industry or some type of engineering research following graduation, though one was also considering applying her engineering skills to a career in developmental entrepreneurship. In contrast, three of the ten U.S. participants planned to pursue careers that were only tangentially related to their engineering training following completion of their doctoral degrees (patent law, science policy, and educational consulting), four wished to pursue teaching careers (at least two outside of a research university setting), and only two planned to pursue a career in research or industry (with the remaining participant undecided between a career in research or teaching). Thus, it appears that the increased career flexibility experienced by U.S. participants may also result in a loss of more women from traditional engineering careers, though in all cases these women appeared to experience this flexibility as a source of personal satisfaction.

Implications and Conclusions

The results of this study emphasize the complexity of the factors that have supported the persistence of graduate women in engineering doctoral programs. They indicate that there is no single solution to the problem of women's under-representation among doctoral-level engineers; rather, women's persistence is the result of a complex web of external support factors, which interact with an equally complex amalgam of factors that provide internal motivation for persistence. Moreover, the relevance of each of these factors varies widely in response to the intersecting identities to which each individual is connected. Given the diversity of experiences and supports described by the participants in our study, it is not surprising that quantitative methods have been unable

to provide a satisfactory account of the unique combination of factors that come together to promote individual successes.

The complexity of the factors promoting persistence has important implications for educators. Providing effective support for women in engineering requires a coordinated effort on the part of school administrators and faculty, in order to offer interventions at multiple levels. Our results indicate that inspirational contact with a limited number of individuals can have a significant impact on both Asian and U.S. doctoral students, by allowing these women to envision how their identities as women and engineers can coexist. Thus, invited speakers who are able to effectively model both career success and how this can coexist with other life priorities may have a broad impact. Organizations that provide opportunities for women to build relational connections with other individuals who share their interests and values are also important, both as a way to build social connections and as an opportunity for social networking, particularly for Asian students who may feel less connected to the broader academic community. Such social connections appear to be particularly important to women early in their graduate education, while informational resources become more important as they near graduation. Transitions such as the beginning and end of graduate studies would be expected to be key times in terms of potential attrition; particular efforts should therefore be made to connect women with relevant resources at these times.

It is also important to think about how engineering is perceived by the students who may become our future engineers. According to the women in the present study, a desire to be respected and the goal of making a meaningful contribution to society were both powerful motivators on their educational paths. Governmental institutions and

educators should therefore think carefully about how they present the career opportunities created by earning an engineering doctorate, in order to highlight the opportunities that are likely to be of interest to women. The results of this study indicate that the government of some Asian countries may do this more effectively than the U.S. government, by emphasizing the country's need for engineers, and the importance of this role to the nation's future. We might benefit from imitating their marketing strategies, and educating students better about the humanitarian applications of engineering work. Additionally, it is important to recognize that the skills required for engineering success extend beyond math and science abilities. As described by the U.S. women in this study, communication skills are also a valuable asset to a doctoral-level engineer, and yet this component of an engineering skills base is not generally recognized. In short, presenting doctoral-level engineer careers as prestigious careers with opportunities to use both math/science *and* interpersonal/communication skills in order to effect social change might make these careers more attractive to some women. This in turn might encourage persistence to doctoral-level engineering careers, since this study also shows that having a specific career ambition that required an engineering doctoral degree was an important motivating factor for some women.

As we continue to celebrate the accomplishments of the remarkable women who earn their doctoral degrees in engineering, it is important to continue asking ourselves what support structures help to make their successes possible. The rich diversity of the engineering graduate student population brings unique challenges to this task, and the results of the present study show that there is no simple ingredient that ensures success for all women. By paying careful attention to the stories they tell us, however, we can

begin to learn about the range of resources that have supported them, and can use their collective wisdom to create stronger support structures to help future generations of women.

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Table 1

Summary of Descriptive Themes: External Supports of Persistence

Inspirational Contact		
	Experiencing Desired Role	
	Role Models	
Relational Support		
	Emotional Connection	
		Shared Values
		Shared Experience
		Encouragement
	Advice	
		Academic
		Life Balance
	Accommodating Partnerships	
		Career Flexibility
		Balanced Labor Distribution
	Social Capital	
Organizational Resources		
	Concrete Support	
	Informational Support	
Sociocultural Environment		
	Ethnicity and Nationality	
	Financial	
	Women's Minority Status	
	Educational Background	
	Culturally-Based Values	
Chance		

Table 2

Summary of Descriptive Themes: Internal Motivations for Persistence

Professional Priorities	
	Educational Commitment
	Career Ambitions
	Practical Applications
	Social Conscience
Engineering Compatibility	
	Personal Enjoyment
	Personality-Career Fit
	Engineering Self-Efficacy
Perceived Limitations	
	Undefined Career Alternatives
	Track Inflexibility (ASIAN ONLY)

GENERAL DISCUSSION

The qualitative research presented in this dissertation is important to building a better understanding of the factors that women in engineering perceive as challenging and supporting their persistence on an educational path to a doctoral degree. In this section, I provide one possible additional lens for examination of these findings, by discussing how they fit into the theoretical framework provided by Social Cognitive Career Theory. I then review the contribution this study makes to the current literature, address the limitations of this research, and provide suggestions for future research.

Social Cognitive Career Theory

Social Cognitive Career Theory (SCCT) focuses on an individual's self-efficacy beliefs, outcome expectations, and personal goals, and how these three concepts interact. It predicts that individuals will be most likely to persist on an engineering career path if they have 1) a high level of confidence that they can successfully perform the tasks required of an engineering graduate student or engineer, 2) an expectation that this choice will result in desired personal and professional outcomes, and 3) an intention to commit to action that will move them in the direction of the desired outcome. According to the model, each individual's personal experiences influence their self-efficacy and outcome expectations, which have an important impact on career interests and personal goals that move them in the direction of these interests. Educational and career choices are also impacted by inputs from an individual's social environment, which in turn differ with

respect to factors such as cultural background, gender, ethnicity, and socioeconomic status. Self-efficacy beliefs, outcome expectations and personal goals are not stable traits of an individual but are fluid, and changes in the balance between these three elements may cause people to revise their educational and career pursuits accordingly (Lent, 2005; Lent, Brown, & Hackett, 1994).

Understanding Women's Persistence Through the Lens of SCCT

Overall, our findings show that the factors influencing persistence among female doctoral level engineers are complex and multilayered. Consistent with the predictions of SCCT (Lent, 2005; Lent et al., 1994), the women in this study described the choice to persist on an engineering educational and career path as heavily influenced by factors impacting both their self-efficacy as engineers and their expectations about the outcomes of these educational choices. More specifically, these women were motivated towards completion of a doctoral degree in engineering by a belief that they had skills and personality characteristics that were consistent with success on this educational and career path, and an expectation that ultimately the pursuit of a doctoral degree in engineering would lead them towards career and life outcomes that they would find personally satisfying. Importantly, the stories of the women in the present study highlighted how the decision to pursue a doctoral degree in engineering could not be defined in terms of a single choice point. Instead, it was the result of a continuous process of assessment and reassessment of how the continued pursuit of this educational path fit with their broader life values.

The factors that supported the women who participated in the present study in their continued pursuit of a doctoral degree in engineering can be broadly conceptualized

as factors that assisted them in formulating the positive beliefs and expectations described above. This includes personal experiences and interactions that helped them to visualize how remaining on an engineering-related educational path could lead to desired future outcomes (e.g., experiencing an engineering role that they enjoyed, having role models whose lives they wished to emulate), and relational factors that helped to minimize the costs of following such an educational path (e.g., accommodating partnerships that minimized conflicts related to balancing multiple roles, relational support to decrease social isolation). Additionally, these women were assisted more broadly in pursuing an engineering educational path by growing up in a social and cultural environment that allowed or even supported them in following this path, and having access to resources that were essential to this pursuit.

Conversely, the major challenges faced by the women in the present study were factors that contributed to a perception that they did not belong in the engineering world, and that threatened their ability to visualize a future for themselves within this world that was consistent with their life values. In particular, this could involve a lack of social acceptance, either in terms of having to combat culturally based stereotypes about engineers in general or in terms of not finding a community of mentors and peers to provide relational support. Women were also challenged by feeling that they could not be successful in an engineering role, sometimes because of academic challenges but more often because they were unsure that they could successfully assume a role as an engineer (particularly in a demanding and prestigious position such as a tenure-track professorship) without making unacceptable sacrifices with respect to their personal values and goals. These women also struggled with conflicting expectations that often

left them in a double bind, unable to simultaneously satisfy the expectations of society, the expectations of loved ones and, perhaps most insidiously, their own expectations that they be able to balance multiple roles and meet their high internalized standards in each of these roles. These challenges are likely to be more salient for women who are in doctoral engineering programs than for women at earlier levels of education, because women are less common in engineering programs at the doctoral level (Bell, Di Fabio, & Frehill, 2006), role conflict may increase as women reach an age when motherhood often becomes a focus of attention (Xie & Shauman, 2003), and biases towards women may become more apparent once women reach a level of professional attainment that could threaten the gendered power balance that has traditionally been present in engineering education and careers (Gill, Mills, Franzway, & Sharp, 2008).

Contributions to the Current Literature

The present study provides much needed insight into the factors that may challenge and support women in engineering who persist to the doctoral level. Through careful examination of the narratives of 16 female doctoral students, this study helps to fill an important gap in our understanding of women in engineering, as very few previous studies have examined the experiences of women in graduate level engineering programs. The results show that women who persist to the doctoral level experience many of the same challenges described in studies on undergraduate women in engineering (Brainard & Carlin, 1998; Felder, Felder, Mauney, Hamrin, & Dietz, 1995; Hutchinson-Green, Follman, & Bodner, 2008; Marra, Rodgers, Shen, & Bogue, 2009; Powell, Bagihole, & Dainty, 2009; Vogt, Hocevar, & Hagedorn, 2007; Wentling & Camacho, 2008). Moreover, these women do not appear to have unique support structures, rather, the

supports that they describe as important to their persistence are consistent with those that have been described in previous studies focusing primarily on undergraduates (Brainard & Carlin, 1998; Downing, Crosby, & Blake-Beard, 2005; Jackson, Gardner, & Sullivan, 1993; Sax, 2001; Schaefers, Epperson, & Nauta, 1997; Trenor, Yu, Waight, Zerda, & Sha, 2008; Wentling & Camacho, 2008). The missing component in understanding women's persistence therefore does not appear to be any particular factor that has been previously overlooked in the literature. Instead, it appears that what has been overlooked in many previous studies is the need to examine how different factors may interact or accumulate, perhaps snowballing on a trajectory towards increased success or abandonment of a given career path.

Examination of these interacting and accumulating challenges and supports requires careful attention to the current and historical sociocultural context surrounding each woman's choice, as well as an understanding of the psychological impact this context may have on any given individual. This, in turn, requires careful attention to the intersections of identity that affect each individual's educational choices. For example, at a very broad level, the cultural differences found in the present study show how one aspect of an individual's identity may impact their choices. Specifically, Asian foreign national students in the present study faced certain challenges that the U.S. citizens did not face, including visa requirements, challenges related to adjusting to the culture of the U.S., and challenges related to culturally normative gender biased hiring practices in their countries of origin. In contrast, students from the U.S. struggled more with questions of self-definition and a perception that the values they held were fundamentally different than those of their male colleagues and mentors.

However, examination of such cultural differences will only allow researchers to account for one additional dimension of the multifaceted identities that characterize each study participant. The themes that arose from interviews with participants in the present study indicated that their struggles and supports were defined by many additional aspects of their identities, some of which were constantly shifting throughout their educational and career trajectory. For example, participants described changes they had experienced over time with respect to relational status, economic situation, and personal sense of self-efficacy. Different life situations will require different responses, indicating that there is no "one size fits all" solution that can address the needs of this diverse group of individuals. More sophisticated interventions will require attention to the specific needs of each individual, which arise in the context of a specific set of life circumstances. Such personalized support can only be effectively provided in the context of personal relationships with peers and professionals within and outside engineering departments. Through personalized interventions, educators can better attend to intersections of identities and the sociocultural context these provide for each individual's struggles and successes.

Study Limitations

Although this study's attention to intersections of identity is unusual within the engineering literature, it is still restricted in its ability to fully capture some of the complexities encompassed by these intersections. One limitation of this study is that six foreign national students coming from five Asian countries were combined into a single "Asian" group, which is clearly not representative of all Asian students. The Asian continent is a huge and culturally diverse region, and it is important to acknowledge this

fact and not commit the same error of overgeneralization that past studies have committed, only on slightly narrower scale (i.e., generalizing to all Asian women rather than all women). The Asian countries represented in our sample (China, India, Korea, Taiwan, Singapore) were included to reflect the diversity present in engineering doctoral programs in the U.S. That is, 50-60% of the students in these programs are foreign nationals from many different countries, with China, India, Korea, and Taiwan having the greatest representation of students (Hoffer et al., 2004). Thus, the present study's findings with respect to its Asian participants should be interpreted as an introductory overview of some of the challenges and supports that may be faced by Asian foreign national women in U.S. doctoral engineering programs, but should not be interpreted as applying to all Asian students or representing specific Asian nations.

The present study also highlights the additional intersections of identity that could be considered for each of these women, e.g., in addition to differences based on specific nationality, participants also varied in terms of socioeconomic status, educational background, parental careers, relationship status, specialized field of study, and an infinite number of additional dimensions. This breadth of the sample is a strength of the study, in that this diversity permitted observation of a wide range of experiences which might not be captured by a more narrowly focused group of interview participants. Such diversity is essential for an exploratory study such as this one. However, the breadth of the participant pool also made it impossible to achieve complete data saturation without a larger number of participants than it was possible to obtain for this study. This does not change the interpretation of the shared themes that emerged from the interviews, but differences in the themes that emerged from analysis of U.S. and Asian interviews (i.e.,

the absence of a theme in one group) must be interpreted with caution, because it is possible that some these themes might have emerged in both groups if the size of this sample could have been increased.

The diversity of the sample also made it impossible to look at each of the dimensions of individual identity (e.g., relationship status, socioeconomic status, field of study, etc.) in any detail. Furthermore, although efforts were made to represent the full range of possibilities in any dimension, sampling restrictions also resulted in some important omissions. For example, for the most part, women in this study came from a middle class background, and the findings of this study therefore do not encompass the challenges and supports that are important to women from less privileged backgrounds. Additionally, although efforts were made to recruit students who identified with a range of family and partnership commitments, none of the participants in our study were in same sex relationships, and only two currently had children.

Another limitation of this study is that it only included participants from two different universities. Although these universities differed in terms of their prestige, location, and funding source (public versus private), thus broadening the range of experiences that would be represented in participant interviews, they still cannot fully represent the range of academic environments that doctoral engineering students encounter. Furthermore, because the participants were all volunteers, the sample may have been skewed towards students who were particularly outgoing or active members of their campus communities. Although efforts were made to minimize this sampling bias by enlisting a wide range of individuals to help with recruitment (i.e., campus groups for female graduate students and women in science, engineering professors, advisors,

engineering staff, and former participants), the requirement that students give at least two hours of their time to participate in an interview may have served as a filter that deterred many students from participating.

Finally, the Asian participants in this study had varying degrees of fluency in the English language. Although all were able to communicate clearly and proficiently, several participants appeared to struggle to find the words to convey their thoughts and one noted that when she had something "deep" to convey, she generally did it in her native language. Because we did not have the resources to translate interviews from the participants' native languages, this may have restricted the richness of detail that some of these participants were able to convey. Additionally, the difficulty of recruiting Asian participants for this study may have been exacerbated because only students with a relatively high level of confidence in their ability to communicate in English would volunteer for such a study. Because the Asian participant sample was likely biased towards students who felt comfortable communicating in English and being interviewed, the sample may not have included those Asian students who struggled most with the adjustment to the U.S., both in terms of language and in terms of adjusting to cultural norms (e.g., talking about personal stories and issues may not be normative in certain cultures).

Suggestions for Future Research

This study just begins to address the complexities of the supports and challenges of women in doctoral engineering programs. Previous studies have commented on how slow progress has been in increasing the representation of women in engineering (National Science Board, 2006), and others have noted that the available quantitative

models examining the reasons why women persist on an engineering educational path explain only a small proportion of the observed variance, indicating that important contributing factors remain to be understood (Sax, 2001). Qualitative studies that permit a more detailed and nuanced exploration of the struggles and successes of women in engineering who have persisted to the doctoral level can therefore be tremendously informative in addressing the question of why women continue to be so under-represented at this educational level, and what factors may support some women in persisting on an engineering educational and career path.

The broad questions examined in this study were an essential first step towards better understanding women's persistence in engineering. However, the research questions only contributed to our ability to identify the factors that supported or challenged women's persistence, without allowing specific examination of more detailed questions such as when these supports and challenges were most salient, how they differed at different stages (e.g., the transition from undergraduate to graduate school, the transition from a master's to a doctoral program, or after officially becoming a Ph.D. candidate), and how the identities of the individuals providing relational support might vary at different educational and life stages. More focused inquiry and analysis is needed to better understand the specific impact of these factors.

Qualitative studies like this one also provide an opportunity to acknowledge and examine the intersections of identity that influence women's choices, and to better understand these choices within a social and cultural context that acknowledges the uniqueness of each woman's experiences. Future studies should continue to explore these intersections of identity using qualitative methodologies, focusing on the impact of

important personal identifiers such as relational status, socioeconomic status, field of engineering, and more specific national and regional differences. For example, the present study included students from a wide range of engineering fields, including the two subfields which have historically had the lowest representation of female doctoral students (mechanical and electrical engineering). Women in mechanical and electrical engineering programs earned 12.4-12.8% of engineering doctorates in 2005, compared to other fields of engineering in which women earned from 22.3-32.1% of engineering doctorates (Bell et al., 2006). Future studies should separately examine the challenges and support factors identified by women in mechanical and electrical engineering fields versus fields where women are better represented, to determine whether there are differences between perceived challenges and supports of women in these groups.

Finally, future studies should also focus on the experiences of women who leave doctoral engineering programs, in order to gain a better understanding of the accumulated challenges and barriers that can cause a woman to leave engineering. This would allow us to gain a better understanding of why a given set of challenges may be experienced as insurmountable by one student, but successfully navigated by another. Additionally, future studies should also examine the experience of male doctoral engineering students, in order to gain information on the challenges that are shared by women and men versus the challenges that are uniquely experienced by women.

One finding that emerged from the present study is that overt acts of sexism appeared to be less relevant to the participants' current educational and career paths than are more subtle gender biases. Internalized and often unconscious beliefs can be difficult to identify and address, and yet interventions that fail to do so are likely to be

unsuccessful. By creating a space where women can share their thoughts, experiences, and personal successes, future qualitative studies can take advantage of their acquired wisdom and use this to better understand the factors that have supported or prevented them from creating identities in which their personal and professional goals can coexist.

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APPENDIX A

DEMOGRAPHIC QUESTIONS*

*Includes all demographic questions relevant to this dissertation, extracted from a longer demographic questionnaire that participants completed as part of a broader study on women in Science, Technology, Engineering, and Mathematics (STEM).

1. ID Number: _____

Note: for confidentiality purposes, demographic forms and interview transcripts will be labeled only with a randomly assigned ID number and a student-selected alias. A coding form linking student names with ID numbers/aliases will be stored separately from the demographic forms and transcripts, for the purpose of contacting students and linking data for follow up interviews in future years.

2. Age:_____ 3. Sex: _____

Relationship Information:

4. Current Relationship Status (select ALL that apply):

___Single and Unattached ___Single and Attached

___Married/Commitment Ceremony ___Cohabiting (living with a partner)

5. Do you have children?

___yes
___no

Cultural Background Information:

6. Citizenship:_____
(please indicate dual citizenship, if applicable)

*If you are **NOT** a U.S. citizen, please skip to question #8:*

7. Please indicate your ethnicity (select all that apply):

___Black/African American
___Asian American or Pacific Islander
___Latino/a or Hispanic American
___American Indian/Native America
___White/European American
___Other (please specify)_____

*If you **ARE** a U.S. citizen, please skip to question #9:*

8. Please specify your ethnicity as it would be described in your country of origin:

_____

Educational Information:

9. Indicate number of years in current program: _____

10. If you completed a Master's or Doctoral degree in engineering prior to entering your current degree program please indicate number of years in previous program(s):

Master's: _____ Doctoral: _____

11. Please list schools you have attended, location, degree, and major (include anything post-high school or equivalent, and include current enrollment):

School (e.g., Colorado State University)	***Location (e.g., Fort Collins, CO, U.S.A.)***	***Degree (e.g., B.S.)***	***Major (e.g., Chemical Engineering)***

Family Information:

12. How would you describe your family's economic status in the culture you came from?

___lower class
___middle class
___upper class
___other (please describe: _____)

APPENDIX B

COLORADO STATE UNIVERSITY

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

PROJECT TITLE: Socialization of and Support for Women in Science

INVESTIGATORS: Silva Canetto, David MacPhee, and David Randall

PROJECT SPONSOR: National Science Foundation

Please contact Silvia Canetto (491-5415), David MacPhee (491-5503), or Aki Hosoi (491-2968) if you have any questions or concerns about this study.

PURPOSE OF THE RESEARCH:
The purpose of this research study is to describe the career trajectories and experiences of university students in science/technology/engineering majors. It is meant to find out about aspirations, expectations, challenges, resources, and so forth that encourage or inhibit students from entering careers in these fields. The ultimate goal is to identify ways to recruit, retain, and mentor students who are underrepresented in science, technology and engineering.

PROCEDURES TO BE USED:

You will be interviewed up to five times over the course of three years. Each interview will take 45-90 minutes to complete, including completion of a demographic form that will take 10-15 minutes to fill out and may be completed prior to the interview. The interviews, which may be completed by phone if you have moved out of the area, will focus on the following topics:

- Your experience in science/technology/engineering in general terms of rewards, challenges, and how you were treated by teachers and peers.
- Your aspirations and expectations in relation to a career in science/technology/engineering.
- Unique resources that you brought to a career in these fields.
- Challenges that you might have faced in pursuing a career in these fields.
- Factors that might discourage you from pursuing a career in science/technology/engineering.

- Your career plans after graduation from college or completion of a graduate degree.
- Personal, academic, financial and cultural characteristics, and family situations or demands that might contribute to your career decision making.

The interviews will be digitally recorded and then transcribed for analysis. The digital audio files and transcribed interviews will be identified only with an ID number, and kept for up to five years in case the researchers need to refer back to the data.

RISKS INHERENT IN THE PROCEDURES:
There are no known risks. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

BENEFITS OF THE STUDY:
The interviews are likely to help clarify challenges that you might face in pursuing careers in science/technology/engineering, and the resources that you might bring to bear in surmounting those challenges. As well, the interviews will prompt you to consider career options, which is a key aspect of career development. This study lays the groundwork for developing more effective mentoring and support programs for individuals who are underrepresented in science/technology/engineering. As a result of this study, we hope that more effective methods will be developed to help high school and college students with career development related to careers in science/technology/engineering, and to recruit, retain, and mentor underrepresented individuals in these fields. Ultimately, this research addresses equal opportunity. If more individuals from underrepresented groups enter careers in science/technology/engineering these careers will be more representative of our society, providing more diverse role models, and there will be more opportunities for rewarding, high-paying occupations for all citizens.

CONFIDENTIALITY:
The transcribed interviews will have ID numbers but no other identifying information in them. A list with names with IDs and contact information, as well as signed consent forms, will be kept in a locked file cabinet separate from the interview transcripts, so that the information you provide about your career pathway cannot be linked to your name. The list of names and IDs will be kept for five years after the conclusion of the study because we may want to conduct periodic follow-ups of how many participants do pursue careers in science/technology. After five years, the list will be destroyed. Computer files that contain the data also will use IDs. Only general findings and quotations illustrating these findings will be shared with the public, not the specific information you provide.

LIABILITY:
The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

Questions about participants' rights may be directed to Janell Barker, IRB Administrator, at 970-491-1655.

Your participation in this research is voluntary. If you decide to participate in this study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled. Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature acknowledges that you have received, on the date signed, a copy of this document containing two pages.

_____
Participant name (please print)

_____ _____
Participant signature Date

_____ _____
Witness to signature (project staff) Date

CONSENT TO PARTICIPATE IN INTERVIEW (MIT)

Socialization of and Support for Women in Science and Engineering

You have been asked to participate in a research study conducted by Dr. Anette E. Hosoi from the Department of Mechanical Engineering at the Massachusetts Institute of Technology (M.I.T.), in collaboration with Dr. Silvia Sara Canetto and S. Aki Hosoi from the Department of Psychology at Colorado State University. The purpose of the study is to describe the career trajectories and educational experiences of university students in science/technology/engineering majors. It is meant to find out about aspirations, expectations, challenges, resources, and other factors that may encourage or inhibit students from pursuing education and entering careers in these fields. The ultimate goal is to identify ways to recruit, retain, and mentor students who are underrepresented in science, technology and engineering. The results of this study will be included in S. Aki Hosoi's dissertation. You were identified as a possible participant in this study because you are a student in science, technology or engineering. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• This interview is voluntary. You have the right not to answer any question, and to stop the interview at any time or for any reason. We expect that the interview will take about 45-90 minutes.

• Unless you give us permission to use your name, title, and / or quote you in any publications that may result from this research, the information you tell us will be anonymous and confidential. It will only be presented/published in an aggregate form (e.g., as part of a summary of themes present across interviews) without inclusion of identifying information. Below you will have the opportunity to give permission for use of any or some of this information in presentations/publications.

• We would like to record this interview digitally so that we can use it for reference while proceeding with this study. We will not record this interview without your permission. If you do grant permission for this conversation to be recorded, you have the right to revoke recording permission and/or end the interview at any time.

This project will be completed by August 2010. All interview recordings will be stored in a secure work space until 5 year after that date. The recordings will then be destroyed.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

(*Please check all that apply*)
[ ] I give permission for this interview to be recorded digitally.

[ ] I give permission for the following information to be included in publications resulting from this study:
[ ] my name [ ] my title [ ] direct quotes from this interview

Your Name _____

Your Signature _____ Date _____

Signature of Investigator _____Date _____

Please contact S. Aki Hosoi (hosoi@lamar.colostate.edu) with any questions or concerns. If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairperson of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253-6787.

APPENDIX C

ENGINEERING INTERVIEW

Questions about factors influencing career choice:

1. What are the events in your life that led you to where you are now in your education and on your career path?
    a. Why engineering?
    b. What factors have constrained your choice?

2. What individuals were most influential to you in making this decision and why? (a and b are possible follow up questions)
    a. What was role of parents?
    b. Who were your [female] role models (if any), [and how important was/is it to you to find role models and mentors who were also women?]*

    *parts in brackets should be omitted initially, but asked as follow up if the interviewee does not initially come up with any female role models

3. On your demographic form, you list the culture you most identify with as _____. How are women in science, and women in engineering in particular, viewed within this culture?
    a. How common is it for a woman to be a scientist/engineer in this culture?

Questions about challenges/factors influencing resiliency:

Individual factors:

4. How do you cope with setbacks you encounter in life in general and in your engineering training in particular?

5. How did you learn/develop these coping strategies?

6. Who are the major sources of support for you in dealing with such setbacks?
    a. Who are the people that you rely on most heavily for personal/academic support within the engineering department?
    b. Describe your relationship with your peers in your graduate program and how they have impacted your educational experience.
    c. Describe the impact that you have had on your peers in your graduate program.

7. Have you ever considered switching majors/careers, and if so, why?
    a. How difficult would it be for you to give up your current field of study and/or career aspirations and what factors could lead you to make such a change?

Relational factors:

8. If you are currently in a romantic relationship, describe how this partnership enhances and how it challenges your educational and career goals. If not currently in a romantic relationship, describe how you envision such a partnership enhancing or challenging your career goals, based on past experience or observation of others.
    a. At what stage in his/her career is your partner? How do you this has influenced/may influence your education and future career plans?

9. Do you have or plan to have children? How do you think these plans have been or will be affected by your career choice?

Institutional/societal factors:

10. How has your educational experience been shaped by being a woman/man?

11. You said on your demographic form that you identify as _____. How has your educational experience been shaped by this culture?

12. What are the biggest challenges you have faced so far?
    a. Economic
    b. Interpersonal
    c. Family
    d. Relationships
    e. Health
    f. Social expectations
    g. Time
    h. Self Image

13. What do you plan to do in terms of future education and career within the field of engineering and what are the biggest challenges to achieving these goals that you think you may face in the future?
    a. How do you think you compare to others in your program or others in this career in terms of your intelligence, skills, and abilities?
    b. Discuss the differences in the challenges you think you have faced/will face in your academic career versus your career after graduation.

Optional Question (if time allows):

14. If you can remember one, tell me a joke you have heard related to engineering or science.

Final Question (to encourage exploration of additional areas):

15. Is there anything else you can tell me that might be interesting or useful that I did not ask about?