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FACULTÉ DES ÉTUDES SUPÉRIEURES ET POSTDOCTORALES

FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

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Ph.D (Education, Conc. Psychopedagogy)

GRADE - DEGREE

Faculty of Education

FACULTÉ, ÉCOLE, DÉPARTEMENT - FACULTY, SCHOOL, DEPARTMENT

TITRE DE LA THÈSE - TITLE OF THE THESIS

Becoming and Engineer: Doctoral Women's Perspectives on Identity and Learning in the Culture of Engineering

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DEAN OF THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

BECOMING AN ENGINEER: DOCTORAL WOMEN'S PERSPECTIVES ON IDENTITY AND LEARNING IN THE CULTURE OF ENGINEERING

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Thesis submitted to the
Faculty of Graduate and Postdoctoral Studies
in partial fulfillment of the requirements for the degree of

Ph.D in Education

Faculty of Education
University of Ottawa

March, 2004

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395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 0-494-01778-3
Our file Notre référence
ISBN: 0-494-01778-3

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Abstract

Women face many obstacles in their academic careers but there is a gap in the research with regards to their perceptions of science and engineering education and how non/participation in the culture of engineering affects their identities. Moreover, little research has been conducted with female Ph.D. students especially with regard to the reasons they have continued their studies, and their level of satisfaction with their career and lives.

This study was guided by the sociocultural approach and theories of learning and identity. Methodologically, the design adopted is a naturalistic qualitative inquiry using two open-ended interviews with participant verification after the first interview. The life history narratives (Mishler, 1999) obtained from the seven doctoral electrical and mechanical women engineers, at various stages in their programs, were the primary source of data. By examining the path of becoming a doctoral woman engineer, this study makes the educational experiences of women intelligible to the general public as well as policy makers. It gives voice to the women engineers whose perspectives are rarely heard in academic settings or mainstream society.

The findings of the study lend insight to the importance and necessity of more inclusive engineering education, incorporating not only women's studies courses into the curriculum but anti-racism education as well as including the perspective of 'Other' people of difference. Moreover, multi-perspective approaches to increasing enrolment and retention of women in engineering were more effective and in keeping with addressing notions of 'difference' in engineering populations.

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CHAPTER ONE

BECOMING AN ENGINEER: DOCTORAL WOMEN'S PERSPECTIVES ON IDENTITY AND LEARNINING IN THE CULTURE OF ENGINEERING

Introduction

Overview of the Study

The purpose of this research was to understand how sociocultural influences, that is the relationship between learning on the one hand, and the cultural, institutional, and historical influences on the other hand, affect women's choices to participate in science and engineering. This interest developed as a result of my own teaching experience and my M.A. study entitled *The Family, Home, and School Environment's Influence On Gifted Girls' Perceptions of Choice to Take Extracurricular Science Classes*. The findings of this earlier study suggested that the broader environment or the sociocultural influences had greatly impacted pre-adolescent gifted[1] girls' choices to pursue extracurricular science classes (Wood, 1999; 2001).

The analogy of the 'leaky pipeline', that is, the notion of women leaving or failing to choose science in droves is voiced frequently by researchers and scientists (McIlwee & Robinson, 1992; Pattatucci, 1998; Sonnert, 1999; Sonnert & Holton, 1995). "If the structural and cultural causes for the leakages are ignored, attempts at increasing the representation of women at various pipeline segments may fall short"(Sonnert, 1999, p.39). Barriers to women have not been eradicated through studies and programs focusing on individual causes (Correll, 2001; Drew & Work, 1998; Gerdes 1995; Heller & Zeigler, 1996; Lee, 1998; UNESCO, 1999); neither have they been eradicated by those focusing on structural, cultural, or environmental causes (Brownlow, Jacobi, Rogers, 2000;

Dryburgh, 1999; Fletcher, 1999; Fox, 2003; Messing & de Grosbois, 2001; Owen-Smith, 2001; Sandler, 1986; Singh & Vinnicombe, 2000; Steinpreis et al., 2000); nor by those focusing on a combination of individual/environmental (Anderson, 2002; Dececchi, Timperson, & Dececchi, 1998; De Verthelyi, 1997; Fox, 1998; Taylor & Davis, 1999; Widnall, 2000). Other scholars, sometimes viewed as radical, suggest a post-structural analysis to better address the paucity of women in engineering and science (Bloor, 2000; Faulkner, 2000; Henwood, 1998; Herzig, 2001; Jones, 1997; Remlinger, 1995). Employing a poststructuralist analysis, this study attempts to bring a new perspective to research concerning women and engineering. In sum, women face many obstacles in their academic careers. Moreover, there is a gap in the research with regards to their perceptions of science and engineering education and how non/participation in the culture of engineering affects their identities.

Statement of the Problem

The field of engineering was chosen for this study since it is still considered as having the lowest rate of female enrollment in Canadian universities (Association of Universities and Colleges of Canada, 1999). The Canadian Council of Professional Engineers (2000) reported that the percentage of women majoring in engineering compared to men in Canadian universities is 21. The areas of greatest enrollment for undergraduate women were chemical, electrical, and mechanical disciplines of engineering (CCPE, 2000). In addition, the same source reported 15 per cent of doctoral students enrolled in engineering to be women. These results have improved in the last decade although the actual numbers are still small. "Over the past two decades, women have made gains as students and professionals in science and engineering. Yet women continue to lag behind men in the number of doctoral degrees obtained, and even more reason, in levels of professional participation, position, productivity, and recognition" (Fox, 1998, p. 201).

This disparity of female enrollment was further evident in the disciplines within the field. Frize (1998) asserted that "women are clustered in a few disciplines such as chemical, industrial, and environmental engineering, and their enrolment in mechanical, computer, and electrical engineering is currently half the national average [9-12 percent]"(p.4). These disparities were further noted in women's participation in graduate programs. "Programs at the graduate level merit special attention because graduate education is tied, directly and indirectly, to subsequent professional participation and performance in the field (Fox, 1996), and thus the graduate level is a critical stage for programmatic initiatives" (Fox, 1998, p. 201).

In Canadian universities "at the doctoral level, the top three disciplines were chemical, civil, and electrical engineering. All three disciplines registered increases in numbers in 1999 compared to 1998, with electrical showing the largest increase" (Martinson, 2001, p.15). One reason for this increase in electrical engineering interest could be perhaps its rewards. "The average personal income for members, in 2001, (including all sources) is $87,800" (CCPE, 2003, p.16). The CCPE (2003) surveyed their professional engineers to find overall that they were working predominantly in civil, electrical, and mechanical areas. The top occupational areas reported by women engineers included environmental, chemical, and educational, - an inconsistent finding with enrollment and degrees awarded-trends. Only women engineers were asked to answer questions about employer flexibility in relation to work and family. Of the women with families, 90% reported that their employers offered some degree of flexibility, with more than half saying 'a great deal', to balance work and family. The constructs 'some' and 'a great deal' were never defined.

According to the CCPE (2000), the overall total number of doctoral degrees awarded was at its' lowest during this last four year period [1996-2000]. While the total number of doctoral degrees awarded to women in engineering increased to 85 in 1999, a lower number of 72 was tabulated in 2000. Not surprisingly, regional disparities existed. In 2000, Quebec awarded 31 doctoral degrees to women in engineering and Ontario awarded 25, while other provinces in Canada graduated only a fraction of these numbers. The top producers of doctoral women engineers for 2000 were l'Ecole Polytechnique de Montreal and University of Toronto- with a total of ten each. While this seems promising, the areas of mechanical and electrical had only one doctoral woman graduate in each. This is a perplexing fact since female undergraduates choose these disciplines of engineering more frequently. It can be surmised from the CCPE (2000) *Trends in Engineering Enrolment* data that there appears to be approximately 15 doctoral women who are currently completing a full-time electrical or mechanical PhD program in Canada. While the number of participants in this doctoral dissertation appears upon first glance to be small, it must be remembered that they are a significant number of the participant pool of doctoral women candidates.

Significance of the Study

Recruitment and retention programs for women, in Canada and abroad, have attempted to address these disparities at all program levels (Cukier, 1993; Emerson, Williams, & Kieley, 2002; Ennett, 2002; Frize, 2002; Gibney, 1998; Jovanovic, Zinatelli, & Dube, 2002; Male, Lawrance, & Dias, 2002; Martinson & Smandych, 2002; Rinehart & Watson, 2002). Female undergraduate students have been the population most often studied in previous research on non-traditional occupational choices and the engineering culture (Anderson, 2002; Betz & O'Connell, 1992; Devorah, 1992; Dryburgh, 1999; Hackett, Croissant, & Schneider, 1992; Henwood, 1996: 1998; Kowalenko, 2000a; Morgan, 1995; Rowe, 1993; Verderame, 1998). However, little research has been conducted with female Ph.D. students, especially with regard to the reasons they have continued their studies, and their level of satisfaction with their career and lives (Frize, 1998). In Orton's (2000) "Woman On A Mission", issues around women in engineering were examined. Dr. Aboulnasr, the dean of engineering at the University of Ottawa was quoted as saying it is important not to just examine men versus women because "the faculty itself is so fragmented. They are divided along language, along cultural lines. It works in a very neat, fragile way" (p.29).

In the last ten years, approximately 20 graduate dissertations (MA & PhD) have been conducted that remotely deal with gender and engineering. According to Dissertation Abstracts International, six of these dissertations used qualitative research methodologies and are examined in the literature review. Moreover, seven graduate dissertations were completed concerning gender, identity, and science with only one using qualitative methodologies. Studies of engineering, especially in relation to the participation of women, tended to use positivistic designs along with quantitative methodologies. In many cases, survey data obtained from large data banks (i.e. Survey of Natural and Social Scientists and Engineers) were merely recycled-using a different method of analysis or were supplemented with on-site surveys (Bradburn, 1994; Devorah, 1992 Gadalla, 1998; Lee, 1998; Mooncroft, 1996; Verderame, 1998). A disparity in the literature concerning female doctoral engineering students and their perceptions of choosing and remaining in engineering was apparent (Dryburgh, 1999; Fox, 1998, 2000, 2003). In addition, this study investigated women engineers' participation in engineering as well as the affordances and constraints experienced in the culture of engineering. The following research questions have guided this study.

1. What sociocultural influences affect female PhD students' choice to participate in engineering?
2. What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering?
3. What do female PhD students perceive as the 'unofficial' ways of continuing the history and traditions of the profession in faculties of engineering?
4. How does the female PhD student's non/participation in engineering affect their identities?

Organization of the Remainder of the Study

The next chapter will present literature concerning women in science and engineering, the research questions, and the conceptual framework. Chapter three consists of this study's methodology, followed by the findings in chapter four to seven where each of the research questions will be addressed in its own chapter. In this way, a "postmodern research report does not follow a specific format; each has its own rhythm and structure" (Merriam, 2002, p.10). The discussion of salient themes and findings takes place in chapter eight. Finally, the study's implications are presented in chapter nine.

CHAPTER TWO

Literature Review

This literature review examined issues and challenges of women's participation in science and engineering. While not all salient themes could be discussed, this review focused on three main themes. Since the emphasis of this study was doctoral women's perceptions of identity and learning in the culture of engineering, that is where we will begin. Thus, the first theme described the 'Culture of Engineering' in regard to work and the academic environment. The practice of engineering in the workplace informs and influences, to some degree, the research and academic components taught in universities. As a second theme, 'Perspectives of Learning' was discussed in relation to discourse, and how that impacts on 'Identity', that is, as a self-chosen description of a person. A third theme, 'Contextual Influences' examined developmental studies of science self-efficacy and attitude toward science (Middleton, Littlefield, & Lehrer, 1992; Farenga & Joyce, 1998; von Glasersfeld, 2001; Wood, 1999). The chapter concluded with a description of the conceptual framework linking the literature review and the two main theories that guided this study.

The Culture of Engineering

The literature concerning the culture of engineering is presented in three segments. First, the 'work environment' is discussed as it informs practice within industry, and eventually within academia. Next, the culture of engineering is reviewed as it relates to studies conducted with regard to the 'academic environment' or more specifically, university engineering programs. A third section also related to academia, 'Social norms and language', examined how social norms are embedded in language and enacted in engineering programs.

Work Environment

Four key studies examined women's perceptions of various engineering work environments in the 1990's: Industry Canada's- Science and technology study, Sonnert and Holton's- Career paths, Fletcher's- Research and design engineering, and McIlwee and Robinson's- Gender comparison in engineering. These studies were most in keeping with the work environment and employed qualitative methodologies.

Industry Canada: Science and technology.

As of 1999, women comprised 16.9 per cent of Industry Canada's workforce in science and technology categories. Industry Canada credited this attainment of critical mass[2] to their 15-year recruitment and development program, as well as a 'Bridging Program' that internally trains and promotes women. Women were still underrepresented in some categories of science and at various managerial levels. Women made up 5.8 per cent of the technical inspection population and 5.7 per cent of all electronics specialists. They were poorly represented at the intermediate or high managerial levels. "The electronics category is still very much male-dominated [17 women to 282 men] but it does demand some soft skills related to dealing with the public, which managers acknowledge women are often better suited [for] than men" (Industry Canada, 1999, p.12).

Industry Canada found room for improvement in other categories where women were under-represented. Working conditions in some science and technology categories were characterized as high risk and physically difficult. Some required traveling alone to remote locations one to two weeks per month, which proved difficult for women with family commitments. Furthermore, in small district offices, some women felt alone and uncomfortable among a number of male colleagues in "what is still a man's world. When the men in the office socialized together in situations inappropriate to the female staff, the women did not feel part of the team" (p.20). Moreover, the few women in electronics positions felt they must continually prove themselves especially to their male colleagues. Deterrents to recruitment at Industry Canada included the perception of the government as very narrow-minded, the stigma of working for the government, and the decreased market availability of women engineers. These deterrents were compounded by aggressive recruitment by private industry.

Industry Canada's report did include an action plan of change. The components of the action plan identified by their three focus groups reinforced many initiatives: the notion of critical mass in all categories of science; implementing creative, flexible recruitment strategies that target young women; allowing alternative work arrangements as to the number of hours worked and the ability to work at home; and designing network and mentoring opportunities for women. While this action plan addressed key issues, the question remains: Can acceptance and a positive attitude toward women in technology be mandated? Certainly, it is a beginning, but as research points out, inequities and disparities are subtle and are entrenched in the history and culture of science (Sonnert & Holton, 1995; Pattatucci, 1998). Will this be enough?

Sonnert and Holton: Career paths.

A widely cited study by Sonnert and Holton (1995) examined the career paths of American women and men who had been identified early in their careers as promising scientists, mathematicians, and engineers after having obtained the prestigious postdoctoral fellowships from the NSF, the NRC, or the Bunting Institute at Radcliffe College. It appeared that a combination of differences, internal and structural, led to varied levels of career achievement among men and women. This study, although published in 1995, reported thirty-year-old data of the early careers of post-doctoral fellows. The structural and internal differences may have changed somewhat today. The 'typical' doctoral graduates of science were not represented in this study and the selection process for obtaining a fellowship at that time replicated the structural inequities in society. Finally, the participants did not represent ethnic, cultural, religious, regional, or other marginalized populations.

A mixed methodology was used, a questionnaire that allowed for statistical analysis of quantitative data, and interviews that permitted personal life histories to emerge. The findings suggested full gender equality in science careers and women's full "ownership" among men still seemed elusive. A complex web of gender relations and differences emerged instead of the once obvious denial of access to science. Another finding emphasized the importance of the field of science chosen. In biology, critical mass was obtained and may have made 'marginalization' less prevalent than in the other sciences. Although the authors characterized additional findings as subtle and slight, they did not report which marginalized populations were affected or how many exactly. What may appear statistically insignificant may in fact represent the majority of women and postdoctoral fellows of 'color', who may have overwhelmingly experienced these obstacles. Exclusion from the collegial networks and differences in internal predispositions such as self-confidence, ambition, career-goals, and interaction-style were two such examples given. Women also expressed a different viewpoint in relation to the normative notion of 'good science' as well as employing a slightly different style of 'doing' science. How exactly these 'differences' were received in faculties of science and engineering, as well as information on the penalties exacted were not indicated in the data.

Fletcher: Research and development engineering.

The third study, Fletcher's (1994; 1999) dissertation, and subsequent publication as a book, examined the practices that impacted workplace interactions in a Research and Development engineering organization. These interactions seemed influenced by societal notions of femininity and masculinity and how they are socially constructed, thereby maintaining and reinforcing gender inequity. A qualitative design was used to 'shadow' six women engineers at their worksite, observing and systematically recording their interactions with the environment. A priori constructs were employed as well as emergent categories in her analysis of the power-knowledge structure supporting the dominant discourse in relation to 'real' work" (p.150). What "counts as 'real' work" usually does not include relational activities. The marginalization of these activities in organizational discourse resulted in their being devalued and discounted so that they are considered invisible and insignificant.

The findings suggested "three mechanisms of 'disappearing' relational practice" 1) viewing relational practice as inappropriate, 2) limiting the language available to represent this activity as work, and 3) participating in the social construction of gender. Specifically, Fletcher (1994) affirmed that as "the social construction of gender 'disappears' the creation of team, ... [for example] female engineers were expected to listen to others' troubles, or to solve problems between people" (p.159). Moreover, "engineers not only choose to engage in this type of activity, they are expected and relied upon to do so" (Fletcher, 1994, p.159). In addition, female engineers in this study were called upon to do menial labor, to perform favors with no expected reciprocity, and to tolerate differential treatment. Furthermore, they were only 'allowed' by their engineering community to use collaborative language when making statements (e.g. when suggesting an idea, they would say 'we' or 'us', not I think). If they did not comply with these implicit expectations, they were accused of being a "bitch or dragon-lady". This suggested that as relational practices get 'disappeared' as work, they are moved from the public realm, to be seen as a private activity that is, an expression of woman's essential nature. On a positive note, when the relational activity relative to participants' statements and actions were not evaluated in reference to the dominant discourse, the activity could be seen as an act of resistance to the unquestioned assumptions inherent in those evaluative rules about the nature of work, success, commitment, and effectiveness that challenged the models of growth through individuation.

Fletcher (1994; 1999) suggested that more fieldwork is needed to ascertain a more in-depth understanding of gender asymmetry along with a plea for research that explores the gendered nature of many organizational assumptions. The notion of 'real' work needs the gendered nature of many organizational assumptions. The notion of 'real' work needs to be questioned empirically in order to capture the complexity of issues involved as well as the magnitude of resistance to change. Moreover, a new class of interventions is necessary because traditional approaches to these issues locate the "problem of the public/private split at the organizational or societal level and subsequently frame solutions at these levels which often result in giving women the same opportunity and motivation as men to devalue the private side of themselves and sever it from their public selves" (p.187). Although the R & D engineering organization reported ten per cent of their employees to be women and ten per cent to belong to an ethnic minority, none of Fletcher's participants were members of a minority population. Perhaps, only ethnic males comprised the sample. In any case, this issue was not addressed. In addition, it was not the case that shadowing was only slightly intrusive in this engineering organization because some participants reported not being approached as often or that their interactions with the other engineers were more brief and more business-like than usual. To recapitulate, the social construction of gender affected how women got to interact in teams with an emphasis on maintaining the relational practices within organizations.

McIlwee and Robinson: Gender comparison in engineering.

McIlwee and Robinson (1992) was one of the largest and most comprehensive studies conducted by social scientists using partial qualitative methodologies. The data was gathered in 1986 with a random sample of 406 B.Eng. graduates of electrical and mechanical engineering [1976-1985] from two public universities in southern California. The authors randomly sampled 30 men and 52 women to participate in open-ended interviews. The follow-up interviews were designed to delve into the experiences and attitudes relating to women in engineering.

The findings reported by the women participants uncovered academic excellence in math and science as the most important reason for their engineering selection, followed by viewing the profession as practical, and being seriously encouraged by someone to pursue this career option. On the other hand, men cited a love of tinkering, following in their engineering/scientist fathers' footsteps, and their interest in electronics and mechanics as motivators to choose a career in engineering. While the decision to become an engineer was made early by men, women tended to select this major during their second or third year in university. Women's academic successes in math and science prepared them to switch to an engineering program. Moreover, the women engineering students reported feeling insecure about their limited mechanical experience as children and this feeling may have translated into their technical insecurity as practicing engineers. McIlwee and Robinson (1992) posited that both male and female students shared a structural position of powerlessness at the university level, and it was self-interest that led to cooperation especially since the women tended to be the most "talented and diligent in the class related to theoretical-abstract coursework" (p.30).

The women in this last study were 'gender role traditionalists' who appeared to 'drift' into engineering partially in response to the changing social climate and affirmative action programs of the late 1970s. Although hired quickly and with greater starting salaries than many men, the women in this study remained in lower status positions because they thought that the male engineers held the power of the workplace where emphasis on male-defined styles of interaction were valued. The 'culture of engineering' in both the academic and workplace settings, along with the women's family lives all contributed to the complex dialectic of structure and gender role, power relations, and inter-actional resources that placed the women at a disadvantage.

Based on the dearth of information, McIlwee and Robinson (1992) may have thought it necessary to compare male and female graduates' perceptions of the culture of engineering although it would perhaps, have been beneficial to explore within gender/sex[3] differences. Although they mentioned minorities in relation to "tokenism", they did not examine whether the female participants represented diverse races/ethnicities, or whether they were perhaps doubly stereotyped. This study explored the effects of gender, power, and the culture of engineering but neglected to investigate non-conformity in relation to gender, sex, and sexuality.

In summary, all of the studies examined the workplace environments of undergraduate engineers with the exception of the Sonnert and Holton (1995) study which included the postdoctoral work environment of many disciplines of science, math, and engineering. Interestingly, two of these studies included comparisons of genders in relation to work environment (Fletcher, 1999; McIlwee & Robinson, 1992) while the two other studies looked at within gender differences (Industry Canada, 1999; Sonnert & Holton, 1995). All of these studies predominately used qualitative research methodologies and were important in providing new ways to view and study the disparity of women's representation in engineering.

Academic Environment

Academic research, while usually directed by professors, was influenced and sometimes contracted by industrial partners. At some Canadian universities input from industry ranged from Co-op placements and summer jobs, to mentoring programs, or sponsorship and contracts as part of doctoral students' research. In many ways, the work environment eventually affected engineering research, curriculum, and practices. Four informative studies are discussed in this section of the literature review: (1) Dryburgh's: Professionalization process of women engineers, (2) Anderson's: Social construction of female engineers, (3) Dececch et al.'s: Non-traditional environment, and (4) Fox's: Participation and performance.

Dryburgh: Professionalization process of women engineers.

Dryburgh's (1999) qualitative study examined the professionalization process of women engineers in a Canadian faculty of engineering. Dryburgh posited that as women progress through academic and professional training, they are required to make additional adjustments and adapt to the masculine culture. "The rituals, ceremonies, stories, and symbols associated with engineering training are cultural forms that convey the masculine ideology of the engineering culture to aspiring engineers" (Dryburgh, 1999, p. 681). The first rite of passage included adapting to the 'hard work culture' in the first year of the program and the symbol of this successful adaptation was the engineering jacket- a sign of solidarity. Engineering students were united in hardship and this strengthened their team building as they work in groups. Engineering courses are known to be difficult and anxiety producing for most students. The engineering school served as a 'gatekeeper' and those who do not successfully adapt are weeded out.

> The anxieties these women experienced stemmed from their gender identification, rather than their ability to do the assigned jobs. Strategies women use to deal with the gender-related challenges included defining sexist behavior as exceptional, working hard to show their solidarity with male colleagues and coworkers, and accepting uncritically the masculine culture into which they are entering (Dryburgh, 1999, p.676).

After completing the final year of their program, two more rituals made visible their solidarity with the profession. The ritual of the 'Calling of the Engineer' and the 'Common Oath of Obligation' bound them to the history and practice of the profession. The iron ring, as a symbol, and the oath were constant reminders that they needed to perform well and show competence, diligence, and confidence. "Women engineering students consistently identify themselves with the masculine culture of engineering" (p.680). This identification helps women fulfill the demand for solidarity and develop a strong bond with the 'work hard' and 'party hard' image. "Having made their affiliation known, women vary in their actual participation in the engineering play culture". What appeared to be central was their conveying "the impression that they are not a threat to the traditions of the play culture" (p. 680). To this end, "learning the occupational culture, how to portray their competence to others, and how to convey solidarity required extra effort beyond what was asked of men in a similar position" (p.681) but was required of women engineering students.

Anderson: Social construction of female engineers.

Anderson's (2002) predominantly qualitative dissertation uncovered the social construction of female engineers at the University of Saskatchewan during three different stages of engineering education: (1) in the first year, the social factors influencing the choice of engineering as a profession; (2) in the following years, what causes students to discontinue engineering studies; and (3) engineering students' educational, social and cultural experiences during their third and fourth years of the program. Anderson's cohort, that is, students entering first year engineering were racially homogeneous. Women entered engineering with high academic credentials and took pride in the mathematical and physics abilities while the males took these abilities for granted. The female engineering students' reported motivation for enrolling in engineering studies was their ability to do math and science well. Those graduating students who participated in the study reported combining personal interests, skills, and strengths when choosing an engineering specialization.

Overall, Anderson found a 'chilly climate' of fewer educational opportunities for women in the college of engineering. "The culture, which in addition to exclusionary features includes a heavy work load with little time left for outside activities, was a major reason for attrition from the engineering program" (p.2). This learning environment was also fraught with discomfort related to the harassment of female students. Women who attempted to voice their objection to this treatment were labeled as "troublemakers, poor-team players, and lacking a sense of humor" (p.11). Engineering students chose to leave the engineering program because they were uncomfortable with the male dominated culture where attitudes of superiority and elitism pervade. Second, attrition was related to unrealistic expectations of learning and its subsequent heavy workload. Interestingly, women did not respond well to the linear nature of engineering education.

The participants in this study reported numerous factors that affected their success, such as "the size of classes, the course load, the professors' skill, teaching style and dedication, and an inviting climate both within the classroom and in social interaction among the students and between the students and their professors" (p.145). Engineering pedagogy focused on "information and testing, and less on exploration and understanding of concepts" which many male and female students disliked (p.188). Women were not acknowledged or considered in the pedagogy of their courses. Moreover, the "workload left little room for social interaction outside....the masculine culture of the college" (p.186). Feeling excluded, women sought opportunities to socialize in activities with other women since they were "always being judged through male students' eyes and perceptions" (p.215). Moreover, "in the social environment some of the women experienced a hostile climate of jealously and sexual and disparaging remarks and objected to extra curricular activities that generally appealed to male students" (p.213).

In sum, Anderson asserted that a critical aspect of attrition was the "hostile environment in the engineering culture" (p.215). Furthermore, for those women who did not leave the program, exclusion was an ever-present aspect of their learning. "The results of this study reinforce the view that gender is performed on a daily basis at the micro-level and requires the active participation of all the actors in the environment, men as well as women" (p.221).

Dececchi et al.: Non-traditional environment.

In another study, Dececchi, Timperson, and Dececchi (1998) investigated the non-traditional environment of the Royal Military College of Canada (RMC) where the majority of female cadets were enrolled in engineering programs. This study argued that the multiple barriers the women engineering cadets faced negatively impacted their educational opportunities. These identified barriers were classified as situational, institutional, and dispositional.

Situational barriers, that is, obstacles that arose from one's situation in life, were identified as major impediments to the women continuing in engineering. Women in the study spoke of lack of realistic preparation for university or for a military lifestyle, physical fitness requirements at RMC, and absence of support systems of family and friends.

Institutional barriers were considered to be those practices or procedures that excluded or discouraged participation of "women in military college life, [including] equipment or clothing designed to fit the male body, safety, mentoring, and harassment policies" (p.23).

Women engineering students also described dispositional barriers. Self-perceptions of mental and physical abilities, personal appearance, comparison to others, survival and other coping strategies were thought of as barriers to learning and participation.

The interview and questionnaire data of the women engineering cadets at RMC contained stories with sexual harassment overtones. Dececchi et al. found that "although some of the problems detailed by the respondents could be described as forms of sexual harassment, and many would appear to be defined as systemic harassment, none of the cadets interviewed used the term 'harassment', or would allow the interviewers to us the term" (p.28). The necessity of being 'part of the team' was essential to learning in engineering and compounded by the fact that military cadets lived and worked together. The women did not report the verbal comments "in part because of their desire to be part of the group, which causes them to resist anything that they see as putting up barriers to their inclusion. They identify the 'banter' as part of the close relationship between cadets" (p.31). To complain or lay charges against another cadet would ensure marginal participation for women engineering cadets. Moreover, "to call the situation harassing may be seen as admitting that the situation is beyond their control... Not naming the problem is therefore an avoidance strategy in that it allows them to believe that they are in control of the situation" (p.31).

Dececchi et al. (1998) posited that female cadets were reluctant to lodge complaints of harassment because they had developed a friendly rapport with male cadets and they wanted to belong to the dominant culture. This presented a contrast to the Dryburgh (1999) study, in which the women engineering students treated the male engineers' sexist behavior and comments as 'exceptions', and called on the 'solidarity of engineers' to keep harassment in check thereby operating within the 'brotherhood' code or norm.

Fox: Participation and performance.

Fox (1998) examined the relevant factors thought to affect the participation and performance of graduate level women in science and engineering. This predominantly qualitative study brought to light connections between theory and implementation of three basic types of programs: re-entry, student-led, and co-op. "The programs' *definitions* of the problem represents levels of analysis, individual and structural; the *meanings* of gender and gender disparity represent theoretical perspectives; and the *solutions* represent practice, and often operational policy" (p.202). This study found that each program's definition in relation to the disparity of women in science and engineering varied according to whether the administrators viewed the problem as "reflecting individual characteristics of the women or regarded it as a result or reflection of the environments in which women are educated and work" (p.220). Based on the type of graduate science/engineering program, that is, re-entry, student-led, or co-op, programs were in keeping with their definitions in relation to the paucity of women enrolled. Therefore, the re-entry programs for mature, diverse students were individual in definition, that is, problems were thought to be related to the individual characteristics of the woman. The student-led initiatives in graduate programs were environmental in definition, related to the context and educational experiences. The co-op partnerships and industry-academic programs had mixed foci, identifying both individual and environmental factors, while the comprehensive programs had divided foci in their definitions.

In relation to gender, "a perspective of 'difference' predominated across program types and perspectives, individual and structural. Further, the perspectives of two-thirds of these programs have shifted or are expected to shift- usually toward a view of gender neutrality. This fluidity or non-static nature of programs indicates the importance of considering the evolution of programmatic foci" (p. 220). At this time, 'gender as a hierarchy' has not been addressed in any of the programs. It is perhaps, at this time, too great an endeavor to 'deconstruct' power at the macro-level in social institutions. One reason for this may be that "the attempts to fit individuals to existing structures of education and the workplace meet fewer barriers and obstacles than do efforts to change organizations and their hierarchies"(p. 220). Therefore, the one program that was moving towards a 'hierarchical gender perspective' "tended toward solutions of creating alternative environments rather than of making changes in existing departments or research groups" (p.221).

Interestingly, the only program that identified one of the main problems for change was the industry-academic partnership. "The relationships between programs and their institutional, disciplinary, and regional contexts illuminate the dependencies of programs and, more specifically, expose facilitators and restrictions on programs' objectives" (p.221). One of the noted barriers to meeting program objectives was the advisor-advisee relationship expressed by the site "external to the university and its intra-organizational power relations" (p.221).

In another study, Fox (2000) affirmed that despite changes in organizations and leadership aimed to improve participation and performance of women in science and engineering, the advisor-advisee relationship has remained "untouched" (p.57). These modifications in programs have not impacted on the 'decentralized' laboratories where individual faculty members train their 'own' students-- an example of a type of privatization. This was in part related to the high costs of facilities and of staff being funded through research grants of individual faculty members. "Graduate students work on faculty's funded projects, acquire skills and experience, and proceed toward a doctoral degree... The research programs, external funding, and graduate training of science and engineering departments have been especially critical to the status and national ranking of universities" (p. 57). Therefore, universities are unlikely to decentralize and possibly risk negative changes in status and rankings. Decentralization is "particularly at odds with initiatives to transform department, research groups, and advisor-advisee relationships" (p.58). For example, in the absence of guidelines for sufficient work for the PhD, this allowed "individual faculty members nearly complete latitude in the decision of whether to award individual degrees, with a potential for abuse" (p.58).

In doctoral programs in science and engineering the representation of women as faculty members was deemed important to the advisor-advisee relationship (Fox, 2003). Fox (2003) found that more women faculty performed the role of primary research advisor for female students, had more women doctoral students on their research teams, and overall, had larger numbers of students on their teams– both male and female. Women faculty advisors tended to view the relationship as "mentor-mentee", and to make appointments "by design" to see and discuss student research once a week (p.105). While women faculty put more emphasis on helping all students, they placed greater importance on female students performing a "range of interactional capacities, not only publication of papers" such as participating in laboratory meetings, making presentations, and interacting with faculty (p.105). Importantly, women advisors not only emphasized ambition and hard work with their women students but also encouraged "alignment with successful faculty" as necessary for success within academia. "Thus, women faculty are recognizing the role of social and organizational opportunities/constraints, as well as personal characteristics, in understanding and explaining success for female students" (p.106).

Constructing Engineers: Social Norms and Language

The social norms embedded in our language help construct engineers. Three studies examined the roles of: (1) language and differential treatment, (2) language in constructing experience, and (3) language in dominant discourses.

Remlinger: Differential treatment.

Remlinger (1995) examined language, gender, and sexuality within the faculty of engineering at Michigan Technological University. Ethnographic data illustrated how and why the everyday talking and writing of university students revealed their attitudes, values, and beliefs about gender and sexuality. Findings suggested that students "simultaneously produce, resist, and oppose resistant ideologies. Thus, ideology is a dynamic, constantly constituted set of cultural meanings where community members make sense of their world"(p.172).

Differential treatment based on sex, gender, and sexual practices limited the women's access to the same education as the one given to the male engineering students. These limitations often occurred through "constraints on meanings and through events and activities that center on androcentric and heterosexual ideals of romance and relationships, and therefore, through the exclusion from the participation in and constitution of the campus culture for those students not meeting these ideal standards"

(p. 177). Moreover, the apparent approval through inaction conveyed to students that resistance to these normative notions was ignored or silenced.

Jones: Language in constructing experience.

Similarly, Jones' (1997) employed a post-structural analysis of the ideological role of language in constructing rather than representing experience. Regardless of their self-reported ethnicity, gender issues provide constant obstacles for women in the sciences. All of the women described feelings of exclusion while 'men of color' appeared to be the most acculturated of the non-traditional group. Some men used their masculinity more effectively than others in the community, thus contributing to the perception that some people are more different than others. 'Women of color' live at the intersection between racism and sexism never certain which form of oppression was behind the treatment they received. The notion of the 'culture of science' seemed to contribute to the fact that certain underrepresented racial/ethnic groups continue to be denied access to scientific knowledge as well as the right to participate in its production.

Henwood: Dominant discourses.

Henwood (1998) examined discourses on gender, sexuality, and work in a college of technology in Britain. This interpretive post-structural study investigated how participants made sense of their experiences in traditional and non-traditional subject areas and illustrated the need for a new approach to understanding the positions of women in engineering. Educational and occupational choices for different types of work can be seen as a negotiation of "complex interconnection of discourses concerning the relationship between gender, sexuality, and work" (p.46). Dominant discourse constructs this relationship and, therefore, the subject positions allocated to women. Henwood noted a major contradiction in the dominant discourse; namely, "gender differences are understood as natural and yet at the same time vulnerable to change and blurring through education, training and work especially where women are encouraged to enter areas associated with the opposite sex" (p.46). This paradox helped explain the limited success of "equal opportunities initiatives, the confusion and conflict experienced by many women studying in non-traditional subject areas and the reluctance of these women to discuss the problems they face" (p. 47).

'Difference' was constructed in two contradictory ways by lecturers [professors] in the department of engineering. "Women are understood as 'different from men' in that men are seen as immature whilst women have a 'civilizing effect' on men in mixed groups. Here, feminine subjectivities are being produced alongside masculine ones as if one somehow complements the other" (p. 43). Next, women engineers were perceived as 'different from other women'. They were viewed as "high flyers, really strong characters", in essence- 'exceptional women' and "therefore, by implication, different for the majority of women" who would be "put-off" by engineering. This construction placed "extreme pressure" on women entering engineering to be outstanding (p.43). When women performed as well as male students the boundaries of gender were transgressed. "In order to restore equilibrium in the gender order [in engineering], those who feel threatened seek to reassert gender differences at every opportunity and thereby reconstruct gender relations and appropriate gendered subjectivities in discourse" (p.43).

Henwood identified three mechanisms by which participants are constituted in discourse. 'Identification' is posited as "the mode of good subjects who freely consent to dominant discourse; 'counter identification' is the mode of those who reject this discourse or set of meanings offered; and 'disidentification' is the mode which works on and against the prevailing discourse" (p.40). Women engineers found it hard to speak outside the dominant discourse of 'difference'. "Engineering women talked of men's sexism but were reluctant to develop a more systematic critique of men" (p.44) and gender. Such a critique is associated "in participants' minds with feminism, which in turn is associated with a challenge to dominant constructions of sexuality, particularly heterosexuality" (p.44). While these "accounts demonstrate that issues of sexuality are ever-present in these women's consideration about work, its significance in those deliberations is never fully explained" (p.45). Henwood concluded that a position of 'disidentification' is necessary for a transformation of "existing gendered power relations" and requires a readiness to put forth a real change in relations between the sexes, "even where this might mean undermining the dominance of conventional heterosexuality"(p.47). The obduracy of occupational segregation patterns may in fact be related to the realization of what measures are really to effect change in gendered power relations.

In sum, the literature on the culture of engineering examined both the work and academic environments. In addition, the notion of language replicating social norms and contributing to the process of 'constructing an engineer' were introduced. The next section of the review will examine the learning process in becoming an engineer.

Perspectives on Learning

This section of the literature review addressed perspectives on learning from a broad context as well as those specific to science and engineering. Two focal areas were discussed. The first, 'Discourse, Conversation, and Language' examined language as a tool affecting gender/sex and learning, as well as how they act as a vehicle for knowledge construction. The second area, 'Pedagogy', that is, the teaching process was reviewed from a broad constructivist–historical standpoint as it pertains to engineering curriculum reform.

Discourse, Conversation, and Language

During the 1990s, gendered social norms permeated learning. In keeping with this view, Guzzetti and Williams (1996) examined the perceptions of students who participated in science class discussions. Because young women frequently expressed their opinions in the form of questions, males in this study thought that this suggested a lack of knowledge (Guzzetti & Williams, 1996). "Women's' explanations for their differential participation in whole class, refutational discussions alluded to issues of self-confidence and social norms" (Guzzetti & Williams, 1996, p.41). This finding was in agreement with Mehan (1996), who posited that the way events are represented in language influenced the way we think about the events and the way we act toward those events.

The young women in Guzzetti and Williams' (1996) study of discussion in the science classroom complied with socially learned norms of gender-appropriate language. They refuted less often and posed refutations as questions. The self-confident ones openly expressed themselves as "feeling ineffectual and having their opinions dismissed by the men" (Guzzetti & Williams, 1996, p.41). By the time young women take science classes at the high school level, they had already learned when women should speak and when they should be silent (Brown, 1998; Gilligan, 1993; Lewis, 1990). Even women who choose to take science at the university level "did not report [perceive] gains as high as male students in the science, technology, and quantitative skills areas" (Drew & Work, 1998, p. 543). In post-secondary classrooms, "all female students are more likely to be quiet in class and less likely to assume a powerful role in discussion" (Sadker & Sadker, 1990, p. 23). Gilligan, Lyons, and Hanmer (1990) think society sends a clear message, "keep quiet and notice the absence of women and say nothing" (p.26).

In discussions with men, women are placed in inferior positions. Males seldom give females a chance to talk, regard what they said as important, or consider them as equal participants in the discussion (Guzetti & Williams, 1996; Leroux, 1997; Lewis, 1990). Bernstein and Gilligan (1990) reported that young women think fairness and listening are intimately related concepts. Furthermore, Cherryholmes (1988) and Foucault (2000) affirmed there are hidden rules that govern discourse, establishing who can speak, when, and with what authority. It is not necessarily what is being said, but who is doing the talking that reflects the 'power' in a relationship (Guzzetti & Williams, 1996). The acknowledgement of power or validity of knowledge has been given the term 'positionality' (Davies & Harre, 2000; Maher & Thompson-Tetreault, 1992). Kelly and Chen (1999) posited that the tendency for men to achieve more than women in science results from greater opportunities to engage in academic activities where discussions prevail. Why are discussion opportunities so important in the learning process?

Depriving females of discussion was especially harmful in science therefore, it is important to discuss ideas when students' theories are contradicted by scientific thought (Alvernann & Hynd, 1989; Driver, 1995; Kelly & Chen, 1999).

Bruner (1996) noted that thinking and conversation reflect Bakhtin's 'dialogic imagination', where "I cannot become myself without the other", and that both enhance the learning process (Bakhtin, 1979, p.12). Classroom learning and discourse is thought to take place in phases. 'Authoritative discourse', the first mode, "stands or falls together with that authority" (Bakhtin, 1981, p. 343). The second, 'Internally persuasive discourse', in which a word is a combination of ours and someone else's, "is able to reveal ever new ways to mean" (Bakhtin, 1981, p.343). Dialogical aspects of classroom discourse are considered to address cultural differences of students and teachers, where classroom dialogue may not be .educationally effective. Sidorkin's (1999) 'Third discourse' is based on Bakhtin's (1984) 'carnival' and is "the mechanism that creates the possibility for the genuine dialogue to happen...where one is known in an informal way" (p.136). In other words, what sense students make out of classroom talk outside of the classroom. This aspect to learning has not been given enough consideration when planning learning situations. In a similar vein, Wells (1999) affirmed that "by contributing to the joint meaning making with and for others, one also makes meaning for oneself and, in the process, extends one's own understanding"(p.109).

In sum, discourse and narrative are described as a mode of thinking, as a structure for organizing our knowledge, and as a vehicle in the process of science education (Bruner, 1996). Moreover, Bereiter (1994) asserted that this is a time when the belief in 'objective truth' has been replaced by an awareness of contextual influences, both cultural and historical. The only way to move scientific discourse forward is for students to experience an apprenticeship into this field, "moving from peripheral to more skillful and central participation" (Wells, 1999, p. 219).

Constructivist Pedagogy

The implementation of constructivist notions of theory into practice has been attempted in many learning environments, and most recently in technology and engineering. Vygotsky's sociohistorical theory of psychological development, further enriched by Luria and Leont'ev, informed the foundation of sociocultural theory and constructivist practices of teaching and learning. "Vygotsky emphasized the complex mental functions of categorical perception, logical memory, conceptual thinking, and self-regulated attention. The development of these capabilities is determined by the sociohistorical heritage" of the person's culture and social experience (Gredler, 1997, p.269). Therefore, the person's interaction within their society and the history of that society cannot be taken out of context.

> Throughout history, humans have continued to develop a variety of signs and symbols that function to develop the cognitive abilities of each new generation. In addition to speech, the symbol systems developed by various cultures include written letters, mathematics, musical notation, and computer languages...[that] bring about behavioral and psychological transformations leading to development of complex mental processes [in learners] (Gredler, 1997,p. 241).

Major contributions of Vygotsky's theory include the "role of culture in learning and development, recognition of the psychological functions, and the importance of social action during learning" (p.271). More specifically, "this theory establishes the sociocultural setting as the basis for development and learning. Therefore, learner characteristics, cognitive processes, and the context for learning are all viewed from the same perspective" (p.266).

Duffy and Cunningham (1996) have compiled a list of assumptions for designing constructivist practices in technology-based classrooms that view: (1) learning as a process of construction so there will be multiple constructions/perspectives, (2) learning should occur in contexts that are relevant to the learner, (3) learning is mediated by tools [technology] and signs [semiotic tools], and (4) learning is a social-dialogical activity. Therefore, learners are 'distributed', multidimensional participants in a sociocultural process of making 'knowing how we know' the ultimate human accomplishment.

Based on these constructivist assumptions, Harper and Hedberg (1997) suggested that appropriate learning outcomes be devised that "no longer rely on the behavioral bias of current instructional design models... such as traditional hierarchical, prerequisite sequences [i.e. learning taxonomies] that concentrate on recall and application of knowledge" (p.4). Krathwohl (2002) has asserted that students need to be aware of their metacognitive activity, and then use this knowledge to appropriately adapt the ways they think and problem-solve. In this vein, Jonassen and Tessmer (1997) presented a new taxonomy that details higher order cognitive, metacognitive, and motivational learning outcomes not considered in current taxonomies. New taxonomies should inform the development of instructional strategies that encourage many 'types [styles] of learners' such as active, strategic, intentional, conversational, reflective, and 'ampliative' that is, learners who generate assumptions, attributes, and implications of what they learn.

The development of learning situations that are compatible to the different learning styles can seem intimidating to many professors/teachers. "To the learner, the constructivist learning experience may … seem daunting and complex to those who feel ill-prepared for such creative freedom and choice of direction. Often constructivist learning situations suddenly throw students on their own management resources and many fend poorly in the high cognitive complexity of the leaning environment" (Harper & Hedberg, 1997, p.5). In order to compensate for this less structured learning environment, Harper and Hedberg (1997) suggested constructing explicit learning outcomes. In other words, metacognitive self-management and well planned curricula, as well as employing scaffolding and apprenticeship models to ease learning discomfort are encouraged. Going beyond recommendations for learning strategies, Voithofer and Foley (2002) posited the "use [of] postmodern frameworks to recognize the complex social, cultural, and political dynamics that have implications for the negotiations of race, class, gender, and ethnicity within diverse learning environments and that are set in motion when learning with technologies" (p.12).

From the constructivist perspective, technology mediated learning environments can act as a mediated tool to enhance student learning. Different methods of implementation have been used in engineering classrooms and faculties including Constructivist Learning Techniques (Fowler, Armarego, & Allen, 2001; Gallini, 2001; Gruba & Lynch, 1997; Pang & Hung, 2001; Tan & Hung, 2002), Student Learning Communities and Methodologies (Carpenter & Schunck, 1999; Fowler, Allen, Armarego,

& Mackenzie, 2000; Lee, Budd, Doornbush, & Fyfe, 2000; Morgan & Rinehart, 1999; Reklaitis, 1999; Trigwell & Prosser, 1996:1997; Van Boxtel et al., 2002; Van Driel, et.al., 1997), Computer Assisted Assessment (Roy & Armarego, 2002), and Problem Based Learning (Armarego, 2002; Hannafin, 1997; Proulx, 2003; Woods, 2003). Most of the strategies and methods mentioned above are included in the ideology of Problem Based Learning [PBL] that is rooted in experiential learning traditions and is student centered.

Savin-Baden (2000) asserted that PBL should pursue the following objectives: acknowledge student experience, emphasize student responsibility for learning, cross boundaries of disciplines, combine theory and practice, focus on the process of knowledge acquisition, transform professor to facilitator, focus on student self/peer assessment, and emphasize communication and interpersonal skills. What sets this method apart from the other teaching strategies is the context and purpose(s) of learning. Walton and Mathews (1989) emphasized an integrated curriculum organized around real-world problems, not disciplines, with an emphasis on cognitive skills. PBL should take place in small groups with tutorial instruction promoting active learning. Learning outcomes should promote the development of skills and motivation to become lifelong learners.

Faculties of engineering have endeavored to incorporate these curricular changes and teaching strategies into their practices by implementing integrated curriculum in first year engineering (Al-Holou et al., 1998; Sheppard & Jenison, 1997). Laboratory courses were modified to include interdisciplinary curriculum (King et al., 1999). Integrating PBL with curricular changes in upper-class levels (Woods, 2003) was another variation.

The full integration of curriculum at all levels, PBL, and team-teaching of 'just in time concepts' was another attempt to address the need for improved teaching strategies and curriculum (Proulx, 2003).

While these constructivist changes to the learning curriculum and environment are in their infancy, it is not clear how this will affect the students' learning of content necessary to 'do' engineering, or how this will in fact shape the culture of engineering.

Contextual Influences

The lived experiences of females in science are affected by many sociocultural influences. Key studies addressing sociocultural issues of identity and belonging in science pursuits are reviewed in light of the intent of this study, that is, the home and school environments and their subsequent effect on women's self-efficacy and on notions of sex-roles and science.

Home Environment

The American Association for University Women (1992; 1998; 2000) asserted that family and schooling have a greater impact on self-esteem than do peer-groups. The home environment was a critical component in the success of students' level of school achievement, interest in school learning, and years of schooling sustained (Kellagan, Sloane, Alvarez, & Bloom, 1993; Martinez-Pons, 2002). Pride in schoolwork, the belief that one is able to do many things well, and the feeling of being important in one's own family were the major contributions to self-esteem (Kerr, 1994).

Parents of gifted children appeared to have different expectations than do parents of non-gifted children (Karnes, Shwedel, & Steinberg, 1984). The former expect a greater sense of independence in terms of self-care and achievement. Bandura (1997) argued, however, that parental beliefs about their children's capabilities differed depending on the sex of the child. Hence, parents frequently have different expectations for gifted females and these may influence their decision not to enroll them in a gifted program when the child has been offered. Surprisingly, some parents only provided monetary support for post-secondary education of males (Maccoby, 1999). Parents often failed to enroll a daughter because of sex-typed values that reinforce conformity, docility, and other sex-role characteristics such as love of children, gentleness, and understanding (Bem, 1974; 1993). The more strongly females adopted gender-roles that are stereotypically feminine, the more frequently they underestimated their capabilities (Bandura, 1997; Kerr, 1994).

How do parental expectations transfer to their children's behavior? Males and females exhibited different patterns of self-appraisal, the origins of which are partly rooted in their parents' gender-linked beliefs about the capabilities of their children (Pajares, 2002; Phillips & Zimmerman, 1990). Hence, even when students were equally competent, males exaggerated their sense of competence and females generally disparaged their capabilities (Phillips & Zimmerman, 1990; Wigfield, et al., 1996). Parents viewed school as more difficult for their daughters despite evidence of high academic achievement (Hollinger & Fleming, 1992; Phillips & Zimmerman, 1990). Similarly, females often perceived that their mothers had lower academic expectations and tolerated lower grades and achievement for them compared to males (Phillips &

Zimmerman, 1990). Howard-Hamilton and Robinson (1991) believe that males are encouraged to develop independence and risk-taking abilities. They are persuaded to be adventurous. Conversely, females are not being provided similar social learning experiences; oftentimes they are encouraged to underestimate their own intellectual, psychological, and emotional abilities (Bussey & Bandura, 1999; Pajares, 2002; Zelden & Pajares, 2000). Thus, the very characteristics that some parents' value, model, and teach to their daughters may cause them to perform poorly and avoid so-called 'masculine' subjects such as math and science.

School Environment

An ideology of equality has permeated school policies, teacher training, curriculum guidelines, as well as textbooks and distributors of educational materials. Many of these sources of information truly believed they were conveying gender and racial equality. However, there appeared to be a hidden curriculum in which verbal and nonverbal messages about appropriate gender behavior was transmitted. Students received information about themselves and others of their gender and race through illustrations, language, content of books and film, and from feedback from the teacher (Bandura, 1997; Howard-Hamilton and Robinson, 1991; Martinez-Pons, 2002; Pajares, 2002).

Findings of a study conducted by Evans (1996) posited that equality was based more on status, than on gender/sex. Within small groups of students, those who were different from the typical child were more often pressured to make the most adjustments to fit in. Hence, high achieving girls and women can be seen as occupying a lower status because of their sex, as well as being 'different' by virtue of their level of intelligence (Tavris, 1991). The burden of this adjustment process required them to repeatedly adjust to the dominant group, thus using or wasting their energy on these adjustments instead of on their goals (Evans, 1996; Kerr, 1994; Tavris, 1991).

What other adjustments or inequities did females endure in the school context? During large-group discussions concerning scientific concepts, science teachers have taken males' arguments more seriously and have elaborated more on males' responses (Gaskell, McLaren, & Novogrodsky, 1989; Jones & Wheatly, 1990; Lemke, 1990; Leroux, 1997). "Many teachers are gender blind, believing that the equity issues in science teaching are resolved" (Bailey, Scantlebury, & Letts, 1997, p.29). Interestingly, Fordham (1997) asserted that many African American female students were thought to be loud and must become silent and invisible in order to be successful in the classroom. Where students' experience "culturally related cognitive dissonance to their science classes", this can lead to collateral learning (Aikenhead and Jegede, 1999, p. 277). This treatment of young women does not appear to be intentional but may be related to a lack of awareness. Researchers reported that teachers are usually unaware of gender bias in classroom discussions and activities because they only look for gender bias in their own explicit attitudes and behaviors (Gaskell et al., 1989; Jones & Wheatly, 1990; Leroux, 1997; Sadker & Sadker, 1992; Tobin, 1988). According to a study conducted by Guzzetti and Williams (1996) with grade 11 physics classes, female students attributed gender inequity to the males in the class, and not the teacher. Moreover, those students who did not recognize gender inequities were most often men (Guzzetti & Williams, 1996).

Not all teachers are able to address multi-faceted issues in the classroom. With the increase in technology coupled with ever increasing social pressures and responsibilities, many teachers do not think they can fulfill expectations put on them by the institution. Bandura (1997) believed "teacher efficacy in science education was of particular concern, given the increasing importance of scientific literacy and competency in the technological transformations occurring in society" (p. 242). Evaluation of classroom environments by teachers is needed to ensure equity and to provide young women with active participation in the learning process (Hollinger & Fleming, 1992).

In addition, it has been suggested that making the science classroom more girl-friendly would be one way to address the different learning styles and experiences of girls (Belenky, Clinchy, & Goldberger, 1986; Gaskell et al., 1989; Maher & Thompson-Tetreault, 1992; Sadker & Sadker, 1992). A girl-friendly environment is one where teachers ensure equal participation, where women scientists are discussed, and where social issues associated with scientific discoveries are examined (Gaskell et al., 1989). Such small changes in teaching style may help some females see the social significance and the meaning in science lessons.

Self-efficacy

Hard work and persistence were attributes that teachers and parents cited most frequently when describing females' successes in science, while males' successes were credited to special abilities (Bandura, 1997; Chipman & Thomas, 1987; Wigfield, Eccles, & Pintrich, 1996;Yee & Eccles, 1988) and their scholastic failures were thought to be due to lack of effort and disruptiveness (Bandura, 1997). Chipman and Thomas (1987) believed these attitudes not only influenced parents' and teachers' behavior, but they also adversely affected the development of females' self-concept about their abilities. According to Greenberg-Lake (1991), there appeared to be a circular relationship between liking math and science, self-esteem, and career aspirations. According to this report, it seemed that young women who enjoyed math and science had higher self-esteem and aspirations and vice versa.

Prior to Bandura (1997) some researchers did not clearly differentiate the terms self-concept, self-esteem, and self-efficacy. In fact, they often were used interchangeably. Self-concept is a combination of views about oneself that are formed through direct experience and evaluations adopted from significant others. Bandura (1997) claimed that efficacy belief, rather than self-concept, may be highly predictive of behavior. He defined self-efficacy as the expectation that one has the capacity to complete a given task or goal. Thus, the strength of females' self-efficacy will determine whether they will pursue science studies, as well as the amount of effort that will be devoted to pursuing the goal and the degree of goal persistence in the face of barriers (Bandura, 1977). An early study by Lent, Brown, and Larkin (1984) affirmed that students with high self-efficacy in science tended to achieve high grades in science courses and remain science majors. However, this same pattern of findings was reversed in two other studies by Lent et al. (1986 & 1987) where significant sex differences in career self-efficacy expectations were not found between college women and men. This contradicted research findings that argued that even young gifted women gave greater weight to the gender appropriateness of careers than they do to their abilities and interests in career decision-making (Betz & Hackett, 1981& 1983; Kelly, 1993; Post-Krammer & Smith, 1985). It was possible therefore, that lower self-efficacy was most prevalent in adolescent girls (Post-Krammer & Smith, 1985). Hence, the college population of young women in Lent et al. (1986; 1987) may have had higher self-efficacy than those women who did not attend college. Moreover, other sociocultural influences other than gender/sex may have influenced the young women's self-efficacy (Martinez-Pons, 2002; Pajares, 2002).

More recently, O'Brien, Martinez-Pons, and Kopala (1999), found that grade 11 students' career interest in science and engineering was predicted solely by science-math self-efficacy, however, self-efficacy was predicted by academic performance and ethnic identity, and, academic performance was predicted by income level. While sex predicted students' career interests in science and engineering, ethnic identity significantly predicted math self-efficacy. In this case, being female or belonging to a different ethnicity was detrimental. This study failed to examine if participants were doubly hindered by sex and ethnic identity.

Bradburn (1994) developed a model of occupational choice taking into account gender/sex by integrating self-efficacy theory with expectation states. Applying this model with engineering students' efficacy beliefs at Cornell University, Bradburn (1994) collected survey data from 397 first year engineering students as to first-year attrition rates within the engineering program. Women reported knowing fewer same-sex role models in engineering and experiencing more discouragement in engineering school along with having higher levels of anxiety signs than men. Moreover, women also reported lower levels of self- efficacy beliefs while in engineering programs as well as higher rates for transferring out of engineering school during their first year. On the other hand, women in engineering school reported having both received more attention, encouragement, and negative comments than men. Perhaps their visibility contributed to their receiving more attention, and their self-efficacy beliefs may have influenced how they viewed and responded to this attention.

Sex-roles and Science

Howard-Hamilton and Robinson (1991) reported that females who do not follow prescribed traditional sex roles do achieve better then those who accept feminine sex-role characteristics of nurturance, kindness, and gentleness. This conflict between sex-role characteristics and intellectual capacity seemed to affect adversely self-concept, IQ scores, and the estimation of achievement related behaviors during adolescence (Howard-Hamilton & Robinson, 1991).

Despite the prevalence of traditional sex-roles in gifted females' lives, some still pursued their interest in a science career as well as the desire to work with children (Raymond & Benbow, 1989; Wells, 1985; Wood, 1999). Even at a young age, some participants have already chosen one option over the other (Spielhagen, 1997; Subotnik & Arnold, 1997; Wood, 1999). Gifted girls' choosing to work with children or even combining their interest in science with children perhaps, are motivated by career decisions based on traditional sex-roles rather than capacity. Studies by Bandura (1997), Kerr (1994), and Spielhagen, (1997) concluded that the more strongly girls adopt gender-roles that are stereotypically feminine, the more often they underestimated their capacities.

There is a critical shift in adolescence from achievement needs to relationship needs. Gilligan, Lyons, and Hanmer (1990) and Kerr (1994) affirmed that some girls want to combine the desire to work with children and an interest in science for a future career. This may explain why younger gifted girls talk so excitedly about careers in paleontology and other areas of science (Kerr, 1994). Hence, most girls change their career interests many times before deciding on a career. According to Kerr (1994), gifted students showed less stability in their interest patterns due to their ability to select and develop any number of career goals. In addition, gifted girls in one study reported that parental influence in career interests appeared minimal (Wood, 1999).

Moreover, the influence of sex-roles was not exclusive to early school experiences. Holland and Eisenhart (1990) concluded that the traditional culture of romance affected high-achieving college women's choice of a university-major and a career path. "As these women's career identities became more marginal, their romantic identities became more central" (Kerr, 1995, p.105). In this study, half of these women started as science and math majors and none tried to escape the demands of the culture of romance that affected their fulfillment of intellectual potential. What of the women who continued to pursue math and science endeavors?

Conclusion

The context of a woman's life strongly affected her development (Noble, Subotnik, & Arnold, 1999). Nationality, race, gender, and class were obvious influences but other subtle factors may be just as important. Astin and Leland (1991) posited that the sociocultural milieu of a woman affects her perceptions and her performance opportunities. Demographic factors also played a role in the access to higher education, civil and legal rights, and of professional achievement (Noble et al., 1999).

Circumscribed as to roles and stereotyped as intellectual inferiors, women previously were confined to domestic tasks (Lyn & Todoroff, 1998). Public achievement by women is rarely attained since many women are still foreign to top career ranks in prestigious fields such as mathematics and science (Heller & Ziegler, 1996; Noble et al., 1999). Hence, many categories of women (ethnic minorities, working class and rural, lesbians, and women with disabilities) have been multiply marginalized and distanced from centers of power and socially valued achievement (Noble, et al., 1999). The extent of this 'distance' is determined by white heterosexual males who belong to the urban middle class and who adopt Western traditions, values, practices, and assumptions (Martindale, 1998). Therefore, for non-white, non-privileged women, gender coupled with multicultural issues is more complex than for middle-class white women (Cassidy, Lord, & Mandell, 1998; Giroux & McLaren, 1994; Noble et al., 1999).

Historically, women who succeeded in inhospitable areas had to become well versed in both the traditional female domain and the masculine agentic-career domain (Silverman, 1996). Lorde (1984) posited that all women alternate amongst public, private, and cultural spheres, and all are, to varying degrees, 'outsiders within'. "Beyond the external constraints of 'outsider-status' lies the damage from internalized gender inferiority"(Noble et al. 1999, p. 143).

An area of contention for many academically successful women is that of identity and belonging (Subotnik & Arnold, 1996). When talented women choose new aspirations and ways of 'being and knowing', they frequently feel estranged from their culture and family. This conflict resonated with the findings of Gilligan et al., (1990) who reported that adolescent girls suppressed their 'voice' or altered the path to fulfilling their potential. Therefore, each woman comes to the 'achievement arena' with their baggage of background experiences within their class, race, ethnicity, culture, sexual orientation, and levels of ability (Britzman, 1998; Butler, 1999; Spargo, 1999) and these interact with individual factors such as personality, family background, early experiences, and psychological tendencies (Bandura, 1997; Gerrard & Javed, 1998; Maccoby, 1999). This distances women from the mainstream and ultimately influences the availability of opportunities for success (Noble et al., 1999).

From this shared perspective, identity is not an internal, individual process as suggested by some psychologists, for it is neither separated into individual characteristics nor external stimuli/influences (Bruner, 1996; Mishler, 1999; Wenger, 1998). Wenger (1998) defined identity as

> a layering of events of participation and reification by which our experience and its social interpretation inform each other. As we encounter our effects on the world and develop our relations with others, these layers build upon each other to produce our identity as a very complex interweaving of participative experience and reificative projections. Bringing the two together through the negotiation of meaning, we construct who we are (p.151).

Female engineers must 'individuate' within a community of practice, as well as negotiate what this may mean in terms of who they are and who they will become. Wenger (1998) contends "talking about identity in social terms is not denying individuality but viewing the very definition of individuality as something that is part of the practices of specific communities. The focus must be on the process of their mutual constitution" not one aspect as a unit of analysis (p. 146). Moreover, it is difficult, if not impossible to determine where the individual ends and the collective begin. "Our practices, our languages, our artifacts, and our world views all reflect our social relations. Even our most private thoughts make use of concepts, images, and perspectives that we understand through our participation in social communities" (p.146). Women doctoral candidates in faculties of engineering can be viewed as members of communities of practice[4] constructing a unique identity.

Weaving these perspectives of experience with the culture of engineering, learning, and contextual influences provides a glimpse of the dynamics at play in women engineers' lives. The conceptual framework pieces together these perspectives of learning with theories of identity in a sociocultural frame to best inform this study.

Conceptual Framework

Sociocultural Approach

According to Wertsch, Del Rio, & Alvarez (1995), "the goal of a sociocultural approach is to explicate the relationships between human mental functioning, on the one hand, and the cultural, institutional, and historical situations in which this functioning occurs, on the other" (p.3). Hence, human action, as the focus of analysis, is seen as a "dynamic dimension or moment of action that change in fundamental ways from activity to activity, depending on the way, in each activity, the purpose, form, cultural tools, and contexts are coordinated" (Penuel & Wertsch, 1995, p.84). Wertsch (1995) suggests that theorists recognize that as long as we try to separate the components of sociocultural approach into 'cognition and setting', or 'individual and society', there will be confusion, unless we realize that these terms are only conceptual in a process of inquiry.

The sociocultural framework of this study is discussed in terms of three key concepts that views 'identity' as a self-chosen description influenced by critical contexts. Next, 'difference' is an integral part of this self-chosen description. And finally, 'Learning as social participation' shifts the analytic focus to learning as social participation and performance in the social world.

Sociocultural Influences and Identity

The sociocultural approach examines how identity, as self-chosen description of a person, takes place within human action. Narrative data is recognized "as modes 'secondary production', drawing on and redoing culturally available plots to construct their [the participants'] own distinctive stories" (Mishler, 1999,p.25). In addition, other culturally 'defined categories' that influence 'stories' such as gender, sex, power, and sexuality need to be uncovered (Britzman, 1998; Butler, 1999; Henwood, 1998; Nicholson, 1998; Remlinger, 1995; Spargo, 1999). The notion that these 'stories' are "situated retellings… responsive to the contexts of their production", co-produced and "developed within the on-going dialogue between interviewer and respondent" (Mishler, 1999, p.25) requires an emphasis on language when considering identity.

Penuel and Wertsch (1995) assert that identity formation must be "viewed as shaped by and shaping forms of action, involving a complex interplay among cultural tools employed in the action, the sociocultural and institutional context of the action, and the purposes embedded in the action" (p.84). So then, the tension of participating in social communities is an indicator of mediated action. “From this perspective, speaking, thinking, and other forms of human action are taken to involve an inherent, irreducible tension between agent and cultural tools such as language and narrative texts” (Werstch, 2002, p.6). Participants’ recounting their engineering experiences requires remembering these ‘texts’, since the actual production of some of these tensions may have occurred in the past. “From this perspective memory- both individual and collective- is viewed as ‘distributed’ between agents and texts, and the task becomes one of listening for the texts and the voices behind them as well as the voices of the particular individuals using these texts in particular settings” (Wertsch, 2002, p.6). Moreover, when retelling experiences and contexts, participants speak for themselves and others- interpreting meaning. “In this approach, performances … are inherently multi-voiced rather than the product of an isolated speaker or cognitive agent” (p.6).

This ‘collective remembrance’ of participants contains positive aspects to learning called affordances, as well as more negative aspects referred to as constraints (Wertsch, 2002). In some instances, participants may choose a more neutral position in recounting their experiences. Verbal explanations or ‘texts’ are learned during their participation in the culture of engineering, and then appropriated. Appropriation is thought to be the process of “the text’s having ‘personal sense’ for its user, as opposed to abstract, distanced ‘meaning’. As such, a text that is appropriated may serve as an identity resource- a means for anchoring or constructing one’s sense of who one is” (Wertsch, 2002, p.120).

Of course not all participants fully appropriate what they learn- it may not be relevant to ‘who’ they are or the identity they wish to adopt. Wertsch (2002) identifies this behavior as resisting which "is the opposite of appropriating a cultural tool…Just because someone is exposed to a cultural tool-and just because she had mastered it-does not guarantee that she has appropriated it as an identity resource" (p.120). Perhaps, this notion of resistance may eventually help women engineers to dispel the engineering practices that cause them discomfort.

Identity and Difference

Difference is an integral part of the notion of identity formation. Hall (1996) asserts that

> Identities are about questions of using the resources of history, language, and culture in the process of becoming rather that being: …what we might become, how we have been represented and how that bears on how we might represent ourselves. Identities are therefore constituted within, not outside representation…that arise from the narrativization of the self…and are constructed through, not outside difference (p.4).

For Butler (1999), normative judgments of difference exert a regulatory function on heterosexuality that is linked to the determination of gender identity, for "persons only become intelligible through becoming gendered" (p.22). Thus, judgment is seen as related to power and is discriminatory in many respects to those not within the confines of these normative distinctions. Her theory requires the 'denaturalizing' of gendered and sexed identities, that is questioning the reality and categories of gender, and seeing them as a type of performance.

Thus, Butler (1999) posits there is a kind of convoluted negotiation between the subject, the body and identity, where the subject is discursively constructed in relation to sex. She asserts

> Sex not only functions as a norm, but is part of a regulatory practice that produces the bodies it governs, ...whose regulatory force is made clear as a kind of productive power, the power to produce-demarcate, circulate, differentiate-bodies it controls...sex is an ideal construct which is forcibly materialized through time (1993, p.1).

This productive power requires performance; the "reiterative power of discourse to produce the phenomena that it regulates and constrains" (Butler, 1993, p.2). The view that gender is 'performative' attempts to illustrate that what we consider to be an 'internal essence' of gender, is created through a continued set of acts, and "posited through the gendered stylization of the body" (Butler, 1999, p. xv). Moreover, 'performativity' can be understood as consisting of linguistic and theatrical components that comprise an instance of power, ambiguously termed a 'speech act' (Butler, 1999).

This notion has evolved over the past decade and many suggestions for enrichment have been answered in Butler's subsequent works. Hall (1996) praises Butler's (1993) efforts in making a case that all identities operate through exclusion; that is, through the discursive construction of an 'outside' and the making of marginalized subjects, and in what appears outside the parameters of the symbolic or those usually represented (Hall, 1996).

Because most normative judgments of subversive acts are based on description and cultural inferences, they cannot occur out of context, nor be accurately defined in ways that endure through time (Butler, 1999). Interestingly, the repetition of subversive performances can become a cliché within the all-important "commodity culture where subversion carries market value" (Butler, 1999, p. xxi). Such a contention is supported by Bauman (1996) who proposes a kind of postmodern identity in which the previously marginalized minority lifestyles that were available during modernity become the only lifestyle available to the majority of people. From this perspective, the styles of living once practiced by the marginalized are now no longer a choice (Bauman, 2000), as postmodern life is too messy and complicated for a single model. For Bauman (1996), the analogy of the pilgrim presented modernity with the task of identity-building, whereas the stroller, the vagabond, the tourist, and the player represent analogies of the postmodern that illustrate the terror of being stable or fixed.

While the notion of identity was born as a problem, a task that needs to be solved, Bauman (1996) summarizes the dilemma thus

> And so the snag is no longer how to discover, invent, construct, assemble (even buy) an identity, but how to prevent it from sticking. Keep the game short...beware of long-term commitments. Well-constructed and durable identity turns from an asset into liability (p.24).

Bauman's diagnosis of identity may in fact be astute since it provides metaphors that imaginatively illustrate his points of view. However it seems hopeless, for it offers no remedy. Taylor (1989) suggests that the lack of a frame of reference renders possibilities unfixed, undifferentiated, and without meaning and presents a painful and frightening experience for the individual. Perhaps it can be considered as a cautionary tale; that is, a path or frame to be avoided.

The importance of 'narrativization' in identity formation has been emphasized by many researchers (Bruner, 1996; Butler, 1999; Hall, 1996; Heckman, 1999; Henwood, 1998; Hopkins, 1998; Lara, 1998; Taylor, 1989, Wertsch, 2002). Thus, Bruner (1996) stresses the importance of narrative as a solution, as a form of cultural cohesion, and as a way of structuring an individual life, for "learning in its full complexity involves the creation and negotiation of meaning in a larger culture, and the teacher is the vicar of the culture at large" (p.84). The involvement of the educational process is also stressed through "building school cultures that operate as mutual communities of learners, involved jointly in solving problems with all contributing to the process of educating one another" (p. 82). Although Bruner (1996) advises, that "it is a complex pursuit of fitting a culture to the needs of its members and of fitting its members and their ways of knowing to the needs of the culture" (p.43). This theoretical position resembles ideas proposed by theories of and learning and social participation.

Learning and Social Participation

An extension of the sociocultural approach, situated learning, emphasizes the importance of context in learning.

> Legitimate peripheral participation provides a way to speak about the relations between newcomers and old-timers, and about activities, identities, artifacts, and communities of knowledge and practice. It concerns the process by which

> newcomers become part of a community of practice (Lave & Wenger, 1991, p. 29).

This also requires a shifting of the analytic focus from the individual as learner to learning as participation and performance in the social world. Performance in relation to technology and science research has become increasingly important (Butler, 1999; Haraway, 1997; Law & Singleton, 2000; Latour, 1993; Mol, 1999). It is thought that to "tell techno-science stories is, in some measure or other, to perform techno-science realities...[that are] a particular and located enactment or performance of technological knowledge and practice" (Law & Singleton, 2000, p.767).

Lave and Wenger (1991) recognize the importance of social relations within a community of practice because students do not learn only from their instructors. As well, "it seems typical of apprenticeship that apprentices learn mostly in relation with other apprentices" (Lave & Wenger, 1991, p.93). More recently Wenger (1998) elaborates that "more experienced peers are not merely a source of information; ... they also represent the history of the practice as a way of life. They are living testimonies to what is possible, expected, desirable" (p.156). This concurs with the research that affirms the importance of role models in developing an 'imaginable' identity, especially in regards to women (Bandura, 1997; Brown, 1999; Gilligan, 1993; Franks, 1998; Frize, 2000; Kerr, 1994; Maccoby, 1998).

Theories of learning and identity with regards to science education are intricately inter-twined. The process of becoming a female engineer is studied in light of learning as social participation. Wenger (1998) contends that "participation here refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities" (p.4). Wenger's (1998) approach to learning include four basic components

1) Meaning as a way of talking about our changing ability -individually and collectively- to express our life and the world as meaningful.
2) Practice as a way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action.
3) Community as a way of talking about the social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence.
4) Identity as a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities (p.5).

Importantly, "[this] perspective is not a recipe; it does not tell you just what to do. Rather, it acts as a guide about what to pay attention to, what difficulties to expect, and how to approach problems" (Wenger, 1998, p.9).

Research Questions

The interplay between the components of learning and the performance of one's identities in relation to the sociocultural context is germane to understanding the process of becoming a female engineer. These lenses, within which to frame the dissertation, assume that there "is a social dimension to the construction of scientific knowledge…which is constructed and transmitted through the culture and social institutions of science" (Driver, 1995, p. 395). If one does not participate fully in this sociocultural environment can learning take place? It is important, therefore, to investigate how the learning context impacts on what is actually learned and how this affects the achievement of women in science. The following research questions will guide this study: 1) What sociocultural influences affect female PhD students' choice to participate in engineering? 2) What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering? 3) What do female PhD students perceive as the 'unofficial' ways of continuing the history and traditions of the profession in faculties of engineering? 4) How does the female PhD student's non/participation in engineering affect their identities?

This chapter has presented an overview of studies conducted in relation to women in science and engineering. While the focus of this study is on the present lives of doctoral women engineers, earlier experiences and influences serve as a background. Theories that informed my conceptual framework were also discussed and the research questions were introduced. In the next chapter, I will address the research methodology employed.

CHAPTER THREE

METHODOLOGY

The methodological design of this study is the object of this chapter. I will introduce this chapter with an explanation of the logic of justification of my research paradigm. A full description of the research procedures will be detailed in the main section of the chapter. These will include sampling, data collection, data management, and data analysis. Brief 'snapshots' of participants' lives will be presented in section two.

Research Paradigm

In order to frame the research questions of this study, it is necessary to really move away from positivism and to look at the complex process of negotiating the tension of living between individuation and socialization through a sociocultural lens. Qualitative research is concerned with the participants' perceptions and how they make sense of their lives (Bogdan & Biklen, 1998; Fraenkel & Wallen, 1996). Cresswell (1998) proposed that the underlying philosophy of a qualitative study is shaped by the ontological perspective, that is, the nature of reality, and the epistemological issues underlying the relationship between the researcher and the researched. Moreover, other in-depth standpoints are also made visible including the role of values in the research [the axiological perspective]; the rhetorical perspective that is, the role of language in the study; and lastly, the process of the research itself [methodological issues].

Ontologically, social constructivism asserts that "realities are apprehendable in the form of multiple, intangible mental constructions…and dependent for their form and content on the individual person or groups holding the constructions" (Guba & Lincoln, 1994, p.125). In this way, this paradigm rejects the notion of one universal truth but rather affirms pluralism, relativism, and subjectivity. The overall interpretation of this study's findings acknowledges that reality is subjective and constructed by the participants in their various social, cultural, and personal circumstances. In addition, this study attempts to uncover the subjective meanings and multiple realities of the participants' lived experiences with 'meaning' here viewed as "fluid and contextual, not fixed and universal" (Riessman, 1993, p.15).

Epistemologically, the doctoral women engineers in this study are referred to as participants and viewed as collaborators and valued experts. The narrative data in this study is co-produced and co-constructed, an ongoing dialogue between researcher and participant (Mishler, 1999). Axiologically and rhetorically, the narratives of the participants' illustrates how language, as a vehicle of identity, reveals attitudes, values, and beliefs about the participants' constructed meanings of themselves and their world. Moreover, the focus is centered around the participants' narrative stories and not the researcher's voice. As the researcher, I acknowledge that research is value laden and in some cases, I do not share the same cultural background or personal experiences as some of the participants in this study. Having argued for the notion of pluralism, I align myself with poststructuralist/postmodern feminism that 'problematizes' the self in 'decentered' modes of discourse. "Postmodernism dissolves the universal subject and postmodern feminism dissolves the possibility that women speak in a unified voice or that they can be universally addressed. Race, class, nationality, sexual orientation, and other factors prevent such universalism"(Rosser, 1998, p.192). This acknowledgement of 'difference', or binaries in some cases, brings a new perspective to research on women and engineering.

Methodologically, the design adopted is a naturalistic qualitative inquiry using two open-ended interviews with participant verification after the first interview. In this way, the transcripts of the co-constructed narrative can be reflected upon to better illustrate the participants' stories. In addition, the second interview allows the participants to further elaborate upon the co-constructed stories and perspectives discussed. An opportunity to obtain thick, descriptive data on the process of becoming a female engineer is my foremost objective.

Research Design

The purpose of this study is to understand how sociocultural influences affect women's choices to participate in engineering/science. It is also important to understand those influences on the choices related to enrolment and retention of women in engineering programs at multi-levels. On the basis of these statements, qualitative data was collected using a case-centered approach. In keeping with Mishler (1999), this study can be seen as a collective case study, that is, one story with multiple characters. In educational research, we often draw upon concepts, theories, and research techniques from anthropology, history, sociology, and psychology. Moreover, Merriam (1995; 2002) has identified four important components in conducting a qualitative case study including: focusing on a particular phenomenon, having rich description of the phenomenon, illuminating the reader's understanding of the phenomenon, and relying on inductive reasoning for the shaping of concepts. In this way, the process of developing a case study begins with the selection of a phenomenon to be investigated including the person, site, program, process, community, or any other social unit based on the researcher's interest and the applicability of the study. Then, the collection of raw data takes place and data are organized into manageable units. The writing of the case study narrative completes the activity (Merriam & Simpson, 1995, p.109).

More specifically, Mishler's (1999) case-centered research is an approach with distinctive features that requires individual trajectories of change to be retained through all stages of analysis. "Findings, therefore, do not refer to measures of variables aggregated across groups of individuals but to similarities and differences among intra-individual or intra-case patterns of change" (Mishler, 1999, p.11). The collective voices of my participants are used to, in the end, develop typologies to exemplify both similarity and difference within this unique population. This is supported by Mishler (1999) who posits "rather than suppressing the variability among my respondents in how they achieved their adult identities, this approach retains and respects their differences and addresses them within a comparative framework" (p.11). This attention to studying diversity and change in lives and locating participants within the social and cultural matrix is a "step toward a relational conception of identity that contrasts with a view of identity as immanent or indwelling within a person, stable or consistent, carried into and expressed across situations" (Mishler, 1999, p.16).

The life history narratives will, from the participants' perspectives, help explain how they have come to be doctoral engineering students, what paths they have chosen, and how their relationships influenced these choices.

> From this perspective, our identities are defined and expressed through the ways we position ourselves vis-à-vis others along the several dimensions that constitute our networks of relationships. Emphasis shifts from inner conflicts and their resolutions to the social production of our multiple sub-identities and the dynamics of their relationships. And this, in turn, shifts our attention in theory and research from the assessment of 'personality' variables to the study of forms and contexts of discursive genres, such as personal narratives and life stories, within which identities are produced and performed (Mishler, 1999, p.17).

In summary, my objective is to obtain thick descriptive data, stories composed by the doctoral women to tell me who they are and who they would like to become.

Participants.

Seven participants were purposefully sampled according to their availability and willingness to participate in one formal interview and a second informal interview. The participants were enrolled in doctoral electrical or mechanical engineering programs at various Canadian universities. Electrical engineering programs vary from university to university and may include traditional areas as well as the newer computers systems programs. In a similar vein, mechanical engineering programs have evolved to include new subdivisions such as biomechanical engineering. Purposeful sampling is suggested by Creswell (1998) so as to select participants that "show different perspectives on the problem, process, or event" (p.63). Moreover, Glesne and Peshkin (1992) affirm that selecting a large number of cases is not in keeping with case study method and the constructivist paradigm.

Based on the number of female graduates conferred with a Ph.D. in electrical engineering at the University of Ottawa (2000), one from the total of ten was a woman. Similarly in the areas of mechanical and electrical at the l'Ecole Polytechnique de Montreal and at the University of Toronto (2000), there was only one doctoral woman graduate in each. Because of this disparity, it was impossible to purposefully select female participants from various social classes, ethnicities, religions, ages, and sub-disciplines of engineering. In fact, I concur with Mishler (1999) and did find "some version of these differences and their associated effects of identity development ...among members of the group to which [the] respondents belong" (p. 149). The participants represented many doctoral institutions in central and eastern Canada. All but one woman attended a variety of universities during their undergraduate and graduate programs in both Canada and abroad. The seven participants were at various stages along the continuum of their doctoral programs such as their comprehensive exams, proposal, research, writing, and defense. Two of the doctoral women were international students while the other five originated from different regions in Canada.

Sampling.

Based on ethical guidelines established by the Tri-Council of Social Sciences and Humanities' -Guidelines for Ethical Approval and the implementation of these guidelines at the University of Ottawa and other Canadian universities, recruitment of participants was challenging. After completing the process of seeking ethical approval, I was given permission to put 'letters of invitation' for potential participants in University of Ottawa/Faculty of engineering intra-mail boxes. In attempting to do so at ten other Canadian universities, I was informed that I would have to go through each university's 'Ethics Committee' if I was using the university for distribution [i.e. faculty secretaries to put letters in the women's mailboxes].

I then contacted WISE [Women in Science and Engineering] groups at the same universities and asked them to post my letter of invitation on their website, bulletin boards, and newsletters – or any 'other' method they deemed appropriate in order to avoid the long procedure of going through many 'Ethics Committees'. This strategy was slightly successful- one participant responded. Next, I E-mailed my letter of invitation to the Regional Chairs of Women in Engineering asking for their assistance in posting my letter. This method of distribution helped to secure one more participant. After interviewing these two participants they volunteered to 'pass-on' my letter of invitation as well as their endorsements for participating in my study to their engineering colleagues. Luckily, two more participants responded to this strategy.

I then went to each university's faculty of engineering [mechanical and electrical] websites hoping to find a list of doctoral students. After the 'Montreal Massacre' in 1989, security of engineering students in Canadian universities is certainly a priority on university websites. Only through information posted concerning engineering research groups/teams was I able to trace the elusive female engineers. If a picture of a woman was found, I then went to the team leaders' [professors'] university link which usually lists papers published. In the list of references, I surmised that the students' names were listed. From there, I 'googled' their name on the Internet and usually found some type of university address or E-mail. Unfortunately, not all students' sex/gender can be discerned from their name alone, and I believe many males also received my request to participate. This method of solicitation took approximately three-four months from sending the E-mail or letter in hard copy form, to receiving a positive response. Three participants were obtained from this method of sampling, for a total of seven doctoral women participants.

Procedure

Once approval of the research proposal was obtained from the Ethics committee, I distributed the 'invitation to participate' in my study to potential participants' via intra-mail, E-mail, Canada post. Those who were interested in the study contacted me for more information and the opportunity to ask questions (appendix A). The participants were informed that their participation was entirely voluntary and they could withdraw from the study at any time without any consequences.

The letter of invitation described the purpose of the research and the role of the participants, and provided assurance of the confidentiality of the information. The letter also explained that the participants were free to withdraw from the study at any time and that the interview tapes would be carefully stored (see appendix A). In order for the individual interviews to be used for research purposes, participants were requested to sign consent forms. The consent forms were attached to the letter of invitation and the participants kept a copy of each (see appendix B). For those contacted by E-mail, they were given the option to return the consent form by mail or fax. In any case, interviews were not conducted until the consent form was received. In addition, verbal consent was given at the beginning of the first interview and recorded.

Formal Interviews

The individual interviews in this study were conducted using life history narratives (Mishler, 1999). In this way, participants were asked 'how they had come to be doctoral women in engineering'. Mishler (1999) affirmed "we express, display, make claims for who we are-and who we would like to be-in the stories we tell and how we tell them. In sum we perform our identities" (p.19). If the participants did not respond to this very unstructured method of obtaining interview data, eleven open-ended questions were used to guide the participants. The 11 questions were constructed from the literature review and suggestions from my dissertation committee during the proposal stage of the study. The interviews were conducted with the aide of the telephone, as almost all participants did not live within driving distance. In all cases, the first interview lasted approximately 1 hour 45 minutes (see appendix C), with one interview lasting 3 hours. The seven formal interviews elicited approximately 14 hours of data. When transcribed, each interview contained minimally 20 single-spaced pages of typed data.

For this doctoral dissertation, ethical approval was obtained in February 2002 [see introduction to procedure]. All seven participants completed both phases of the interviewing process. After reading my letter of invitation, most participants reported "giving a lot of thought" to their reasons for choosing engineering. Forethought on the critical issues took place for all the participants, and was evident in their reflective answers. The collection of data took place from February 2002 to September 2002 including the initial search for participants.

Interview data were transcribed after each interview session in order to summarize the interview, formulate probing questions for the second interview, and for the subsequent interviews of other participants [see Figure 2]. "Rich data that are detailed and complete enough that they provide a full and revealing picture of what is going on" adds to the study's trustworthiness (Maxwell, 1996, p.95). An example that Maxwell (1996) suggested was verbatim transcripts of interviews, not just casual notes regarding what was noticed. The verbatim transcripts were 20-30 pages of single spaced data detailing the researcher and participant's dialogue. The recorded interviews were transcribed verbatim including repetitions, incomplete utterances, laughs, and sighs.

Each participant's transcript was then summarized into approximately 5-6 pages, that is, my interpretation of the essence of our interview. The summary was organized around the four research questions. This summary was E-mailed to each participant for verification. Four out of seven of the participants corrected my summary and returned it to me. Most corrections were details that were meaningful to them or engineering terms I didn't understand or summarize properly. The full-transcript was offered to those who were interested in viewing it. Only two participants requested a copy of the full-transcript before the second interview took place [see appendix D].

Second Interview

Following the completion of the formal interviews, an informal one-hour telephone conversation was conducted with each participant. This informal session took place approximately two weeks after the individual interview and for one participant who was defending her dissertation, one month later. The purpose of this informal session was to gather the participants' feedback on my interpretation of their life story and their perspectives on becoming a female engineer. A summary of themes was provided to the participants as E-mail in advance of their informal interview. The full narrative transcripts were offered to all participants. Two women requested a full copy of their transcribed interview. Follow-up questions formulated for each participant, from the first interview and the summary data, were asked. I jotted down notes during the informal interview as well as writing detailed notes after the termination of the session [see Figure 2]. The second interview did not produce new 'stories' or new data, with the exception of one participant. The participants elaborated mostly on their original topics. One international participant, who elaborated extensively on her story, did so mainly due to a language barrier. Having more time to reflect and think of how to answer in her second language was beneficial. These doctoral women reflected on and planned what they were going to say before my first interview. For the most part asking, "how did you come to be a doctoral engineer" produced copious amounts of information. They had mentally prepared what they were going to say. They were methodical in preparing their answers.

Reflective Journal

I recorded in a reflective journal observations, feelings, insights, reflections, and thoughts throughout the research process (Creswell, 1998). The journal outlined the rationale for decisions made regarding the participants, the interviewing process, and the analysis and interpretation of the data (Miles & Huberman, 1994). In my journal, I sketched ideas, questions that needed clarification, my perspectives of the participants, concepts and themes for analysis. In other words, this reflective journal helped keep a complete record of how the data were collected, recorded, analyzed, and interpreted which increases the trustworthiness of the study (Miles & Huberman, 1994).

Trustworthiness.

Trustworthiness is determined on the basis of the quality of the "craftsmanship during investigation, continually checking, questioning, and theoretically interpreting the findings" (Kvale, 1996, p.241). Trustworthiness was accomplished during this study as thick, descriptive data was collected, as well as participant verifications of data and interpretation helped ensure trustworthiness of my data (Cresswell, 1998). Conducting these two verification procedures are very common among naturalistic researchers and according to Cresswell (1998) "underscores qualitative research as a distinct approach" (p.201).

During the research process I made regular journal entries that included field notes, conversations, ideas, and well as logistical information. During the initial stages, the journal helped keep track of which faculties of engineering were sent my 'letters of invitation', and which universities would allow the letters without ethical approval, women in engineering chairs, and WISE provincial/university group information. The participants' names and other identifying information were not recorded in the my journal.

Analysis of Data

From an interpretist perspective, the analysis of the data consisted of five general analytical phases that included: (1) organizing the data, (2) generating themes, categories, and patterns, (3) testing emergent concepts, (4) exploring alternative explanations, and (5) composing the account (Marshall and Rossman, 1999). More specifically Polkinghorne (1995) affirmed that the task of narrative analysis moves from "elements to stories", configuring events or episodes into plots (p.12). Mishler's (1996) 'collective' case life histories or stories make no claim for holistic descriptions of individual cases. In fact, the strength is in the applicability to a series of cases employing a comparative analysis of patterns. Moreover, the emphasis is on similarities and differences among trajectories or structures (Mishler, 1996). Case centered analyses retain the

> temporal patterning of events such as the sequence of narrative episodes. This allows us to retain the variability of life history narratives while at the same time recognizing them as modes 'secondary production', drawing on and redoing culturally available plots to construct their own distinctive stories. It alerts us … to how gender as a culturally defined category may differentially inflict and inform men's and women's stories (Mishler, 1999, p.25).

In addition, other culturally 'defined categories' that influence 'stories' such as gender, sex, power, and sexuality were targeted (Britzman, 1998; Butler, 1999; Remlinger, 1995; Spargo, 1999). The notion that these 'stories' are "situated retellings… responsive to the contexts of their production", co-produced and "developed within the on-going dialogue between interviewer and respondent" requires close examination of details and production of the dialogue (Mishler, 1999. p.51). Furthermore, Mishler (1999) suggests a comparative approach to interpreting similarities and differences among respondents' life stories. This is accomplished through the "presentation of and reliance on detailed transcripts of interview excerpts that display their structural features" (Mishler, 1999, p.147). More specifically, "transcription is not simply a technical procedure but a critical step in the analysis of discourse, reflecting theoretical perspectives on language structure, function, and meaning" (Mishler, 1999, p.169).

Data analysis and management.

The first transcripts were read for meaning and themes were written in the margins. The emergent themes provided a basis for creating nodes in the qualitative software program [NVIVO]. Then imported transcripts were re-coded for emergent data and sub-themes (nodes) were added. This software helps the researcher organize their data and keeps track of changes made to documents. The identified sub-themes were then organized around each research question. The narrative data identified as being related to a research question was then crafted into a 'patchwork of accounts' attempting to tell a story or add to the understanding. This process of testing the 'account' had to be reworked many times. In addition, the constructivist notion of 'affordances' and 'constraints' helped analyze and provide a frame to display the data for some particularly lengthy research questions [see appendix D].

Display of analyzed data versus confidentiality.

Because of the low number of women in doctoral mechanical and electrical engineering programs in Canada, it was essential to keep their identifying information confidential. In order to do this, profiles of the women were not developed with identifying information and quotes were not assigned pseudonyms. Instead, analysis of data was presented in relation to similarities and differences (Mishler, 1999) and in some cases as affordances and constraints (Wertsch, 2001). Although profiles of more complete demographic data, and in some cases more personal quotes, would have helped tell their stories, my first priority was to my promise of confidentiality. In retrospect, using life history narratives with extremely open-ended interviews was not the best choice to collect the data for this particular sample. Not being able to display and analyze the data as intended, due to issues of confidentiality, constrained its use. To this end, general portraits of each participant will provide a 'snapshot' of who these exceptional women are and their process of becoming.

Portraits of Participants

In order to better appreciate the experiences of participating in the culture of engineering, it is important to have at least some sense of who these women are, how they have described their lives, and how engineering fits into the overall pattern of their adult lives. In order to realize this, brief portraits of each of the seven women will now be presented with identifying information removed.

Participant 1

Participant 1 was in her mid-twenties and grew up in a rural town in the Maritimes. Both of her parents worked and although they were not professionals, they explicitly encouraged and provided hands-on science activities at home. This participant knew her parents were proud of her and reported all members of her family supporting her engineering choices. She was the oldest sibling having also a younger brother and sister. Currently, this participant was not in a dating relationship.

Attending a rural high school did not afford her many choices in relation to course selection. Excelling academically in public school was a reason given for choosing more challenging courses such as physics and math. Continuing to excel in physics and math led to similar undergraduate choices. Moreover, physics students were aggressively recruited for master's programs in engineering. NSERC funding influenced her to pursue her interests in graduate programs. Completing her degrees consecutively, and trying to adhere to funding timelines caused 'burnout' for this woman. Once again, the belief that NSERC funding may not be obtained later on persuaded her to continue with her PhD in spite of mental exhaustion. Ultimately her selection of a university for her doctoral studies was based on the desire for both she and boyfriend [at the time] to do their research at the same university. Hence, their previously long distance relationship could be continued in greater proximity. Interestingly, this relationship dissolved just before she moved to start her PhD.

At the time of the interviews, this participant had just completed her comprehensive exams and had settled into her new university. Although she reported feeling isolated because she was the only doctoral candidate in her discipline of engineering and not being a 'real' engineer, she had found ways to network and establish friendships. She thought that finding a female mentor in each of her university programs increased her level of success. During her university programs, she attended four universities in three provinces. Her future plans include a postdoctoral fellowship in Australia and eventually becoming a university professor as well as having her own consulting practice. She thought her future career could be pursued all the while starting or planning a family.

Participant 2

Participant 2 was an engineer who was almost 30 years of age. Her mother was a stay at home mom and her father was a professional in a Maritime province. Although neither of her parents were engineers, two of her close male relatives were. She was engaged to an employee of a large IT company who was not an engineer but worked in familiar territory. Both parents supported her in her choices of programs and engineering career. Her mom not only assisted her with homework but also encouraged many extracurricular activities. Both grandmothers modeled persistence and encourage her to be what she wanted.

This participant appreciated her high school teachers who provided praise and support. She attended a school with a congregated gifted program and small class sizes. Her science teachers challenged their students beyond the curriculum and helped them practice writing actual university exams in order to build their confidence. Much of her high school science learning was project-based, personalized, lab/inquiry oriented, and grounded in real examples-problems. Knowing she could be successful with math and science at the university level led her to choose engineering. More specifically, this participant knew she wanted to help people and a WES presentation examining 'Engineering Prosthetic Devices' helped her decide on a career choice that merged her abilities with her 'ethic of caring'. Earning high marks during her B.Eng. gave her the opportunity to receive undergraduate NSERC scholarships as well as NRC summer jobs.

This undergraduate funding was designed to encourage women to pursue graduate studies in science. Although she felt obligated to continue her studies, she also experienced self-doubt since some male peers jealously accused her of receiving funding solely based on her gender. This participant has continued to blend her 'ethic of caring' with her graduate research although not in the area of prosthetics. She has been funded by NSERC throughout her three university programs and has attended two universities.

At the time of the interviews, she was trying to finish up her research before her funding ran out. She was disillusioned with engineering and academia and had contemplated leaving to teach in the school system where she believed she could effect some 'real' change. She was encouraged when she located a researcher who was undertaking prosthetic research in Canada. She was also considering starting her own consulting business with her fiancée so she could choose her own research direction and adhere to ethical practice in engineering. This participant defined herself as a woman in engineering and acknowledged that this may be different from men but that it is an important perspective that must be included in the profession of engineering.

Participant 3

Participant 3 was an engineer and an international student who had just successfully defended her PhD in engineering at an eastern university. Her mother was a stay at home mom and her father was a professional. Although neither of her parents were engineers, a close female relative was. The choice of a university program and of a future career was left up to her, but she knew her parents would approve of a scientific area.

To take advantage of better teaching and smaller class sizes, she had attended an American School in her country. State exams and curriculum still had to be followed which emphasized rote-memorization and little questioning. Her mother spent a lot of time helping her prepare for these exams. Throughout her public school education, state exams were written which affected her direction of education. In her school experience, this participant was comfortable with math and science, and she reported having to exert little effort to obtain high marks. Although her country encouraged women to choose careers in science and engineering based on ability, stereotypes still affected choice of disciplines in engineering and subsequent workplaces.

Having completed a workplace co-op placement in her country helped her to weigh carefully the choice of graduate school. She found working in industry harsh but thought academia allowed freedom of choice while acknowledging a greater workload and decreased pay in universities. During her undergraduate and master's programs, she had more time for friends and completed school work with peers. During her doctoral program, her research topic, the demanding workload, and the fact of being the only woman graduate student in her department left her with a feeling of isolation. Although she had a good relationship with her doctoral advisor, she knew she was treated differently. Male colleagues were often hired first for RA positions. She thought Canada was a 'service center' for students and that pedagogical practices were much more student centered compared to her native country. This participant thought the effort and sacrifice required to complete engineering programs was not always worth the salary engineers were paid.

This participant was married to a new professor in her engineering faculty last year. They had dated throughout their doctoral engineering programs and married as soon as he defended. Having a partner with the same devotion to research was seen as beneficial. Now that she has graduated, she doubted she would be able to work in the same province as her husband since they were not hiring professors in her area of research. Now in her early 30s, this participant and her husband were considering having children. She thought family life and academia were a good fit, in spite of her interviewing for faculty positions in the US-being separated from her husband. In the future, she saw herself teaching and having a faculty position. She thought she was a positive role model for women in engineering.

Participant 4

Participant 4 was an engineer who was in her mid 30s. Her parents were married and she grew up in a Maritime province. Her mother was a stay at home mom and her father worked in an "engineering like profession", although he did not hold a B.Eng. Her mother instilled in her the belief that she could do anything she aspired to. She did not perceive her father as supportive. Her high abilities and the positive challenge of science and math during high school led to her choice of entering an engineering program. After completing her B.Eng., she completed her master's to have a better theoretical understanding. Although she felt isolated and excluded during these programs, she chose to do her PhD at this same eastern university. During her academic career, she attended two universities in the same province.

After her master's degree, this participant worked for approximately seven years in various consulting companies, government, and industry before returning to do her PhD program. Her work experiences were not challenging and did not put her theoretical knowledge to good use. Moreover, her attractive appearance caused stereotypical behavior in some work places. Obtaining doctoral funding was challenging. She thought many of the programs today over-inflate their marks in order for students to compete for NSERC funding with other universities. At the time of the interview she was completing her research. She also participated in WES and professional associations to try to improve engineering for women but found these experiences disappointing. During her Bachelor's and Master's degrees, she experienced very negative treatment from male peers. Being disillusioned by both the workplace and academia has left this participant quite unsure of her future plans and where she fits in.

Participant 5

Participant 5 was in her late 20s. Her parents were very supportive of her academic/career choices. Since her father was an engineer, he could help her with the math assignments she didn't understand. Although her mother was a housewife, she also assisted with homework throughout her public schooling. This participant was single but has dated engineers and other science students.

She thought that curiosity made her love math and science. She thought the quality of her teachers in public schools influenced her choice to pursue her science education. She especially found CGEP teachers to be encouraging since they had more depth of scientific knowledge, put more effort into their teaching, and liked teaching. Her undergraduate degree was in physics and her master's was in another field of science. When her master's supervisor got a faculty position at a South American university, she followed him to complete her research there. Realizing there was a lack of jobs in her area of expertise, she chose a more applied area when selecting a PhD program.

At the time of the interviews, this participant was just starting to conduct her research. She had received provincial funding as well as funding from her advisor's research project. She thought she had a good relationship with her advisor and the interdisciplinary research group. At this point in her PhD program, she had not yet decided on either academia or industry. She was keeping her options open.

Participant 6

Participant 6 was an international student and engineer who was in her late 20s. Both of her parents were engineers although their particular jobs/areas did not interest her. Her relationship with her parents was very strained. She thought they put too much pressure on her as a child to excel in math and science. She preferred art and music but was good at math and science and was streamed into those areas from an early age.

Because of her high abilities, she was enrolled in the only 'all girls' school' in her Asian country. Throughout her days as a student, she was exempt from entrance exams because she was at the top of each level. She liked science and math in junior high because of her high ability, therefore, there was less pressure. She continued in high school to like math and physics because it was easier for her than other courses. She chose undergraduate engineering because of her ability in math and science and it was the best area for finding a job. She was encouraged to complete her masters' in Asia, again related to the university recognizing her abilities. Her masters' advisor was not helpful, she ended up becoming a 'pioneer' in her area of research. She chose a university in Canada because she thought it was a leader in her present research area and because her country lacked basic resources that she needed to conduct her research. Her PhD research topic combined her interest in the Arts with electrical engineering.

Like other international students in her department, this participant was sustained by her advisor's research grants since she could not apply for Canadian scholarships. Having to work for her advisor, she believed, extended the length of time to complete her doctorate. During her first year as a doctoral student, she sometimes had to go without food. Getting 'immigrant status' was very important so she could have decreased student fees and also to be able to work in Canada. Three years into her doctorate, she switched advisors because her current advisor is at least interested in her area and runs a 'good' interdisciplinary research lab. At the time of the interviews, she felt she had wasted three years as she was only at the comprehensive exam stage.

Before coming to Canada, this participant had aspired to be a university professor because of the flexibility of research endeavors. She didn't want to return to her country of origin because of the low pay and unfair treatment in universities. She was considering working for industry because she thinks it is too demanding to be a new professor in Canada and her health isn't up to it. She has thought about totally changing careers after her doctoral program.

Participant 7

Participant 7 was an engineer in her mid 20s who had completed her degrees consecutively. Her parents were married and assisted her financially. They told her she could accomplish whatever she wanted to. Her father was a professional who had hoped she would be a medical doctor. Her mother was a stay at home mom. Although her parents were proud of her and didn't discourage her career choice, they didn't really understand her area of research. Her fiancée was an engineer working in industry.

When this participant was young, she 'hung out' with boys, liked science, and was curious about how the world worked. Her parents bought her "Barbie stuff" but she didn't play with it and would have preferred a microscope. In the gifted program, she felt supported by teachers who provided relevant and interesting lessons. She really liked science in high school and didn't know girls weren't supposed to do science. She fast-tracked through high school and lived in France for a year in order to learn French. She had applied to a university science program before going to France, but switched to engineering at the last moment. She chose an engineering program for practical reasons, that is, she would end up with a professional degree after four years. At her undergraduate university, women comprised a higher proportion than the Canadian average. Also the traditional categorization of engineering disciplines did not exist; it was interdisciplinary from the beginning.

In the last year of her B.Eng., she went to a WES conference and was inspired to continue her education in engineering by a speaker who became her masters' and PhD advisor. During her engineering education, she has had women mentors, role models, and professors. She was involved in a networking group concerning women in science and engineering, and she was acquainted with women engineers/scientists and academics. This participant first and foremost self-defined as an engineer and she knew as a child she was destined to be one. She thought women in engineering were a "self-selected group" who had the qualities to survive. She set high goals but was not sure how to attain them. She liked the organization side of engineering and supervising students and thought this may lead to being dean of engineering or president of a university one day.

In sum, this study was guided by the sociocultural approach and theories of learning and identity. Mishler's (1999) life history narratives were used to examine how sociocultural influences affect doctoral women's choices to participate in engineering/science. This approach reminds us that "personal narratives and life stories are: socially situated actions; identity performances and; fusions of form and content" (p.18). Research trustworthiness was assured by multiple data collection methods, thick descriptive data, and participant verification of my interpretation of their life story and their perspectives on becoming a female engineer. The narratives obtained from two open-ended interviews with seven doctoral women engineers, at various stages in their programs, were the primary source of data. In the next chapters, the findings of the study are presented.

CHAPTER FOUR

FINDINGS

The next four chapters present an analysis of the data as it related to the four research questions.

1. What sociocultural influences affect female PhD students' decision to participate in engineering?
2. What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering?
3. What do female PhD students perceive as the 'unofficial' ways of continuing the history and traditions of the profession in faculties of engineering?
4. How does the female PhD student's non/participation in engineering affect their identities?

The reader is reminded that the interplay between the components of learning and the performance of one's identities in relation to the sociocultural context was germane to understanding the process of becoming a female engineer. These two perspectives were used as lenses within which to frame the research. Moreover, theories of learning and identity with regard to science/engineering education were intricately intertwined. The process of becoming a female engineer was studied in light of learning as social participation. Wenger (1998) contends that "participation here refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities" (p.4).

The individual interviews were conducted using life history narratives (Mishler, 1999), that is asking participants how they had come to be doctoral engineering candidates. Eleven open-ended questions were used to guide or further probe the participants and the interviews were transcribed verbatim. The participants' stories or remembrances were analyzed to grasp the meaning and identify influences, using a series of cases employing a comparative analysis of patterns (Mishler, 1999), with an emphasis on affordances and constraints (Wertsch, 2002). The subsequent themes and sub-themes were organized in relation to meanings given by participants to the corresponding research question.

1) What sociocultural influences affect female Ph.D. students' decision to participate in engineering?

Women participating in doctoral engineering programs shared common sociocultural influences that affected their decision making processes in selecting engineering studies, persevering in university programs, and finally choosing engineering as a career. These issues were not described in a linear fashion but more as 'collective remembrance' that can be categorized in three major spheres of influence: Familial background, School influences, and Engineering contexts.

Familial Background

Relationships asserted an enormous amount of influence on girls and women's decisions regarding choice of school and careers. Moreover, choices made in adolescence often precluded other selections made later on in life. Since the participants were asked how they came to pursue doctoral engineering, the influences were recounted as 'stories', with regard to the context of their choices. The noteworthy familial influences in order of importance were: a supportive family, the role of the mother, role of significant others, and the role of father.

The role of a supportive family.

All participants spoke of their family as supporting them in studying science in school or at the very least encouraging their decision to choose engineering. Of course, there are variations in the supportive process and network. " They were quite happy about it. Basically they put me all the way through. My parents always told me that I could be whatever I wanted". This participant's choice of university was her own decision. Another participant knew that her parents would be pleased if she chose a scientific area. "My family wanted me to study, they left it to me but they would have been happy if I would study engineering or medicine or you know more scientific things".

Parental encouragement took many forms. Some parents played a more direct role in assisting their child with their everyday education.

> It's true that my father had a big role to play in it because he could help me with math basically. So obviously so if you are a child and you don't really understand your homework, and there is someone at your side that can help you, well, I'm sure that it helps. So I guess it's not only my dad, but also my mom who even though she was home, she could go into a dictionary and look for explanation.

Some parents encouraged their daughters by orienting them to a particular university because of its strong reputation as an engineering institution.

> My siblings are supportive; my dad is supportive of whatever I do. My mom loves the fact that I am going to have a PhD but she wanted me to go to Waterloo to do my engineering. She thought it was an excellent engineering school-she had done some homework. And I have family [close by] so if I was going to go outside of [the province] she liked the idea that I would have my [family] right there. Waterloo has a great engineering program from what I have heard.

Although this participant did not attend this particular university, it was this participant's mother who took the time to research engineering schools and considered the proximity of other supportive relatives for her daughter. Interestingly, the perception of family support can be riddled with sibling rivalry. This same participant described the tension as follows

> But now I am in love with my school and I just got burned out last term. My brother is pretty apathetic; he started off doing engineering and flunked out. Well, the one thing my parents always reminded me was that my brother's IQ was much higher than mine. So, when-he even lived with me, and I used to try and get him to do his homework and I took him to classes I made sure he did this and that. And I couldn't get him to do his homework. It seemed a little ironic that my brother flunked out of engineering and I was doing graduate studies in engineering.

Perhaps the sibling competition may have encouraged her to persist in her doctoral engineering program. Another participant voiced that her mother was quietly supportive while she felt a tension in her relationship with her father.

> My mother was very supportive; she just basically let me do my own thing. My first year of university I moved back to [a city close to university] right after my graduation but I had already applied for residence so I moved out for a year anyway. Went back home, had the big talk- you have lived on your own so you can do your own thing- that was fine. So my mother was just kind of supportive, quiet- in the background, if I wanted to talk about it I could kind of deal. My father, on the other hand, which has always been a complicated relationship- at times I think he felt threatened. In the sense, that he did 'quote-unquote' engineering work but he didn't have a degree. He would ask me about certain things, but where I had just learned it, I wasn't feeling very confident about it myself and I wouldn't always want to talk to him about it- and I find out later that he interpreted it- that I thought he wouldn't understand it. So, he wasn't always helpful in a lot of parts of my life so I didn't expect that to change with school.

This participant was in retrospect able to understand how her father may have misinterpreted her and thought she did not want to talk about her engineering education. Another engineer reports, " My parents were both engineers actually, so I think they had a lot of influence. Actually, I prefer not to talk about them". She explained that her parents strongly encouraged her orientation towards science, a path she did not really want to take. Their knowledge of what it took to be admitted into an engineering school appeared to have fueled their pressure that she pursue an engineering degree.

Role of the mother.

Mothers had encouraged school science, and later engineering as a career, either very proactively or more tacitly. Some of the mothers had been actively involved in extracurricular science activities and encouraging science in their daughter's everyday life.

> My parents' house is books- wall to wall. My mom bought a Britanica Junior when I was 5. First time there was a solar eclipse we looked it up in the encyclopedia and I brought the encyclopedia to school and I explained it. If there was a dead animal, like if some body caught a fish or my brother used to trap or my father trapped, and we dissected it. My mom used to try and organize science experiments-we built chemical rock gardens at my parents' house. So, my parents, despite-neither one of them had university degrees, they were both super encouraging.

Another participant spoke of her mother's encouragement making a difference.

> The big thing that my mother would say to me as a child was you can do anything that you want to do. It doesn't matter whether you are a boy or a girl. She was determined that that wasn't going to be an issue for me. I mean it still is. It still was, but in my own mind. And so I think that makes a huge difference. I don't know if, like when I decided what profession I was going into, I really didn't have a full understanding what the engineering profession was, so I wouldn't be able to really grasp what I was going into.

The influence of the mother, for this next participant, lies in how to interact with people.

> My mother always raised me to think before you speak, before you act, or before you do something. How is that going to affect the person or thing that you are behaving that way towards? So it was always kind of, think of other people. That was very much indoctrinated from an early age. So that sort of lends itself to the fact that I feel responsible for what goes on in design [engineering].

Another woman described her mother's lack of understanding and interest in engineering all the while supporting her as a person.

> My mom is certainly very proud of me and she knows that I love what I do and everything but she doesn't understand what I do. I remember talking to her one time to try to get more women into science and engineering and my mom said to me, "Why would girls want to do science?" And I just laughed and I asked her, Mom, what do you think I've been doing for the last 8 years. Do you think I'm weird? The thing is that she is not interested in science. She couldn't understand why other women would be. She wouldn't even consider the fact.

In summary, the mothers' encouragement of their daughters' choices of a science direction was very salient to their persistence.

Role of significant others.

Some of the women spoke explicitly of friends or significant others influencing their choice to enter and pursue an engineering degree.

> And being recruited for graduate school, I was- my entire cohort, like my friends from undergraduate were all honor students-we all did research. Like almost everybody I know that was a close friend in undergraduate is now in either a graduate school or professional program. Like I don't know of any of my friends who actually have real jobs yet. So, that is just "birds of a feather flock together" yeah. We were all recruited to do a physics honors degree, we were all recruited to do master's degree or to go to medical school, or dentistry or veterinary school, or some sort of graduate program.

In the same manner, an intimate relationship while in graduate school often influenced the choices of some participants.

> Well it was personal reasons. My ex of 3.5 years, we were dating in undergrad. We went to different schools, he went to [Atlantic region university] for his master's and I went to [a university in Ontario]. And we had decided we were going to try get [in]to the same university. So I hunted around and I found a project. And he hunted around at other schools but this project was perfect for my career because it wasn't in existence. Here, they were not ready for my kind of qualifications so we are dragging each other kind of along. So, I came here even though we broke up 3 weeks before I finished my master's because I didn't have the time or the energy to go explore other options again- so, kind of for personal reasons but also for career reasons.

Interestingly, some participants met their partners after beginning their doctoral work, and as a consequence, the often difficult process of navigating the demands of research and of a relationship surfaced.

> My husband is also an engineer. Actually, he is a faculty member in my department. And he just graduated and we were both PhD students we didn't- well, we knew that we weren't going to go out at night. We don't have the weekends; we don't even plan for the weekends. For sure we will either go to school to work or we will work at home. So we understood each other. There was no problem; there was no demand from the other side to go to a bar or to go see a movie.

Selecting partners with similar understandings of the demands of doctoral work can be seen as a positive influence.

Role of the father.

Selecting partners with similar understandings of the demands of doctoral work can be seen as a positive influence.

Role of the father.

There were two types of roles for 'father figures', that is engineer and non-engineer. Although some participants spoke of their father or a close family member as being engineers, that fact was not in the forefront of their decision-making. The following participant initially spoke of being aware of engineering based on her father's work as an engineer.

> My father is an engineer so I guess for me an engineer was more, you know, a person working in a plant, and you know, reading, -reading like math and stuff like that... it wasn't really what I thought, you know. What I'm doing right now is completely different, so I guess that's why ...I never thought I could do that for university but when I started to do research that's really when I discovered all the research aspects of engineering and where I got interested in engineering.

Even though her father was an engineer, she did not report being impressed or interested in his domain of engineering. She credits her interest in engineering to discovering the research aspect of science in her master's program. This early knowledge of engineering as a career option offered some participants a model or another option when trying to match their abilities and interests with a university degree.

> My father was in an engineering-like profession. Umh, technical work I guess but he is from [European country] so over there, anyone who does technical work is called an engineer. So, that would have been my only knowledge of anything related to the

Another participant acknowledged the influence of her family members' jobs on her choices, "I wanted to study engineering or medicine, medicine was always an option because my father was a doctor. So it affects of course. My aunt was an engineer, … there was someone I knew". Interestingly, some participants had no family members who were engineers or scientists. Parents appreciating science in their occupation or as a 'hobby', even if they had not obtained a degree, was a great encouragement for some children.

> My dad wanted me to be an astrophysicist. Yeah, my dad is crazy about astrophysics; a [blue collar worker] who is crazy about astrophysics. Go figure. Umh, we used to listen to 'Quirks and Quarks' all the time at my parent's house. If there was a science-like Nature Things, do you know how many nature thing episodes I have seen. If there was a science documentary on CBC or ATV I have seen it. Dad used to spend a lot of time in the woods and he would give me a rock hammer and tell me to go find whatever and give me a little gem book or rock book. And go find pieces of rock.

Similarly, another participant reported also being encouraged by her father to pursue his interest in science.

> My dad always wanted me to be a doctor and he's [in the health care field]. And all my patients could go to his [place of work] and that was always his thing so we joke about that. I'm going to be a doctor but not the one [he] you wanted. My parents certainly never discouraged me from anything but they maybe never really understood what I do exactly. My brother also became [in the same health care field] and he would go and talk about [their specialty] which is fine because I grew up on that-- I can join in on it. But there were very few conversations about engineering-like so what are you doing now? And then well

> ok back to [health care field] stuff, so it wasn't like they weren't interested either-- they are very proud of me but they never really knew what I did.

Having fathers or family members who were engineers provided some knowledge of engineering, and opened engineering as an option for future career paths.

School Influences

Significant relationships at home and in school are considered to be the main socializing agents for students. School environments were second only to familial influences on how strongly women spoke of early experiences of learning. Teachers and special learning experiences in school had a huge impact on how participants perceived learning and ultimately how they view themselves. Doctoral women's contextual retellings were organized into the following salient themes: Special/enriched programs, Teachers, Success experiences, and Motivation nurtured.

Special/enriched programs.

Some of the participants voiced their experiences within enriched programs or special curriculum that strongly reinforced their interest in math and science, and their choice of program.

> Isn't that where all the smart kids go [sciences]? Seriously though there is no one in high school advocating doing an arts degree really. Once you prove yourself to be fairly intelligent and you get--I graduated from high school with a 99.4% average, it just seemed like high school was a walk in the park. And then you do well in physics, you do well in chemistry, you do well in math, and I went to a very small school so there weren't a lot of other options for other programs.

Living in a small, under-funded, rural area, she thought high ability students were encouraged to take science as a way of enriching their abilities, even if this was not an area of interest. Based on high abilities in math and science, another participant earned a place in an 'all girls school', the only one in her Asian country.

> [Enrolled in the only girls' school in Asian country] I think in a girl's school when I was in high school. That was very good, especially in [Asian country] because they wanted to keep that school a girl school. So actually all of my classmates were girls. And so most of them went to other areas... into arts, only very few people went into engineering.

This engineer reports that high ability females were encouraged to excel in the Arts. Her ability in math and physics was seen as an anomaly but one that won her many scholarships. Another participant spoke highly of her experience in a special program.

> I was in the gifted program so I guess we did more science than other people. I mean I remember going through, we're from a small town so we went to math through university , and we did ... you know... we had to plan camping trips and figure out what we were going to bring and how you were going to cook it. Take like nature around you into consideration. Yeah because you know we also did... well we had to build a casing and throw an egg off the school roof and you had to make it drop without it breaking, so we had to do a lot of design there.

The opportunity to 'do' more science and work with students of similar ability allowed this student to experience more hands-on, applied math and science. In this particular small town, congregated gifted programs appeared to be seen as salient. This next participant thought the practice tests given in the enriched program gave her the opportunity to 'know' she could excel in the engineering curriculum.

> So that we knew what we were getting ourselves into and we had a pretty good idea if we could hack it coming out of high school. So, yeah it was a very supportive environment. And I seemed to have focused on the sciences and math in high school. In retrospect [laugh] umh, but my English teachers were good but they don't seemed to have stuck with me the same way.

Having a connection, both on a personal level with the teacher, and with the work they assigned, helped some participants take a strong interest in science.

Teachers.

The amount and type of encouragement for science coming from teachers differed for each participant. The quality of teacher encouragement for these participants varied according to grade level, number of students in class, subject area, level of students' abilities, and the ability of the teacher. The overall climate of science education for everyone was quite a positive influence.

> Like I never knew that girls weren't supposed to do science and engineering. I don't ever recall any teachers telling me that I shouldn't be interested in science. But I don't, I mean in grade 6, 7, 8, we did experiments in science class. I guess mostly I felt support from my teachers when we did science in class, but there really wasn't any "go do this on your own".

Another participant spoke of public praise by her grade 11 physics teacher as being most encouraging.

> Umh, the only thing that I can say that may have-- the only teacher was my grade 11 physics teacher. I did very well in his class and he made bones about praising me for it. And he encouraged me to continue in the subject somehow. And actually if I remember right, he was an engineer before he became a teacher. So that may have had something to do with it subconsciously.

Another engineer suggested a link between student performance and teacher support.

> I found all my teachers were supportive but that could be I did very well in high school as well. That could be a contributing factor, that I did get that praise from them or that sense of accomplishment from them. I remember my physics teacher- I was in the enriched stream, so there was a small group of us for all of our classes. So we were much more interactive with all of our teachers too. And like my physics teacher at one point said that he used my test to double-check his answer sheet to make sure it was correct.

Challenging learning experiences provided this student with an opportunity to feel successful and boost her of level confidence in her abilities, she knew she could do calculus at a university level. In addition, having small, interactive classes allowed the teacher and students to develop a close working relationship.

> So, it kind of pushed me in the direction of saying, "ok, I can do this. This isn't something to be afraid of". And my math teachers were also very good, they challenged us which was nice. It wasn't just sticking with the curriculum. One math teacher in particular had started a class on chaos theory. And a number of us took that class, and it wasn't offered in any of the other schools in the province as far as I know. But he had taken the initiative to give us something that we might be interested in and we might find challenging. So, I guess that

> helped bolster our confidence in our school too. And he also taught us our calculus course and he would use midterms that people would bring back from university to him. He asked them to bring back midterms and finals. And that is what he gave us for practice and he used it on our tests as well.

Another participant surmised that high school teachers with advanced degrees [CGEP in Quebec] in their particular area was also important.

> Well I think I was already interested in science so it probably gave me the confidence to continue in those fields. Especially that, it was not a big CGEP it was a small one. You could really talk to the teacher easily. So they were really encouraging and so I think that was probably an important thing, having good teachers in CGEP.

Encouragement of teachers was reinforced by the scientific challenges that they provided. And they were usually verbally expressed through praise, positive interaction, and repeated successful experiences.

Successful experiences.

Past successes and ability in the sciences were recurrent themes for these women when telling the 'story' of how they have come to be doctoral engineers.

> The main reason for me was I was comfortable in math and science. Especially in my high school education that was the main thing. I wasn't really interested in social sciences... And I wasn't really good in biology. That really affected- I was happy to study chemistry and mathematics and they were my favorite subjects. I was successful- that was my motivation. My grades were higher, usually the geography courses whatever, those were the ones you used to increase your average. But it was the opposite for me, geography,

history, literature, religion I wasn't successful at all- I was successful but like I never had really high grades in them.

Another participant reported being exempt from writing entrance exams because of her high performance and ease with the work required.

So it's not really- do what you like to do. For me it's easier to do mathematics. It's just easier so that's why I liked it. So since I'm better at physics and mathematics, that's why I chose the engineering direction. In public school I was like the top student, and the school recommended me to the junior high school. I was still one of the top students so I went to high school, and then actually we had a lot of competition in mathematics and physics for high school students. I got the first award for the physics competition in high school so that's actually how I got the exemption from the entrance exams and enter a good degree. And from there- also they have some exams... in my undergrad university [in Asia] they have exams to choose [areas]. They also [gave] me an exemption from that into graduate studies, so then I went to another university for my masters'. So that's why I didn't take any exams.

High marks was also evoked by another participant.

In high school I did very well in math and physics. My first choice was actually to be an architect and then at the age of 16 you are thinking that all architects do is build houses. So I wanted something where I could use what I was good at and make some money and that was engineering.

Ease and comfort with the subject matter of engineering was salient for all participants. She explained, "Well, at the same time there are not many guys who would pick a profession if they knew it was going to be an uphill slog [struggle] all the way. I don't think they would".

Motivation nurturing.

Those students who had an intrinsic motivation for science were drawn to persevere in a doctoral engineering program. One participant viewed personal interest for a particular discipline of science as determining her career path when asked if high marks influenced her choice.

> I had good marks but I don't think so. My lowest marks in science were in physics and I decided to go into physics. I really think that it was the field itself that made me more interested in physics more than biology or chemistry or it's really my personal interest that decided where I was going to go instead of the marks.

Her interest and subsequent research in physics later led her to a doctoral program in engineering. It is her interest in her area of research that led her to engineering, perhaps the only program where she can pursue her research goals. Similarly, this engineer posited

> I'll say it wasn't definitely anything my parents did for me in that way. I think it was- I have a 2 year older brother. All the neighborhood kids were boys as well. It was kind of play guns and tag or play with girls who were 3 years younger than me. I hung around most of the boys. I've always been interested in science, in grade 3 we went to the 'sugar bush' and the boys found a snake and they were too scared to pick it up. And I picked it up and all the guys were so impressed and I gave it to them and they dropped it and I had to go pick it up again. So I mean I always liked science and have been curious about stuff.

Another participant concurred, "I think it's the curiosity that makes you love science and math in general". More specifically, this engineer remembered her interest in electricity.

> The thing that really kind of pushed me towards it was, I think the last year in high school, like grade 12 the last half of the year was all electricity, you know about how motors work and basic circuit theory and stuff. And I loved it. So it was more interesting for me. I think it is more- make science interesting.

Interest in the subject matter did not always lead a student to choose the same discipline of science. Another engineer explicated, " I was mostly interested in math, chemistry and physics. Those were my three favorite subjects in high school, and I was more interested in the theoretical aspect of science at that time". Realizing that her interest was in theoretical matters, she chose another scientific route.

> Well, basically I started with a bachelor in physics. When I was doing high school I was really interested in science, but I wasn't really sure in which field exactly, so that's why I chose physics. After that, I did a master's in astronomy and I figured that well, since there are not many jobs I could see in astronomy, that I wanted to work in a more applied field that I was probably better changing into engineering. So that's why I finally chose to do some research in engineering.

The doctoral women's ability to combine their interest in science with an engineering program helped them sustain their career direction.

Engineering Contexts

There were three aspects to the engineering context that gave my participants an orientation towards this domain. The tension in these complex themes became most apparent when the women made career choices. The following themes were gleaned from the women's stories including: Practical aspects of engineering, Funding, and Job security.

Practical aspects of engineering.

Success and interest in science/math led many participants to choose engineering as a career. Interestingly, these women did not know the specifics of the engineering program and its subsequent working environments at the time of undergrad selection.

> I had no idea or actually I only had a little inkling somewhere around the end of grade 12 that this wasn't something that girls did. But I didn't really have a full-force idea until I actually showed up at [undergrad university] and looked around the classroom. It was really kind of, I didn't know what I was getting into I will put it to you that way. And I think that is like a lot of us.

These highly successful students were confronted with a spectrum of program options.

> I remember in grade 10, one of my friends telling me that he had just started engineering and he said, "Oh you'd really like this." So it was like in grade 10 - I didn't even know what engineering was. When I applied to university, I saw something about [a type of interdisciplinary] engineering. So someone told me that engineering was building things and designing things. And I thought, ah well that's cool because I thought it was just cars and stuff. One of my friends, I guess she was saying that she wanted to be a cosmetic engineer. I asked her what that was and she said well you're a chemical engineer and you make make-up. I was like oh... cool... I didn't know that you could do that!

Although this participant did not question or research this area of science, it became an option later on when she became aware that four years of studies assured a good engineering job.

> All I knew is that you got to build stuff and design stuff and I thought that sounded cool. I didn't' know it was supposed to be a really hard program. The other reason why I chose engineering over science was that I thought back when I started, I though well in 4 years I'll have a professional degree and I'll be able to go out and get a job, whereas if I did biology I'll need a master's degree to specialize. Ha, ha, ha, 9 years later... I'm still in school. So that backfired, but that was my reason for going into engineering. Also I didn't know that it was a well paying job, either. I didn't know about the iron ring ceremony at all until the end of 3rd year, so I really had no idea about engineering. But I liked the courses that I took and I liked the people in my class.

Enjoying the content of engineering courses, along with the duration and outcome of the program influenced women's choice of engineering.

Funding.

When participants spoke of being given the opportunity to complete a PhD, it was usually in relation to funding. All of the doctoral women participants received some kind of funding or scholarship in their academic careers either national, provincial, institutional, and soft-funded [thesis advisor's research grant]. NSERC (National) funding was very competitive and this prestigious award was often difficult to turn down.

> And when I finished my master's degree I had a bit of burnout and I had NSERC funding for my master's and I have NSERC funding for my PhD. So I am fully funded plus I have another scholarship from an employed health organization here. Which is really helpful in

> case NSERC doesn't give me full funding for my third year. So, I was given the opportunity and I thought if I don't do it now, when I am fully funded, will I regret not taking this, at least trying it?

Applying for NSERC doctoral funding takes place approximately one year before the grant can be accepted. Completing interdisciplinary research in time to defend a master's thesis and start doctoral courses was difficult.

> It was kind of because the money was there and I hadn't put much effort into finding other things because I was too busy with my master's degree. But I hadn't really explored any of the other options although career-wise this is what I want. I have kind of been building towards [this] the last 7 years anyway. That is kind of the short end of why I am doing my PhD in engineering. The reason I am in engineering [field] is because they are the only people who do this kind of research to the complexity that I am interested in.

Another participant was funded for her undergraduate studies and her graduate program.

> Well when I was in undergrad I worked for the National Research Council in Ottawa for 3 summers. And for the most part found it a really positive experience. Umh, that was with the Women In Science and Engineering (WISE) scholarship program. So, I guess I kind of felt an obligation to keep going; [laugh] 'No pressure but we are giving you all this money to keep going'. So that was intended to promote research- to promote women entering master's and continuing on with academia.

Because of her coveted undergraduate scholarship, this participant felt responsible to continue her academic engineering career. In addition, not all students can apply for

Canadian scholarships; some must rely on research assistant positions with their thesis advisor.

> [Immigrant status] That helps a lot because my first year here as an international student was really hard. Sometimes I had to starve myself a bit. That's why it was very urgent for me to get immigration.

Once this participant received Canadian immigrant status, she could apply for various scholarships as well as work to supplement her funding- a reality that not everyone had to experience.

Job security.

Engineering was seen as a practical solution for many doctoral women, one that combined their interest in science with job security. When asked how she had become a doctoral engineering student, she replied

> It's still like the best for finding a job and these kind of things so especially in [Asian country], there are a lot of people and lots of competition, so it's very important to find something that you can really find a job in later. So that's why I chose electrical engineering. Actually I don't like electrical engineering and unfortunately, I'm not into mathematics and physics. I do them well, but I don't enjoy them so much as I would imagine, some people. I also like music and drawing things. I like those things, but they don't guarantee a good job. Fortunately, what happened is that electrical engineering field [has expanded into a new area with computers]. It's similar to, ... it's close to what I'm interested in, my drawing. Because when you do the processing image, I feel interested in my drawing, so then I feel interested and then I continue until where I am now.

This participant was passionate about the Arts and drawing, but through school and parental encouragement she had focused on her more ‘marketable’ abilities. Astoundingly, this participant had found a way to combine her engineering abilities with her more artistic side, for the moment anyway.

CHAPTER FIVE

Research Question Two

2) What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering?

The doctoral women's perceptions of learning in faculties of engineering are complex and context driven. This research question was troublesome, as the women's discourse about participation was confusing. When describing how they have come to be doctoral women in engineering, these women's 'stories' were transposed into themes by way of inductive analysis. Therefore, their words and voices describe the contexts of their learning experiences, some of which are quite extensive. This 'collective remembrance' contains positive aspects of learning called affordances, as well as more negative aspects referred to as constraints (Wertsch, 2002). In some instances, participants chose a more neutral position in recounting their experiences. The themes are ordered according to salience, that is, how strongly doctoral women spoke of their learning experiences [see Table 1]. Thus, 'Doctoral Advisors' which is discussed first, were more of a constraint, while 'Pedagogy' was second and more of an affordance. Thirdly, 'Research Groups' were spoken of as an affordance, while 'Peers' and 'Work Experience' were seen in a more negative light.

Doctoral Advisors

Doctoral students' relationships with their advisors were perhaps one of the most important elements of perceived success in their studies and access to employment. Advisors can be mediators or barriers to effective learning; more often professors/advisors were not a positive influence on learning. The women who considered their doctoral advisors to be constraints criticized how they 'Treated graduate students', their 'Ineffectiveness as advisors', and their 'Poor teaching'. Next, the 'Charisma of certain professors' and the qualities of certain advisors will be highlighted as an affordance. Lastly, 'Lab experience as a trade-off' between finishing doctoral research on time and gaining additional laboratory experience will be presented.

Table 2

Doctoral Advisors

Constraints:	***Affordances:***
Treatment of graduate students	Charisma of professors
Ineffective advisors	Good advisors
Professors as poor teachers	Laboratory experience as trade-off

Constraints

Treatment of graduate students.

In the relationship with their doctoral students, a number of advisors treated their advisees as marketable commodities

> And there were profs that were incompetent and who took advantage of their graduate students-- kind of abused the situation; paid their graduate students minimal amounts and got the maximum amount of work out of them. Got them to do other things like baby-sit their kids and stuff. Yeah, there are people who abuse their graduate students that way.

It was expected that graduate students assist professors in the engineering courses by observing, grading papers, and tutoring students. This apprenticeship was supposed to help both the professor and graduate student. In some instances, the benefits seemed minimal.

> I had profs take advantage of my last TA position at [master's university]. Three female grad students; we set the exam, all of the assignments, marked all the assignments, marked the exam, and we taught the tutorials. And the prof, all he did was walk in and teach three lectures a week. So we did the complete evaluation of the students and it was just-- does the prof care? His first time teaching the course, and the grad students were pretty much running the course and he was teaching lectures... we thought it was ridiculous that he had no say in the way his students were being evaluated. And here we are three grad students who had never set an exam before.

This engineer did not receive the guidance she thought was appropriate to design evaluation measures or to evaluate the students effectively. She was outraged that his incompetence was at the expense of the undergraduate students, even if it was this professor's first time teaching the course.

Many advisors fund their graduate students' dissertation research, all the while expecting them to participate in the overall research theme of their lab. Some engineering professors accepted outside contracts from industry and students assisted in these projects. In some cases the contract fitted the dissertation topic of the student, but in some cases it did not.

> I know many professors have companies of their own. So actually they put more effort into their companies, so that's why they don't care what their students are doing. And

> sometimes even worse, they use what their students did in their companies, and then they make profits out of it and the students make nothing. And that's very unfair. And also another thing that I think is worse in Canada than in [Asian country], we have a fixed period of time for doing a PhD study. So no matter how bad a professor is, they have to make you finish on time but here they don't have a limit. So usually professors, they don't care. They just let you go on and on; that's not good.

Having to work on industrial contracts was often incompatible with students' doctoral research. But for some students, funding from the professor was the only way they can be accepted into the PhD program.

> In our department, all the students get research and you are paid. Many of us came as international students and if we don't get paid, we don't come actually. Then the bad thing is that you get the money and you have to work for them. But then if you reach six or seven years, the department has the right to kick you out.

This student perceived the professor as putting his own research agenda over and above the welfare of his graduate students. In any case, she stated that completing doctoral research on time ends up being the student's responsibility. "So then all the bad things happen to the students, not to the professor".

On the surface, the following participant viewed her dissertation topic and the guidance she received from her advisor as helpful.

> As PhD students we're really free to chose where we should go as researchers because I think that really depends on the supervisor. But for my advisor, I think it's very important for him that he wants his students to become university professors or researchers so it's important that those students can be independent and choose really fair direction of

> research and choose really what they are interested in... You know he will support you; he will assist you in that, so it's really your interests that are important more than his actually. But obviously, if your preferences are not related to his, well there's a conflict but if your interests follow more or less his research, well it's fine with him. You're really in charge of your project.

Although she expressed her belief that she was free to choose her own research subject, matching her dissertation subject with the advisor's interests was inevitable. The student had to accommodate her advisor.

Ineffective advisors.

Discussing their common problems was a means for doctoral students in one engineering department to vent their feelings of disappointment.

> The students from our electrical engineering department, every time we meet we talk about our supervisors and we talk about all the problems. We have many problems in common: we don't get guidance, or they push a lot just to get the results but they don't really give some suggestions, or they just don't care at all. All these things especially, there are only very few professors who care about the students' situation. So actually that's really disappointing to me. I hoped Canada was better.

Some of the participants perceived their advisors as having poor communication skills, with discourse that was insensitive or non-communicative.

> I think my advisor doesn't have the world's best social skills [laugh]. I think that perhaps he doesn't always understand how his actions are sometimes perceived. And what he is saying when he is not saying anything.

This participant had hoped to find experts in her area while attending Canadian universities.

> The first year I was taking courses [at doctoral institution] it was fine. I found many professors were knowledgeable and the courses were interesting. I learned a lot. But later when I started doing research, it [took me] one year to finally realize what my professor was doing. He didn't give me advice, and actually what he did was distract me from the direction I wanted to go. So I worked with him for actually two almost three years. The disappointing thing is he is not much better [than Asia]; he is not really into computer vision. He is working on something else. But he needs you to work on computer vision but he doesn't know anything about it. So actually he gives the topic and I still have to work on it myself. But the good thing is that this time when I changed supervisors, I got myself a 'cool' supervisor who is very good at computer vision. So I hope I could get some guidance from him. Recently I was really busy because the whole topic changed, and I had to adapt to the new lab.

While some advisors were especially good at motivating their students, others were not.

> In undergrad it was more marks and doing well ...but it is such a drawn-out project at the master's or PhD level that seems to get so little feedback. But when we do get feedback it is either negative or none, which is really discouraging. I don't know if he is trying to motivate us by telling us, "you know you have to work harder". [laugh] When he hasn't said whether or not you are on the right track. Or what he thinks of what you are working on. It's

hard because he is so hands off and removed from work that I am focusing on a daily basis. He doesn't really seem to be that much in touch with what I am doing but at the same time the feedback is not necessarily useful for either motivation or forging ahead. Not that I expect him to take my hand and lead me through it, because it is a PhD, it is novel work. Nobody knows where it is going exactly but just a little bit of encouragement from time to time.

This participant doesn't doubt her advisor's advice, just his ability to convey it. Having an advisor that also taught course work added to the perplexity.

Yeah, I know my prof. is very confusing as a professor. Students are always perplexed as to what he is trying to tell them. And he doesn't communicate well in front of an audience. My experience with him is he will tell me something. I won't understand it. I will ask for clarification and he will take me further down the path that I don't understand at all [laugh]. And three months later, I will be working through the problem still and realize-- oh, that is what he is talking about. [laugh] Which doesn't help me get there faster.

One participant's hypothesis for her professor's mode of interaction with his graduate students was linked to his own learning experiences.

One of my peers in the group I work with thinks that when her supervisor did his PhD, he took extra time and it wasn't a problem because he was working on other projects for his prof and he sort of expects us to do the same. Yet at the same time, our funding runs out [laugh] and we can't really afford to go into more debt at this point...it is the difference between finishing and not finishing.

> And now that I am approaching the end of my funding... I went to see him last week and he said basically-- I want you out by the end of December because your funding runs out then you are a liability not an asset. [laugh] I don't know if he realizes that it could be something that I interpret as being really insulting. [laugh] Or if he thought it was funny because there are a lot of off the collar remarks that he makes that make me feel uncomfortable. And I haven't said to him directly- "stop it [laugh] it makes me feel uncomfortable when you say things like that or do things like that in front of all of us". I think he needs better interpersonal skills.

Interestingly, this learned style of communication did not befall all engineering advisors. A male professor was remembered as being very accommodating, implying that exclusion was not always a gender issue.

> I know that at least one of my profs was male and very conscious of using inclusive language. There were other profs that I have less respect for and they probably did use exclusionary language but it probably wasn't because of that. It was their style, I guess, it just wasn't good. It was obvious that a couple of our profs didn't want to be teaching undergraduate students and that they had better things to do with their time. They scheduled their office hours during one of our core courses so that we couldn't go. They made themselves completely unavailable. An example of the 'old boys network', who was actually female and in our department- so there were kind of a dichotomy of one woman who was a prof and she was feminist but not exclusionary towards males. The other one was trying to fit into perhaps of what she perceived as engineers to be.

This perspective painted professors' "style" of interacting with students as perhaps more indicative of how they viewed their role as advisors and if they respected their students.

There seemed to be an expectation of guidance from advisors- one that was not always forthcoming.

> When I was doing my master's in [Asian country], my supervisor was about 65 years old and he was very busy. I don't know what he was busy with, but he didn't give me any advice, so I actually found a topic myself. Because I already did some image processing projects during my undergrad studies and I read some papers and I felt that I could just extend that topic and try to work more on that. So, I did find a topic myself and worked hard at it. And so everything I've done, I've come up with it myself. All the topics and methods and he didn't give me any help. I was hoping that after I came to Canada I would get some help.

Engineering students looked to advisors for advice, direction, guidance, and support. Some advisors fulfilled their students' implicit expectations while others performed their role in the manner they saw fit.

Professors as poor teachers.

Generally speaking, most participants complained of poor teaching in their undergraduate engineering programs. It was felt that professors were not trained in pedagogical skills.

> Profs are lousy teachers for the most part. There should be better education on how to be an educator. There is no good program that I have encountered that teaches a prof about contemporary educational theory and how to teach. They give you great profs that first year because that is the only way they can keep you-if you have a shitty prof the first year

> you are going to drop out. So all the good profs teach introductory level courses and may be they teach some of the second year courses so you don't really get exposed to how horrible teachers profs are. Like my third and fourth year profs, they might as well not been there, they could have just given me the text book and I could have read it and probably done equally as well, if not better. Instead of being confused by the lectures and the way the material was taught.

One participant recalled the following experiences.

> I had a prof who used to teach with the same yellow notes he taught with in the 70s. So I would call that apathy. And he often went off on mental leaps of I don't know what. Into stories into something that happened before we were even born sitting next to a nuclear reactor somewhere...And then there are profs who are too smart to teach, they understand everything they just can't explain it to us the other 99% of the population that can't understand Quantum Mechanics. Or...we have so many different learning styles like some of us learn everything in the lab, or some of us only learn by hands on, or some of us learn by a good lecturer-all of the sudden everything just sinks in. Or reading a book or rewriting something over and over again, and discussion.

Participants seemed conscious that their professors lacked an understanding of pedagogy.

> And profs are only taught to teach in one or two ways. That horrible lecture where they get up and write everything on the board and you spend the whole class copying down these horrible notes, you are writing down math which is all Greek by the time you get to fourth year physics, alpha this and beta that. That is all you do is write down the notes. And you get home and you have to decipher this and understand. But that was what the lecture was supposed to do. Or the lab-that aren't really designed to teach, they show you a technique

> but they don't really explain the theory... When I got to graduate school you had more a discussion-based courses, those were great because you actually got to think and interact. And there is not enough exploring of alternative techniques and how can you better present material and profs are not taught how to be educators, they are taught to be researchers.

One participant shared that senior professors "parroted" the content of their course.

> Some professors, especially old professors, they have a reputation already. They have been there for a long time and they know that they won't lose their job. I think they don't care so much, so when they are teaching the class their voice is so hypnotizing. I think it is very important to have the motivation to teach well, but I found young professors are generally better than old professors. I think they are more serious... And I felt that the professor also fell asleep... He is so familiar with it and sometimes he is not even aware of what he is saying.

Availability for consultation and feedback was not always offered.

> The prof was always unavailable, treated us like we didn't deserve to be there, and the teaching assistants weren't very helpful either. When we got our assignments back, the comments were non-existent. And during tutorials they couldn't explain what was going on. So that was very frustrating. I guess it has a lot to do with the prof's sort of condescension towards us. And that was an attitude that I didn't encounter very often, but that would be what I thought was the biggest impediment to learning.

Other negative practices were voiced.

> I had other classes where the prof would show up 20 minutes late and then order pizza [for himself] because we would have to stay late. He had no respect for the graduate students. We didn't get the course outline until half way through the course, the exam was suppose to be 48 hours but it turned into a week long take-home I had to take home for Christmas break because I had booked my plane ticket based on the 48. And then he gives people extensions and doesn't give other people extensions--that was the worst experience I have ever had, like in a course. It didn't matter; he pulled our marks out of his ass anyways.

This participant has experienced three different faculties, levels, and institutions of science and posited that poor teaching practices by engineering professors was not that different from other professors of science--that 'individual personalities' were more of an influence on pedagogical practice.

> I think that some professors they really have this interest of communicating their field to other people, and you can really see that right away when you are a student. I don't think there is any difference between professors in engineering or astronomy or physics. There are some professors that know that they could do better, do more. But it's just with all the [extra] work in the universities these days; it's extremely difficult for them to do the job that they are supposed to do. And I also think that they don't always choose the courses that they are going to teach. Sometimes they are not so comfortable with the subject, you can see that. With all the professors that I talked to whether in my master's or PhD, I think you can feel that it's really a concern for them to really teach well, but sometimes it's just a matter of time, sometimes it's a matter of subject. And also I think that some professors know that if they probably don't have all the tricks.

Making teaching a priority, and allocating time to improve teaching practices and curriculum content should concern professors.

Affordances

Charisma of some professors.

Excellent professors displayed charisma. The following quote was laudatory of one remarkable teacher.

> I have had the best prof and this year I am writing a reference letter for him--he is being nominated for the outstanding teacher award for Atlantic Canada. And he is 65 and he has people all over the world that think he is the greatest teacher that ever walked the face of the earth...Life sciences students would rather take the engineering science physics course, [1st year eng.] instead of the physics for life sciences because he is a better teacher. So, the class has 60 engineering students--the other class has 20 students because biology and chemistry students are coming to take his course instead. I have had other profs where regardless of their age just have not had that same charisma--there has to be a charisma where you interact with students and students actually believe that you care what you are teaching them. And if you don't, you lack that and you are not going to have the same interaction.

A measure of excellence, according to this participant, was when students chose more advanced engineering courses in order to be taught by an engaging professor.

Good advisors.

Being guided through the process of becoming a doctoral engineer was a complex undertaking. PhD candidates must master their course work, comprehensive exams, proposal, research, and finally their dissertation all the while participating in the research lab environment. While some engineering students viewed their working on industrial contracts as a constraint, others appreciated the experience and stressed the importance of the leadership skills of the advisor.

> Well I think it is also our advisor--it's really important for him to have a really good atmosphere. It is always difficult to find money and funding, so he's into finding small industrial contracts and money that comes from definite projects, so guess that's why we have the opportunity to do those kind of experiences... We also do group meetings once in a while, where we talk about one person's project and the whole group asks questions to understand what the person is doing.

This emphasis on discussion of scientific concepts and intra-group communication was thought to be rare in research groups within faculties of engineering.

Having a woman advisor was a novel experience. When we consider the paucity of tenured women professors in Canadian faculties of engineering, the option of a woman advisor for a doctoral program was a long shot.

> And she pushed me like I have never been pushed before, which was great because I got things done that--and she had really high expectations for me which was even more empowering--gives you the drive to get through stuff when you know you are going to let somebody down. And I purposely seek out female mentors whenever I go somewhere, if that doesn't sound crazy. So having a female supervisor was my ideal work scenario. Like

> if I could have a female supervisor for my PhD that would make me happy too. But I am pretty much alone. There are not that many women. I am working on it. I just joined WISE, I had never heard of that before. So, [a woman eng. prof], she is amazing. She is always looking for the opportunity to help people so. She might be my mentor, we will see.

In order to feel encouraged and empowered, most students must connect with the subject matter and be supported by the doctoral advisor.

> I find female profs have higher expectations for female graduate students. And that is maybe because of the feminist issue that they had to fight so hard to get to where they are that they may either resent the fact that we don't have to work quite so hard to achieve the same things, or that they expect us to perform to the high standards that they had to perform to, or maybe they set high standards because they want us to be the best that we can be.

For some doctoral women, having a female advisor and/or mentor provided the opportunity for a deeper relationship and an example of what can be accomplished in engineering. Moreover, the leadership ability of advisors within research groups and their ability to communicate with their graduate students enhanced the learning process.

Laboratory experience as a trade-off.

Learning in a laboratory was research driven and must be negotiated with the doctoral advisor. Students were apprenticed into this culture and learning environment. Knowing this, many students gladly accepted extra work that may benefit them in their future.

> To a certain degree you kind of let yourself be taken advantage of so you can learn more things. It is like, how much do I trade off of doing extra research but getting this skill or getting more information so I can write this paper. Or getting authorship on a paper, or there is a fine line to walk. And then once you are in, how do you get out?

Negotiating the amount of extra work and their needs as students was a difficult enterprise. In some circumstances, the advisor's research interests came first, especially if an industrial contract was at stake.

> My advisor--he is pretty much hands off and he will pretty much let us do our work unless there is something else he wants us to work on, in which case it doesn't seem to matter what it is. It seems to take priority. [laugh] Which can be really frustrating because we are trying to get things done while we are still covered by funding and yet you feel on the one hand you are being sabotaged [laugh] because you are being drawn off on tangents that aren't even tangents from your own work--it's from somebody else's work. But by the same token it is interesting work and it is always interesting to learn about other things. And a little bit of diversion is almost like a vacation from working on my own research but at the same time there can be too many distractions.

How can doctoral students best learn to negotiate the terrain of a research lab and classroom? While some participants have endured numerous negative experiences, many others sing the praises of their advisors.

In summary, the choice of teaching methodologies affected not only how a lesson was delivered, but how students perceived the information, the subject, and the professor. Most doctoral students perceived their overall engineering/science programs as lacking in sound pedagogical practices. Moreover, negative perceptions of how professors interacted with their students revealed their motivation, attitude, and level of respect for their students and teaching- offering, perhaps, a glimpse into the complex context of engineering education.

Pedagogy

In most teaching environments, it was difficult to separate the students' perceptions of their professor from the content and methods of their teaching. Often times, the remembered experience was one of appraisal of success and failure events coupled with students' beliefs and preferences for learning. The affordances of the following section were ordered according to salience, that is, how strongly positive remembrances were recalled. 'Flexibility of structure' in graduate courses is discussed first. Then 'Project/Group work' is presented along with 'Positive leading strategies'. Then, traditional notions of engineering are considered and how these are incorporated into 'Traditional programs'. Nevertheless, certain negative outliers were voiced with respect to the 'Lack of pedagogical training'.

Table 3

Pedagogy

Affordances:	***Constraints:***
-Flexibility of structure -Project/Group work -Positive learning strategies -Traditional programs.	-Lack of pedagogical training

Affordances

Flexibility of structure.

Most participants reflected on the teaching methodologies and curriculum design experienced during their engineering education. "The graduate courses are usually some of the best-taught courses because it is the graduate students teaching each other". The open structure and emphasis on discussion and personal experience appealed to the learning style of many participants.

> And we would read three or four papers and we would actually discuss them. Whereas I found in other classes everything has to be so much more structured. And this had such a loose structure that, we would get a paper, everyone had to read a paper, and we would come in the next day and we would have a discussion. And everyone was actually sharing things that they thought as opposed to a kind of factual like maybe because it was in [her discipline] it was a little more open to subjective comment. But it was much more of a sharing experience than an analytical--there was more commentary, there was more. Well my experience, we tended to draw more on our own personal experiences when we were in these classes than in my other classes.

The unusual occurrence of a whole class consisting of women was a novel experience. Even when the amount of time required for class increased, "it was so enjoyable that we didn't even complain". Planning a class based on discussion of concepts usually required more time and implied having less control of the content by the professor.

> While I was doing my graduate degree I had the opportunity first time ever to have a class with all female students and with a female prof. And that was a complete shock to my system because I had never been in a class where there wasn't any men, even male profs.

> And that- you could tell there was a whole completely different aspect to learning that was completely absent whenever there was a male present.

Another participant reflected on the differences between undergraduate and graduated engineering pedagogy.

> It is also the format of the course that is very different. There is not as much homework; there is usually a long-term project involved in the course, individual projects. Sometimes there are no exams at all. So that's why it's completely different. It's not really your undergrad work where you have to do homework all the time and study for the midterm. I guess that you have to acquire the basics [in undergrad] and what's the best way to acquire them? Well it's difficult to say. Maybe some people think that it's not the perfect way, but probably the way we have right now for people to get the basics of one field. But it's true that sometimes it's just skills, that they're filling you up with knowledge and you don't' really know what you are going to do with it. And I think that you really start to make links and to really start to develop your thinking about your field when you are doing your grad studies.

This student acknowledged the necessity of critical thinking in the graduate program as well as her preference for this style of learning.

Despite the heavy workload and complexity involved in some graduate courses, participants were still able to assess those courses that have been good learning opportunities, that is, those where content was well delivered and interesting projects prevailed.

> One professor, the course he taught was actually a difficult one- and a lot of theory about computer vision, but he was able to explain very clearly. So after his class, it is very easy

> to understand the material. Another professor actually my current supervisor, his course was nice. I mean the workload was very heavy. But it was very well designed. We did a very practical project to use our professor's methods into the project. It was very interesting project. Our project was to instrument the soccer players on the simulator, the Robocup simulator. So it's only software, we don't have to use robots. But you have to implement all the soccer players with artificial intelligence. So then, at the end of the semester [there was a competition] between all the teams produced in our class. And that was a very good course, that part of design. It's very practical. That's what I liked about it.

Complementing engineering curriculum with group learning situations was considered a positive learning experience that depended on many interconnected influences such as the learning objectives, 'type' of learning activities, discussion of scientific concepts, and student preferences and prior experiences. Many multifaceted requirements for learning and teaching engineering curriculum had to be considered when structuring an engineering course.

Project/Group work.

Structuring group learning opportunities depended on the concepts to be taught, the level of difficulty of the work, and how adeptly students were working together. Exemplary learning opportunities were remembered.

> Well, actually that's the one thing I really liked about [undergrad university]. In retrospect too because every year we had a design course and it was an entire course dedicated to design and we had to do a design project and it was group work. I mean first year we were doing boring stuff. Second year we designed a little car that was designed by elastics.

> Third year we had to do quest for proposal, interim reports, and final reports with a presentation. We were in groups of three-five and it was actually in third year we designed the setup of a brewery.

As this participant's experience working in groups increased, so did the level of design complexity and creativity. The practicality and applicability of the competitive group projects was judged favorably.

> And in second year, for a competition, we designed a fiberglass bicycle that pumps water for developing countries. So we had to do two projects there, and it was fun all the way through and then our fourth year project, it was more into the interdisciplinary, so we had actually two people in [one area of] engineering and two in [another area of] engineering and designed a glucose regulating system. So those were by far my favorite courses all through. Most useful as well, in that the formulas that we were taught to write reports, you know when I worked my one course job, it was exactly the way that they wrote their report. And that's helped for writing Thesis and papers and everything. I really find that my writing technique is good because of this one project that we did.

Choosing members of your group and the topic made the assignment more interesting especially when working on 'real' problems.

> We got to choose our group, that I guess was a benefit. I mean ours was more of a fictitious problem with the glucose regulating system but there were other groups in environmental engineering that were actually doing projects for companies. You know and everything was confidential and so like it's great for team building. Fortunately, we got to choose our topic unlike third year you had to choose from two topics, the prof found someone in the industry who wanted you to do a project or something like that.

When choice of a topic or group memberships was not an option, the experience was quite different.

> It was discouraging to work on projects when we were assigned projects, and assigned groups. A couple of times they were assigned alphabetically; there were some people in my group that were very difficult to work with in terms of their attitude, both towards work and me at the time--towards myself and what role I would be allowed to play in designing and contributing ideas. It was very frustrating because they were treating me--like my ideas were all ridiculous. But like at the end-- there was one part of that project that we had to do very thorough mathematical analysis and that was one of the most challenging parts of the project, and they [the group] gave the entire thing to me. I think at the same time they were saying, 'no we don't want you, you can't do this' and then they were too lazy to try the too difficult parts themselves. So, it was a very weird kind of attitude.

Overall, participants spoke of group work as a positive learning experience. Interestingly, the choice of topic and of membership in the group were important learning conditions.

Positive learning strategies.

This section introduced positive learning strategies experienced by various doctoral engineers, starting with 'Questioning' as related to pedagogy. Then, 'project based learning', and 'real life examples' are considered as ways to improve students' motivation to learn. Next, 'application of theories, and the 'timing of examples' are presented as ways to encourage depth of learning.

Learning by questioning and open dialogue were teaching strategies that one participant used when she taught as a TA.

> Here it is wonderful. [What] we have experienced here–the education makes you think, you make comments on things and you don't memorize, it makes you learn and it makes you ask questions, it makes you–not accept it at first but analyze it. That is how the system works, that is [what] I see from my students. Like when I TA, they don't accept it immediately, they ask me, they challenge me.

Another participant's preferred learning method was multifaceted. Discussion with expert speakers and actual clients in industry was seen as great learning opportunities.

> My favorite course in grad school was the ergonomics course with four women and a female prof. That was, we had four or five papers a week to read, plus everybody was giving a talk every other week. Like to the rest of the group and there was presentations coming out of your 'yazoo'. And we had lab [assignments] where you went out with industrial clients, assessed the workstation, and we had guest speakers. That was an amazing class.

One participant found that projects chosen on the basis of personal interest increased her enthusiasm and motivation for learning.

> I really find that it depends on examples. Umh, probably a more lab based or personal experience and in a way project work too. It is amazing the details I can still remember from science fair projects that I worked on coming through high school. If I was asked to describe something similar from the university, the concepts get a little more jumbled and it is not as clear. But, projects–I used to be excited about it and enthusiastic about a topic too. That is probably not the easiest way to approach teaching.

Personalized and project based learning can be difficult for some disciplines and for larger classes but the following participant thought it made learning not only interesting but permanent.

> The one thing that I always think of, well in mechanical courses that I took, the standard in an example involved a [male] person--we were saying that they were 180 cm and 65 Kg. That was the standard. I do remember one of my woman instructors–she used to use people's names in our class! She'll put your name in the exam and it was almost funny. One of the questions one time, because we had a guy who streaked around the engineering banquet naked--so the question in the heat and mass transfer course was if his height and weight is this. How much heat would he be losing per minute in the 5 it took him to run around... So you would have to find out how much work/heat he was losing... It's just those things that made the question interesting. It made you think differently about it, even using an arm instead of a lever in a mechanical question.

The inclusion of fellow students in sample problems added relevance and made this learning experience memorable. In another class, the same student praised her professor for using real life examples that students can understand.

> Yeah and in [my advisor's] circuits class, she gives the example of an RLC circuit being used as a defibrillator. Her students talk to me endlessly about that when I TAed her course and I know she gets a lot of compliments about it and everybody wants to know more about it because it's something that they can relate to ... or at least fascinated by the fact that they now know how to save somebody's life using electrical circuits, you know. It's a lot more interesting than how do you make that light go on and off so I think that using real world applications in examples make a big difference.

In addition, she commended the same professor's innovative teaching technique with her graduate students.

> I really like the way [my advisor] does her courses because it was like you did little modules. She would do a lecture on a certain topic and we would all do research for the week and prepare a little report and the next week we would all present them... so a five minute presentation on what you were doing. I guess it's a bit different because it's health care engineering maybe not as technical but more broad so you can learn a little bit about all the different medical devices while everyone else did their presentation and also practice your presentation skills. That really helped my skill-set because I started to feel a lot more comfortable because I knew what I was talking about. Otherwise, the other courses--I didn't find them near as interesting.

Involving the students in their learning, as well as making the learning process interesting were salient strategies appreciated by some participants.

Taking the notion of 'teaching using examples' one step further, some participants were very explicit in how examples were best used.

> I just found that umh, as far as the math goes- if the teacher or the professor would take the time to apply it to something real, explain how it connected to the real world--I connected with it better, I learned it better than just trying to take a bunch of theories on you know on the second derivative or the directional derivative or whatever surface is in three dimensional space or the gradients and all the stuff. If they just taught it as math, then I didn't get it as well as if they applied it to--'well look at this situation'.

Moreover, the timing of using 'examples of applications' was especially important for undergraduate students.

> So there are so many things that feel so much better when they have a real world example. That is the major key, to understand the kind of applications. More than understanding the mathematical concepts that the prof is giving them, they want examples. [The students I TAed] said, "like can you talk to the prof about this because we try to talk to him and he doesn't listen". So I said well ok...and he [the prof] said, "Well don't worry, they learn that in the last chapter. Everything gets put together". I'm like ... "yeah that's not going to be good enough. They don't understand the last chapter. They got a week to learn it before the exam". They really want the real world applications so they can understand what the point of everything is.

Clarity of applications and sequence of information were salient notions when teaching engineering concepts especially to large classes. Many doctoral students became teaching assistants for professors and were acutely aware of how difficult it was to both learn and teach in large classes.

> I don't know how helpful assignments are without that [group interactions], with a large class size it is really challenging. As a teaching assistant you need to provide meaningful feedback especially when you get the same assignment for the fiftieth time to correct. [laugh] I don't know if that can be remedied with the current funding situation. But I think if you could personalize that again, just having a bit more one-on-one interaction or professors with group meetings, smaller than something like 112 students a year.

The tensions of curriculum planning, coupled with the size of the class, and the timing of proper feedback have long been dilemmas in engineering faculties as well as many other disciplines. Based on participants' descriptions, it appeared that some professors tried to compensate for these teaching predicaments.

Traditional programs.

In Canadian universities, few engineers had the opportunity to experience and appreciate non-traditional divisions within the disciplines of engineering. In many engineering faculties, traditional notions of engineering can be seen when second year undergraduate engineers identified their major area. Some universities were attempting to redefine disciplines and traditions.

> Well first and second year were similar - and everyone had to take a mechanical engineering course first year regardless of whether they were doing [that] discipline. I remember people complaining, like why do we have to use mechanical engineering. And I remember one of our profs saying, 'So that when you are in a group situation and you are working with mechanical engineers, you can understand what they are talking about'. And I was like, Ok. I'll make my way through this course even though I can't stand it but at least I'll have some idea of what these people are talking about. And again, I think that there was no real pecking order in any of the engineering disciplines either. Perhaps I'm just really naive.

The more abstract mathematically a discipline of engineering was considered, the more prestige it received from most within the engineering community. Traditionally, electrical and mechanical engineering were considered the most abstract, and therefore had the lowest enrollment of women at the doctoral level. Currently, these traditions of engineering can no longer be categorized along 'pure' lines.

> And you see the thing is that [undergrad] doesn't have any of the traditional engineering. We don't have the civil and mechanical, electrical--those disciplines don't exist in [undergrad university]. It's all environmental, biological--some of the different disciplines that don't include any of the traditional ones. I mean I took some biological engineering [courses] which includes some mechanical and electrical, and some computer engineering and human physiology. And like environmental engineering is like chemical and well, we did chemical too. They did civil engineering and some mechanical, it's all interdisciplinary from the beginning.

Having interdisciplinary departments of engineering from the start of her undergraduate program, in addition to taking courses outside of her area, encouraged engineering students as this student's university to be more open to participation and cooperation with group assignments. In sum, removing the traditional categories and requiring undergraduates to experience courses in other disciplines of engineering were ways to increase understanding and dialogue within some faculties of engineering.

Constraints

Participants experienced many pedagogical affordances in faculties of engineering. Interestingly, one profound constraint, voiced repeatedly, was the 'lack of pedagogical training' of professors that led to the replication of poor teaching practices. Constraints, such as rigid requirements and comprehensive exams, were well known and became part of the reputation passed on by students within faculties of engineering and may have impacted the enrolment of students at certain universities.

Lack of pedagogical training.

Participants reported that their professors lacked pedagogical training, and thus, better methods of teaching should be impressed. It was thought that professors learned informally how to teach and advise their graduate students. That is, they replicated the treatment they received with their 'own' graduate students which was a form of apprenticeship. Students viewed the replication of already existing forms of teaching in engineering as non-constructive.

> I am not in favor of that at all. And what has been happening you have professors that are teaching history--history being what they learned in their own courses that isn't their specialty. And who are also teaching the very narrow thing that they know. So, I don't think it is very broad based.

Having to teach courses that were broad, all the while having narrow research experiences, and limited time to prepare for the teaching of courses contributed to some participants' negative perceptions of their professors' teaching. Participants thought that professors being given time to prepare to teach, in addition to learning how to improve delivery was seen as a responsibility of the university.

> So, I don't think it matters about age or gender, I just think there are really bad teachers and there is not enough effort by university faculty to get education people to teach PhDs to be professors instead of having their profs in that faculty teach. Because profs in that faculty don't know anything. They know about how they were taught to teach or how they learned to teach. And I don't think any of them have ever taken a course in education.

Although participants reported that some universities have tried to improve teaching experiences of new PhDs, it was viewed as a small token of commitment to improving engineering pedagogy.

> Like there is a course here at [doctoral university]--what happens here is that you get mentored with a prof, your prof, who is suppose to guide you through teaching. Well, where did he learn to teach?? And what is his style and you think he is going to be able to give me feedback on--like he is a lecturer; that is his style. He goes up and talks for 50 minutes, writes notes on the board, and leaves. Well that is not a very innovative technique--is that the best utilization of the time? Are there more creative ways you could do this or ways you could reach more students in the class? And that is their idea of teaching PhDs how to teach. To stick them with another prof and say-you two work together.

Again, the notion of motivation was revisited. Because the new PhDs may be more concerned with their teaching performance and subsequent evaluations, research into learning styles and delivery of instruction was more likely to take place by the novice.

Some universities have more rigid requirements that do not necessarily take into account the specific areas of research of individual engineering students.

> I would have had to do [at Master's university] numerical methods, dynamics, and a statistical course. That would have been my three comps. So, it would have been a real exercise in studying. It wouldn't have been learning, learning as an effective tool that is relevant to my field. That wouldn't have been useful but everything else would have been.

The numbers of students in some graduate engineering faculties have dropped dramatically, especially in faculties where little choice was offered.

> Oh it varied. The maximum I had was as many as ten and the minimum was two [laugh]. The number of grad students in my dept is declining. And there used to be 40-50 students, maybe seven or eight years ago but now there is only I think 10-15 students. Although they don't offer a lot of grad courses, there are three or four people on average.

In sum, professors' lack of pedagogical training was prominent in the women's descriptions of negative learning experiences. In addition, lack of motivation to teach, and faculties/universities not requiring tenured professors' improvement of teaching practices, may be responsible for the declining numbers of graduate engineering students in some disciplines. Knowing which universities do not put the individual student's learning requirements at the forefront may influence where some doctoral women choose to do their PhDs. Therefore, improving the pedagogical practices of professors would be a win/win situation for all involved.

Research Groups

Research groups were selected based on individual engineering students' particular area of research work. Participants voiced many influences that affected this decision. First of all 'Interdisciplinary work', the process of entering into research groups, the sense of 'community' with like-minded of members, and the possibility of working with same-sex members all contributed to a positive workspace. While there were more affordances, the constraints that were mentioned included 'Differences' in the work group that affected participants' position and learning. And finally, the loneliness of being the 'Only woman' in a doctoral program was discussed.

Table 4

Research Groups

Affordances:	*Constraints:*
-Interdisciplinary work	-Differences
-Participating within the community	-Only woman
-Positive workspaces	

Interdisciplinary work.

Advertising and displaying interesting research projects was a method universities employed to attract doctoral students.

> When I decided to change fields, I really looked at--I was looking for an [area] that was interesting for me, so I went through the Web and I looked for professors with interesting projects and that's where I found my supervisor. And so I met him and [doctoral institution] is very lab driven, if I can say so. The profs, they each have a lab and all the professor's students work in that lab and so I started to work in that group. But it was really related to the research of my professor that was so interesting and so that's why I decided to go there.

Most engineering universities dedicated web space for their research lab groups in order to inform the reader of the type of project work and to display pictorially the members of the team, with specific biographical information. Being acquainted with other members of the team was important.

> [In participant's specific area] we've got occupational therapists, physiotherapists, and doctors--it's so much more interdisciplinary... You have to recognize that those people have knowledge and resources that you don't have, that you need. You can't be a snob. It's just not possible; otherwise you just don't get the research done. And that's maybe the difference. Say you worked in fluid dynamics, well who else is going to talk about fluid dynamics except other engineers. You don't have to have the cultural divide. That is not an issue there. Whereas in biomechanics, I can't go and design a prosthetic without talking to an occupational therapist and saying what are the issues of finding out what other people's problems are. You have to work as a team. You can't let some members of the team, who have all of the knowledge that you need, you can't treat them in a disrespectful way.

Having to work as a team and recognize each member's contributions was highly appreciated by the participants.

> But it is so interdisciplinary and interactive in terms of the fact that we are working directly with orthopedic surgeons and rehabilitation therapists, physiotherapists, computer scientists, all the time so it's not a big deal. Umh, like there isn't really an engineering persona--none of it.

The notion of 'discipline superiority' cannot be expressed or enacted in interdisciplinary research groups if they are going to be successful.

> It [our lab] actually has research groups from different departments. There are three departments in our lab- Mechanical Engineering, Computer Science, and Electrical Engineering... So computer vision is necessary for robots, and then mechanical

> engineering like doing robots, like the walking robot kind of thing, and also computer science. They also have people working in computer vision. And also we have people doing control. I think because control is also useful in building a robot. So when you are surrounding the topic of Robotics, you have different departments. The thing is each field has something difficult to solve first before they can really produce to help other departments. We are three [departments] in the same lab but we are working on different things. We will have seminars. All of us go... I think that is a good idea.

Each section of the interdisciplinary team was considered useful and necessary in completing the final product. Many influences contributed to the selection of a research group, including the area of the project, the interests and experience of the principle investigator, and the other members of the team. The composition of successful research teams depended on each person completing a part of the research puzzle.

Participating within the community.

Each member has individual responsibilities in the research group and in the overall community of the laboratory.

> I think it's difficult to do technical projects with everyone at the same computer and, you know, it's very hard so you really have to discuss the project first and then you separate the tasks. Then if you need assistance in doing a particular task then you obviously have to talk about it with your colleagues. Then you verify that everything is ok and that everybody understood what was their part. So that is usually how a project works. The core of the work is done alone. We all have our task and we do it. I think it's really discussion that is important for us. Because it's there where you have new ideas and you understand what are the problems with your theory for instance or things that you never

> thought about in theory. So I think it's the discussion that is important for research in engineering.

The group dynamic within the lab group was thought to be the responsibility of each member, although a group's dynamic depended upon the compatibility of personalities.

> I really don't think that our advisor, well he comes every now and then in the lab. I think the students are more responsible of how things work in the lab. I think it is really related to the people in the lab. I think that you could have a completely different gang with a completely different way of doing things. I think it is just luck that we have that kind of atmosphere. It's really great--the working place that we have and we really get along well, but it's true that if you changed two or three people, the environment would be completely different. It's really hard to tell but I think that if he saw people not really wanting to discuss his research, I think he would be disappointed and he would try to do something about it. He would encourage people to talk to each other by perhaps introducing group meetings more frequently if he found that things were not going the way he wanted them to go. We really talk all the time about our research, so yeah... I think we are really lucky.

Although she attributed her groups' positive working rapport to luck, this participant also thought her thesis advisor would step in to improve communication of the research group if it was not productive.

This same participant described the importance of discussion within the group as a method of verification and as a way of generating new ideas. Members felt 'safe' enough to openly question each other's ideas.

> So we really want to have a group atmosphere where everyone can speak out and ask questions. Sometimes the questions are not what the person wants you to ask--it's like I

really don't understand what you area doing, or I don't like what you are doing but I think it's how you are doing basically. Sometimes these questions are asked. The jury will ask you these questions also, so it's better to have them now than later.

Group members from different engineering disciplines were involved in questioning each other's research methodologies and results, and this proved helpful before the dissertation defense. Participants thought it better to receive criticism from one's peers than to fail their dissertation defense.

The sharing of information within and without the research group was thought to depend on the lead researcher, in many cases the thesis advisor.

> I think to a large extent, it has to do with the personality of the prof and what is happening internally whether it is something that they want to keep--not keep from the entire scientific community--that's not in the spirit of academia, but to a certain extent there is some of that happening. You want to be first to publish it, but by the same token you want to try to establish that you are the expert in that area. I think that is part of it. There is a drive right now to publish a lot. Because they're looking for funding and that's one of the easiest way to prove progress-- by publishing and going to conferences and so forth.

Not all doctoral students publish papers other than their thesis, as this depends on the sharing of information determined by the type of research, private contract or academic research grant. One participant posited that only peers in the lab group actually critiqued each other's papers.

> Usually what happens is that the student will write his or her paper, but the other students will go over it. I've been grading [critiquing] papers from other people in the lab many times, to the point where I know as much as they do, [about] their research. Especially

towards the technical aspects of the paper, I think it's the students who will help the author with the paper. Usually how it works--we read the author's paper, but we are not the co-authors. When we do industrial contracts, you can't write any papers by yourself. So usually the papers that we write are either PhD theses of Master's theses. So that's why it's more related to one student.

Although students received assistance with each other's papers, authorship ended up belonging to the individual. One participant reported that her thesis supervisor and another colleague also received credit on submitted manuscripts.

Well, I haven't had too much experience with that other than most of the papers that are prepared in our lab, our supervisor is pretty good. He's good at contributing to the writing process and helping get the manuscript prepared and so that there are minimal changes down the road. So his name usually goes on and one of the orthopedic surgeons that studies in conjunction with... so they have contributed in that respect. There is not too much completely independent work that happens.

In lab group protocol, what works for one group may not work for another group. Doctoral women reported both the haphazard combination of students as a lucky coincidence, and felt that the tone set by the head researcher enabled a positive working environment.

Positive workspaces.

Some of the women engineers spoke of exemplary working environments.

Well I had the most amazing workspace there [master's university]. The other prof was trying to negotiate time to get his [gender sensitivity training called the-Pink Triangle

Program] done too. And one of my colleagues was trying to be a 'gender affairs- issues officer' for applied sciences...

Anyways, what did I learn from her [head of research]. Well, we had a really unique group- we were almost entirely women. Because we were studying pregnant women, not to be sexist or chauvinistic, but it is really hard to interact, to make pregnant subjects really comfortable when she has to deal with a male researcher, and she is wearing a bathing suit and she is not even comfortable the fact that she is half naked--let alone discussing like, 'I get this pain in my thigh or the inside of my crotch when I try to do this or that'. Those are just not issues that come out when you are talking to a man. And it takes a lot of confidence building to do that with a woman. So we had some really weird discussions that we would not have had in a typical research environment. Like you could walk up to your research supervisor or I have had my supervisor come out and say, "Can I count your spine". And I pull my shirt up to my neck and she is counting down to see if she has the right level for whatever she is trying to do. So it was one of those incredibly enriching environments where research was a group effort too.

In this situation, participants felt more comfortable because of working with other women. In fact the whole topic of this particular research, in her opinion, was more appropriate for female researchers.

The team that I worked with for my master's degree was predominantly female. There was three female graduate students, three female research assistants, a female prof that was leading the group; and for a short time there was a female post doc that was replaced by a male post doc. He did not integrate well with the group at all. We had very open meetings, maybe they were not very focused but sometimes we might talk about someone's

> astrological sign for a few minutes here and then come right back to the meeting but they were much more flowing than normally. I don't think he--he was a Chinese male and I think there was a cultural difference there too. He didn't integrate well into that group because the meetings were so predominately female that he didn't feel included. It wasn't his style for starters and he wasn't included as much because he wasn't interacting; he didn't try to share, and that was the experience with that. But the female dominated group had to be much more sharing, meetings may take longer but they are much more interactive.

The notion of a female dominated group conducting a 'different type' of meeting was salient. In addition, the inability of the male to adapt or productively participate in these interactive meetings was noteworthy.

Constraints

Participants spoke of research groups more in the context of affordances but nevertheless, constraints were mentioned in relation to certain 'Difference' markers such as educational backgrounds, ways of doing science, and ways of relating based on gender. Another constraint, being the 'Only woman', added to the isolation felt by participants in the doctoral program and in fact hindered the learning of these women.

Differences.

Interdisciplinary research groups, by definition, exemplified 'difference'. How differences were perceived by individual members depended on where one positioned oneself in relation to the group.

> ...There are differences. It's true that I'm more comfortable with the theoretical aspects of the research and they're not and that I'm not really good at technical aspects, like programming for instance. And so, yes, they tease me, that's for sure.

Being teased for having a strong theoretical stance in relation to research set this woman apart from her research group. Not all doctoral engineering students in research groups were engineers by trade. Many came to the program because they needed the technical aspects of the research group to complete their study. This same participant often had to explain her theoretical position to the engineers in her group, as well have them 'translate' their technical jargon.

> I think that since people in my group really want to have a discussion about the research, well I guess that's why I'm feeling very comfortable with my background ...I can also rely on them if I have any kind of question about programming or technical aspects. See they are really open to help me with that.

Her reliance on the group for assistance was not in keeping with the engineering profession's value of competence. While this participant admitted that competence and logic were highly respected by engineers, she thought gender had nothing to do with that.

> For that kind of thing, I don't think it [gender] can make a difference. Doing research, if you have a problem to solve, you need to know what you need, what you know, and what you don't know. It's really things like that. You don't really have a female way of doing it. Just logic, there is no real difference for that kind of stuff. I guess it's more of the relationships with other people in the lab. That is the whole difference. I think when men decide they don't like that person, they DON'T like that person. Women tend to be well, maybe he

> thinks that way because of that--we try to be more comprehensive of other people probably. And I guess men are a little more impatient.

This participant illuminated a relationship difference--how men may have made hasty judgments in relation to whom they like, while women sometimes excused away first impressions, and gave the person a fair judgment. This difference might lead to perhaps poor communication within a lab group, or perhaps denial of one's exclusion. Another participant spoke of setbacks within the group that impeded progress.

> I was trying to finish in 2 years because my funding finished in 2 years. And I had a lot of set backs that cost me time that necessarily were not my fault because I was depending on other people's research to do my research. Umh, so I was working 20 hour days pretty much the last two and a half months of my degree. And that really exhausted me.

Although participants mostly spoke of their research groups as beneficial and necessary to complete their doctoral studies, there were inherent dangers when having to rely on others to complete your degree. Most have experienced relationship problems at some time in their academic careers and subsequently attempted to choose more wisely, and participate positively within these environments.

Only woman.

Isolation in a doctoral engineering program can hinder the learning and research process. Participants spoke of isolation not only in terms of being the only woman in the group, but of not having a partner with whom to discuss informally your research ideas. This 'difference' of gender was perceived in various ways.

> I mean if you are the only girl you are going to be isolated because you are not going to have any other girls to talk to. And I hate to use the word 'girls' because when you are still in school sometimes you don't feel like much of a grown-up. I don't think 20something women are like that at all. I think we are more grown up than some of our male colleagues. Maybe that is crude of me.

Wanting to have colleagues that were mentally and emotionally the same age, and that shared some of the same interests was understandable. The notion of having someone to talk with and being included socially was important.

> The guys are really great and they are nice people and I like to work with them, but it's true that I would like to have another one [woman] in the group. It's more related to the social aspect of the working place. You know, being able to hang out with a friend for lunch, going out, whatever. The guys are great but it's not obviously the same. If they go out for beer and soccer or football, so I'm obviously not in. So I guess it's those kind of social things that are different. I mean it's ok. I really like working with them. They tease me because I'm a woman and a [another area of science], and I'm [haircolor] but I think I would really enjoy another woman in the lab.

The 'differences' that this participant brought to her research group provided an opportunity for her to be teased and isolated. Perhaps having fewer homogeneous members in her group, that is, white males, would have improved the social aspect of her research environment.

Participants thought it was problematic not having someone to act as a sounding board for their ideas. Informal discussions of scientific concepts and of new ideas were viewed as essential to creatively working through problems in engineering. Being isolated, for whatever reason, can hinder the research process.

> That is the thing I miss the most--having other graduate students. There is nobody I can sit down with and say, " Why doesn't the equipment do what it is supposed to do"? I recently met one other graduate student but I am teaching him--I am teaching him a lot of the math to catch up so he can understand--like he is in Kinesology. He is a master's student so he is leaving soon anyway. But he was the first graduated student that I met that was even remotely interested in what I am doing. There is a young, new faculty member who is an ergonomist that does upper body motion now. I am really keen to work with him because I can learn from him and he is also kind of young enough so--kind of a colleague interaction as opposed to a supervisor--student interaction. Even though my prof does treat me very much like a colleague because we are really- the group is so interactive. He is great but I do miss having someone that I can appear dumb around. I mean you can't ask dumb questions sometimes--like I worked in a lab before with four other female graduate students. Which is an exception in mechanical engineering but you could actually sit there at 4 a.m. when you are still working and someone else is still at the table and say, "Why- what is wrong with the acceleration"? You could sit down with somebody and say there is

> actually someone else that has the same lifestyle and same curiosity, has the same technical difficulties.

Shared similarities provided the comfort to freely discuss ideas and lessen the fear of appearing incompetent in front of others. Moreover, some disciplines within engineering were accustomed to group based, interdisciplinary research–making these engineers more prone to the negative aspects of isolation when they returned to graduate school.

> I was okay because I was also working in a research center [with] three or four people at that time and we were working on similar projects. So we were always together but I had some master's and PhD student friends, they were really unhappy to be alone because our department is very small. You can be alone a lot. They had some problems. And those are the people who had industrial experience and in industrial you have meetings, you go on business trips, like you are always in a group. In grad work when you are done with your courses, you are alone.

To this end, there were many aspects to 'difference' that contributed to the isolation of doctoral women in engineering. Many of these differences were explicit and freely discussed; many are very contingent upon individual contexts and not readily voiced, such as being teased and excluded from social functions.

Peers

Peer interactions had a profound effect on how participants viewed their learning. These doctoral engineering students commented quite negatively on how learning takes place in mixed gendered classes in both their undergraduate and graduate engineering programs, how tasks were assigned within groups, and how jealously of scholarships and funding affected the group dynamics within their peer groups. The overall tone of their voices, that is, the tension in their relationships with peers, can be considered a constraint- or at best a neutral judgment or appreciation.

Table 5

Peers

Constraints
• Dynamics of mixed gendered classes.
• Tasks within groups.
• Funding.

Constraints

Dynamics of mixed gendered classes.

Women in engineering were described as being few, and this disparity did not necessarily affect the learning environment. The effect that a male dominated environment had on women's learning was 'blurry'.

> We had a really nasty group dynamic; we had one guy who sexually harassed another graduate student pretty much. We had one chauvinist pig in that class too. And we had two students who were ESL who were really challenged by the materials plus they had really heavy course loads because they were doing course--load master's degree. It was a challenge to try and work with them because of their schedules; they were always sleepy--

> they never slept. And then there was the student that asked all the really dumb questions that no one wanted to work with because she never did her share of the work. So, we had a really bad class dynamic, I am sure this doesn't usually happen. But otherwise, the group work didn't go well in her course, she was very disappointed. But I think it was just a bad year and it just didn't work. It worked with future years and past years, it was just that year.

When needs and differences were prominent, the dynamic and intended learning of a class changed. The expression of femininity in a female dominated science class was apparent.

> Undergrad, I found that either the girls were treated as one of the guys--there was a lot of that. The girls were not very girly--girly. Does that make sense because there wasn't enough of them to make it—like I took biology and physics. So, in biology classes there was a lot of girls and you could tell there was a different aspect to classes that are dominated by males versus the ones that are dominated by females.

Other than 'performance of gender', this participant did not explain what typified this difference; wherein comparing one's experiences in various universities was difficult. The notion of being 'similar'--or belonging to a homogeneous group in engineering class made bonding easier.

> So I think that the learning environment is the same. But I think that having a smaller school... well I can't even make a comparison because [undergrad university] had the majority of students who are from out of town so everyone was living in large residences out of town with their friends. Whereas in [Ontario city] people live at home... or there are a lot more international students, where we had almost no international students. So it would be hard for me to make a comparison. Well, I definitely do think that we had a close-knit

> community and I just don't know... it's a variety of factors I guess... everyone is on the same playing field, nobody has got friends from home because they are all brand new people and like I don't know, like in a comparison when I was at [master's university] and I was teaching a fourth year course in engineering and there were only 40 students in the class and it amazed me that everyone didn't seem to know everyone's name in the class and I was like, well you spent four years together and there are not that many of you. You should know them by the end of class. That surprised me and again that had a lot to do with the fact that the people live in [Ontario city] with their parents and have their own friends here and don't mingle as much.

It was not only a question of the number of students, but the insider/outsider effect in the class that affected the community of learners. In some instances, the interplay between similarities and differences seemed to affect adversely the interactions and discussions and hence, impeded learning.

> In undergrad, you had the chance to interact with the other students in your class and you had the chance to discuss things. In my master's and PhD, we really didn't talk to anyone else in the class. I mean, there were maybe like two or three people in my masters' courses that I talked to and most of them [classes] were really small too maybe like 20. I guess you just didn't know people the same as you did in undergrad.

Being able to discuss each other's progress and complete assignments together in undergrad engineering enabled this engineer to feel confident in her capabilities and to know where she stood in relation to her competence. Competence was an expectation that was carried over into graduate engineering classes. It was assumed that each member of the group had certain basic competencies learned in undergrad engineering or they wouldn't have 'made it' into a graduate engineering program.

> But in the mixed gender classes we had a student that right now I wouldn't have thought she belonged in grad school. I personally don't know how the hell she got into grad school. But she frustrated not just the male students, but the female students. She slowed down the pace of the class, she dragged out--she was incompetent, and she would be the one who would be asking what we thought were dumb questions.

Participating in a graduate engineering class with both one weak and one arrogant student allowed this participant the opportunity to value competence. 'Performing competence' was also taken too far.

> There was one male grad student that I had a problem with but he had an attitude that I wouldn't say was necessarily a male—most of my male colleagues are very enlightened young men. And he was a chauvinistic pig. So, he--I wouldn't call a typical male graduate student and I wouldn't work with him. And he would posture and he would act very superior during class even with the profs, especially with the female profs.

In addition, she recalled one male student 'posturing' in class perhaps deflecting attention from his inadequacies to that of inappropriate behavior--the latter appearing to be more acceptable in this learning environment. In sum, the dynamics of mixed gendered classes was influenced by the sex/gender ratio of participants, the overall similarity of group members, the performance of gendered behaviors, and the perceived competence of members for completing engineering assignments.

Tasks within groups.

Many of the participants spoke of the difficulties of working in groups. How work was assigned or negotiated within a group was viewed as stereotypical by a participant.

> We didn't do a lot of group work in [European country] because we were only 12 people. But here [PhD university] what I have experienced and what I have seen, for example in the fourth year the engineering students have to do an engineering project. What I have noticed is that they prefer- I have [seen] there are one or two girls in one project and the girls present it or do the economic analysis or they some modeling. The guys prefer to do the 'real' construction thing while they were doing the senior project. ... we have some female students who work on projects like the super mileage car... I don't know what they are doing, what sections. But I have heard that one of the drivers of one of the cars will be a female student which is wonderful to hear. And then I heard the reason they chose her is because she weighs 120 lbs. [laugh] They needed someone who was light. I don't know, the tendency or the guys say they would love to do it, or they choose it first.

This participant first stated that the men 'preferred to do the real construction' but later in her explanation added that men chose or claimed their preference first. She also voiced the idea that the "guys don't even want to do that" alluding to the possibility of their poor work ethic. Another engineer also discussed differences in work ethics.

> If you work alone, you know what you [can] do, your abilities. You can make sure everything is done and the way you want it to be done. I was lucky, I actually found some very good partners, and we did very extensive projects. I heard many of my friends, they complained about their partners not working at all. They end up having to do all the coding. Some people they are worried they might fail because they didn't do enough or that their partners weren't good... things like that. So I feel it's difficult, I think, if you can find a good

> partner, then everyone is working towards, that's very good experience. If everybody is lazy and nobody wants to work for it, then it is not very nice.

Not always being able to negotiate and enforce members' participation and work ethic within a group was viewed as problematic. This same participant didn't have the same stamina as her group members.

> I didn't have this experience [being excluded]. In my case, I had very good partners for my projects. Like for my soccer team-the 'Robocup' team, we had a very tight schedule. We wanted to finish. We actually had two weeks to finish and then go to the competition. Those days, we worked until 2-3 o'clock. I thought the next day, they came very early but I couldn't because I was tired. I needed more sleep and they were already working. But I didn't feel excluded actually because when I got there they asked all the questions they needed and they needed my help, so I didn't feel excluded.

Even the group experience that she reported as being positive was fraught with contradictions. The negotiation of tasks within groups was an anxiety producing experience for many participants. In some cases, tasks were stereotypically assigned based on body size or gender. In other instances, the women were included as long as their knowledge or services were required--leaving them with perhaps, the illusion of being part of the team.

Funding.

Under the best of circumstances, funding for doctoral programs was highly competitive. All the women participants in this study obtained scholarships from within their doctoral institutions and/or from national or provincial granting agencies. This was another 'measure' of their competency or, perhaps, another 'difference' that set these women apart from their male peers.

> At [PhD university] I notice that people are a little bit jealous but that is because funding is such a challenge at certain universities—having anything more than 20 grand [thousand] of funding, let alone having [more] is kind of an exception. People might be a little jealous or most of them are kind of admirable–they admire that you are able to get that. I haven't met anybody, except in my undergrad–one of my fellow undergrad students who didn't get an NSERC when I got one, umh he told me that I didn't deserve it.

As the number of engineering students decreased when transitioning from the undergraduate level to the doctoral program, grades and perceived competency became measures for all engineering students. This comparison and competitive spirit may have exacerbated the subtleties of exclusion, making differences more apparent within the peer groups of these women engineers.

Work Experiences

Work experience, an essential experience for knowing what was actually required in the workplace, was missed for many of the participants. In most cases, work experience was viewed as a constraint by participants starting with the 'Co-op work experience', that is, placement with a company during their undergraduate program. Next, the 'TA work experience' will be presented during the women's graduate engineering program while the 'Industry work experience' as a P.Eng. was experienced by one engineer. Finally, 'Industry based research' as an affordance was considered as an alternative to lab-based research. Although the women did not report positive treatment in most cases, the lessons learned were perceived overall as invaluable activities.

Table 6

Work Experience

Constraints:	*Affordances:*
-Co-op work experience	-Industry based research
-Teaching Assistant work experience	
-Industry work experience as a P.Eng.	

Constraints

Co-op work experience.

How the participants viewed their co-op work experience depended on how much their participation was valued by the work placement and the university institution. In a particular instance, the engineer was not treated as competent nor given the opportunity to really participate in the work process.

> I did it too. In [home country] it is different. During co-op they don't pay you. So they don't give you a lot of responsibilities. But my ex-roommate, she did her undergrad here, and from her and other undergrad students in my department, they learn a lot. And after they come from co-op terms they have a very different, wider vision to the problems they face and I guess it is really, really helpful for engineers. That was the main reason for me. I

> never liked it in [home country]. Here you have the option to work in a department, you can be more free. But in [home country], you have to do whatever they tell you to do. That is why, maybe the person above you is not very experienced but he has been there for years, and he tells you what to do. I didn't like it. And that was the main reason why I chose grad work.

The practical experience of working in industry gave this participant enough information to know that she wanted more freedom to do research. For this engineer, graduate school was an opportunity to be in control of her work experiences.

TA work experience.

Teaching assistants in engineering courses assumed various types of responsibilities. Since most professors in Canadian universities are involved in teaching, this experience was, for doctoral students, quite worthwhile.

> I think I liked it [being a TA]. It was also, I considered it an experience on how to use English in class- how to be able to explain things. So it was interesting.

This international doctoral student also used the TA experience as a forum to practice explaining engineering concepts in English. Not all graduate students enjoyed the teaching experience.

> My friend–she is brilliant but she can't teach because she is so stiff and formal ... She is so sensitive to the fact that she is a female teaching a physics course that she was unable to ignore–like she was unable to ignore the little jerk in the corner that had a real issue with her teaching the course. And she focused on that instead of focusing on everybody else in the class that was there to learn.

For this TA, overcoming stereotypical notions of who should be teaching physics was difficult. In sum, work experiences provided beneficial opportunities for students to know if they could manage various environments--giving them information to make salient career choices.

Industry work experience as P.Eng.

Engineering undergraduate students do not always have the opportunity to know, through co-op or summer work experiences, the expectations of in the 'real world' of work. For one doctoral woman, experiencing the work place as a Professional Engineer [P.Eng.] was unsatisfactory. In addition, obtaining a master's degree did not insure that the actual work in industry would be satisfying.

> I found it was an extreme disappointment in the sense that I had taken the time to educate myself and then get a master's degree. And what I was tasked with in the real world wasn't very challenging and wasn't very interesting. But I don't know, I don't think personally it has anything with me being female, I think it has to do with how engineers are educated. We are given a lot of theoretical courses and Master's--I did a Master's in applied science which is a more research end of it. So, then to go from there to designing wiring in buildings is a tremendous leap--change. I found it very disappointing. And umh I found it incredibly wonderful, for my first job, to get out and have females around--mind you most of them were secretaries, they weren't professionals. But it was nice to get out of [Master's university] where I think at [this university] I tried too hard to be one of the guys. Umh, but the drag was people's reaction to me, particularly clients. I am umh the only female. I am short, petite, umh some people would say I am attractive. So, umh the response of mostly male clients to me really wasn't what I was expecting.

After completing her Master's, this participant expected to be able to use her theoretical knowledge instead of being given 'disappointing' projects in industry. Although her experience was not much different in the university setting where she tried to fit in with the guys, she was pleased to work with a few women secretaries. This enjoyment was short-lived since many of the male clients responded stereotypically to her gender and appearance.

Affordance

Industry based research.

The experience of actually completing research in an industrial environment, instead of in a lab was important for some participants.

> I may be lacking that I am the only biomechanical engineer student at [doctoral university] but I am not lacking that I have a lot of variety and resources because it is so inter-disciplinary, I get exposed to experiences that I wouldn't get if I was in a really research-oriented lab where it would be- design this, modify this valve. Whereas here, I am interacting with industry and I have to find out why I cannot run the experiment the way I want, plus, what are the limitations on the food quality. So when I go on in my career and this is what I want to do--work with real situations because you can't really create a work environment in the lab the way you want to. You have to really use the 'real situations', the real people, the real equipment to get a really good idea of what is really happening in the work place as opposed to creating a lab where there is no noise, no reflection, and the temperature is nice and ambient, not 20 below. You can't just do that in a lab. So, I am getting really hands-on intensive experience of learning in how to deal with industry.

This last participant viewed her particular industry based research as superior to working in a controlled lab environment. This opportunity allowed her to make an informed decision when deciding where and how to continue doing her research in the future. In fact, this was her first 'real' work experience with industrial engineering.

> Well, I have no real work experience myself. I have been employed in research labs since 1998, so like real work experience to me would be when I worked in an office for [a provincial Power company] as a summer job. But this is the type of research I want to do is work with industry.

Knowing what kind of work environment they enjoyed, along with the required tasks, was important for engineering students in order to select the right career environment for their future. Since this opportunity varied from country, to province, to institution, to department, and individual professors, it was difficult for industry experience to be mandated.

In summary, women doctoral engineers spoke of their many perceptions of learning regarding their faculties of engineering. Doctoral advisors and engineering pedagogy were viewed as more of a constraint to their learning and participation in engineering. As mainly an affordance, research groups provided the opportunity for interdisciplinary work while peers and work experience were seen as more of a hindrance to their learning. The women's learning and participation within the communities of engineering influenced how they spoke of themselves in relation to their identities. This issue will be examined in the next research question.

CHAPTER SIX

Research Question Three

3) What do female PhD students perceive as the "unofficial" ways of continuing the history and traditions of the profession in faculties of engineering?

The portraits of doctoral engineers were heavily weighed with problems of participation for women. The informal practices adopted by the participants as 'unofficial' ways or practices to become an engineer in this 'Culture' will first be highlighted. Next, the roles of 'Professors' in transmitting these traditions, and the roles of 'Peers' as a hindrance or assistance in participating in this community of practice will be presented. A number of other themes were voiced less strongly, but preoccupied some participants. The theme of 'Difference', how these constructs are specific to the engineering culture is discussed. Another secondary theme, that of, 'Non-preparation for the industrial workplace', disturbed some participants. Finally the theme 'Engineering associations', -that is, the few women who have 'work' experience described how their participation in these venues was determined. These 'voiced remembrances' of the doctoral women detailed some of the ways the community of practice imposed these constraints.

Culture of Engineering

The 'culture of engineering', those implicit and explicit practices passed on to a small number of new recruits appeared to be common to most engineering institutions. To give context, my participants talked about the 'Culture of their respected universities' and how this influenced their subsequent practices within the culture of engineering. Next, 'Initiation' was discussed in-depth as the ritual of entrance in the community of engineering for frosh by the more experienced students, and in some cases, engineering alumni. As a follow-up the 'Brotherhood' of engineering, essentially the very masculine practices that exclude 'others' is manifest. Finally, the Iron ring, –the symbol of engineering, the rite of passage crowns the engineer.

Culture of the university.

The culture of an engineering faculty was often overshadowed by the overall climate of the university campus itself. The socioeconomic status [SES] of students as well as the location of the university contributed to the practices.

> Only at [this Ontario university]. Where the rich kids go to school and live in the slums of the city. It is a complete culture contrast. I call it the university of GAP [trendy clothing store] and the ghetto where the students live is the worse part of town- the houses are falling down, there are rats, the whole 9 yards. But the reason is that, I think that there is a culture- you have the whole alumni sending their children where they went, living where they went. Living in that kind of ghetto atmosphere with the run down slum housing. That is the 'cool' thing for your kids to do. That is [this particular university]. And [this university] is one of the richest schools I have ever been at. The students are really- like I had students [when a TA] try to get out of exams because they are picking up garbage on Mount Everest. Or try to get out of the midterms because they are in a yacht race somewhere off Florida. Like in that way.

Students often re-enacted the university days of their parents. Although this last engineer was annoyed with these 'bonding' practices of higher SES students, she appreciated the benefits of socializing with peers.

> I think that the culture of the university should– I think it is fun to know you can go to the grad club at 4 o'clock on a Friday- you are going to run into all of your colleagues. I think that is a good thing. Because it means you are socializing with the people that you work with, you are not just merely saying hello to them in the halls. And the only other people that can live the lifestyle that you live when you are a grad student because you are always broke, you are not like the people you went to undergrad with who are out making $60-70-100 grand a year now. So, it is hard to socialize with someone who makes a lot more money than you. Well, it is you can't have the wine habit, you can't have the car, and you can't have the theatre tickets. So having that social group that has the same restrictions, it is really comforting for a lot of graduate students. Yes, I have to drink cheap beer because that is all I can afford to drink.

Having fun together was one way of developing a positive bond with other graduate students. Sharing in a common plight was comforting for this engineer. Another participant remembered her first two years of her program [diploma] within a close-knit group of engineers.

> Well there always tends to be parties and beer. There was a lot more of that- as far as keeping us together I found at [undergrad university] because we had a smaller group. And we had a little room off of where I described to you where we had an engineering society and there was a refrigerator and a couple of couches and a desk. So we would hang out there at lunch or between classes.

The notion of a 'unique' culture was introduced as a pragmatic endeavor.

> Well, I don't know if there is so much as a culture to engineering, but there is a culture to gadgets, there is a culture to technology; there is a culture to making things work. It is the last male domain. And it is very much in my opinion, it is very much like the garage built out back where the guys all hang out and they talk whatever they want to talk about. And they accept work and they tinker with the car or whatever. It is the same feeling, the same mentality. And I don't know how that gets passed along except that because it is predominantly male and up until may be the last decade, they have had an incredible amount freedom to say and do whatever they liked. Right. Even the guys who didn't necessarily like it, like I said they were my friends wouldn't dare say anything against their buddies, you know. It is the silent acceptance of it.

This "last male domain" provides a space, in her opinion, for engineers to freely include or exclude whomever they want. Implicit rules govern your acceptance in the community. Another participant reiterated the notion of 'making things work' as perhaps the crux of the 'culture'.

> I think there is a culture of engineering but I think it's related to– I guess I can say that I'm not really an engineer, but it's true that since I spent studies in physics. I can see that sometimes engineers are not really interested into the theory but rather more interested in if it works of not. Sometimes you can feel that if the things works, they won't tend to go deeper into the questioning of things like does the method work because of this or that and what the problems would be and stuff like that. There is culture of engineering for that kind of thing. I think they really want things to work and if it does, it's over. Finished. I think for us physicists, for me it's sometimes frustrating. Ok fine it works now but will it work for any

kind of cases and this is the kind of thing that you want to explore and research. My advisor confirmed to me that he really wants his engineering students to not forget the theory and to think a little more deeply about the problem and the consequences of the solutions that you are providing. If it's just a new theory, what are the consequences of your problem that you are studying?

Getting beyond the need to only solve concrete problems was important for this participant.

> Well I think it's more related to the fact that they just consider the questions that we are interested in as physicists as just details and for us it's not detail. And also even sometimes in the way that they will take a theory in physics and apply it to a very concrete problem in engineering and if they really apply it like BANG.... well you know there are conditions you have to fill before you can apply that theory to that and they don't care about that. Yeah it works you now, even if the functions are not continuous then it's fine, I don't' care. So there are all kinds of things like that in engineering I think. And I guess that is why they like me to read their papers because they know I'm going to say, 'well how do you know that you can do that' and things like that.

Another participant attempted to correct society's misunderstanding of the 'culture of engineering'. "I think engineering is exclusive only because society doesn't' understand it. I don't want it that way. I make sure that everybody I talk to about engineering understands what it is". Although she perceived herself as a full participant in her engineering programs, she did discuss with her friends problems they experienced in engineering.

> Well I haven't had any bad experiences as a woman in engineering but I do know women who have. I don't agree with women that say that there is no problem with women in engineering. I think that that is incorrect. Because some people do run into problems ...because they are the only women in engineering. I guess that because I've talked to women who do have these problems that I think people should be aware of them. I've had friends who have had sexual harassment and just simple things.

Women in some faculties of engineering experienced a wide array of treatment based on their fitting into the culture of engineering, sex/gender being just one influence.

Initiation.

Before a Canadian student even begins the process of 'becoming an engineer', initiation must be successfully negotiated. Many universities had unique traditions that have been practiced for many years, one of which was described by this participant.

> It used to be the football post at U of T and [her master's university] stole it. And it has been hidden in garages and first year students are supposed to guard it for a year. And U of T stole it back or some alumni. What it is, is a pole. And last year it wasn't the greased pole because the greased pole was in 'custody'. But it was a power pole and they nail a tam, a Scottish woolen hat, with usually- it used to be filled with shit. And it is nailed to the top of the pole. And the pole is covered with big globs of lanolin. And it is placed in a pit that is 30-some feet wide, a dug pit. And the pit, well now it is just filled with muddy water, in September-October. It used to be filled with everything like excrement, rotten food, you name it. All the first year engineering students have to get into the pit and they have to get to the top of the pole and take the tam off the top with their teeth. And it usually takes

> hours and people get exhausted and people get taken out of the pit because- eventually you get alumni jumping in the pit with the freshmen and upperclassmen until they get the-it takes a whole day.

The rivalry of taking possession of this old goal post has gone on for many decades between these two universities and is still a celebrated tradition. The importance of this activity was illustrated when alumni jump into the pit to show the new frosh 'how it is done'. Regardless of its unpleasantness, alumni replay this tradition yearly. She continued her exposé

> They get up on top of each other's shoulders. They make these rings with their arms- rings upon rings, and then a layer of people get on top, and another round. Well, you would be surprised- it is not because the guys don't let the girls get up I don't think. But the girls, my friend graduated in 80 something. And the girls' job then was to go around with football gear on and helmets and protect the guys who were in the pit from the frozen food and stuff being thrown at the guys. So the girls used to make a perimeter with the equipment- a body shield. It is really screwed up. I told you it was a weird culture. And where it is, is not announced until the day. It is a different spot- they go out and dig a new pit.

Interestingly, she thought women engineers were included but then remembered that their role was to protect the male engineers from getting hit with rotten food. Perhaps, her analogy of a 'perimeter' accurately characterizes how women are sometimes viewed in engineering.

In Canada, engineering initiation and the 'culture of engineering' were synonymous with drinking and partying practices. Of course, amongst universities the ritual varied.

> Well here at [doctoral university] they have 'D' day where they declare one day- the day before they announce, they send an email to all the undergraduate students- tomorrow is 'D' day. They put them on a bus and take them somewhere and they drink. And they miss their exams, whatever midterms are on, and that day is lost from the university calendar. Engineering has got a weird culture, like it is a whole different subculture than anything else.

At this specific university, the process of initiation was 'soaked' in alcohol. At other universities, the tradition was more elaborate.

> I had the opportunity to be around [frosh] week at [master's university] when engineering students paint themselves purple and spike their hair and wear kilts, and their coats and wear the- GPA what they call their "golden party armor" and they dye them purple and go around and beat them [jackets] on the ground. And you would think that there was some big pneumatic pile driver going on at one end of [a street on campus] while you were walking out. But it is a couple of hundred undergraduate engineering students beating their coats in synchronicity at the top of the street. That is the culture. They get in trouble for harassing freshmen when freshmen arrive on campus because they are so intimidating. And then the greased pole. But engineers have the reputation for drinking hard and partying hard and that was their thing.

The traditions and privileges of engineering at this university were made visible for all to see. No other faculty goes to such elaborate lengths to showcase their uniqueness, an attitude that was all pervasive. In engineering culture, being humiliated by older, successful, more 'peripheral' engineering students was often manifested.

I remember vividly. Unfortunately I wasn't drunk for that. ...So we started off in this open study area and we were all singing. There is a song we had to sing, of course it was classy- us being engineers. And whoever didn't sing loud enough were the first ones picked to go in. I mean we all went in anyway, so it didn't matter. They had plastic on the floor, we were dumped with all kinds of stuff. They put axle grease in our hair to start, they dumped a few things- nothing that would drip off of us until we got outside. And once everyone went through that we were strung together with a rope- a lot of the guys had jeans on so their rope went through their belt loops. Unfortunately, I thought I would be smart and I wore jogging pants. Something I could throw out. I had no belt loops so it went down a pant leg. So then they took us outside and we were hosed down, and I was thinking this is great-it is not so bad. And then we were dumped with kitty litter, flour, mustard, and everything they could think of buying. And they did this on campus. And then they walked us down to the [business part of city] and left us there. And we had to walk back. Nice.

The humiliation of new frosh was viewed as a 'necessary' bonding process where upperclassmen take on the responsibility to teach the new recruits. If the frosh endure the humiliation process, they were ushered into the student community. Unfortunately, for some participants, the questioning of their belonging in engineering doesn't always end with initiation. "I actually did have one guy come up to me, while I was going through initiation, say, are you really an engineer? And it was like, no buddy I do this for fun".

Conversely, another participant recalled the process of initiation as non-intrusive and non-threatening.

Actually we had no pressure in our initiation. You had the option of dyeing a body part blue

> and that was it. It may have been the first year they did that, when we did that. There was no pressure, some people dyed there hair, other people did their bodies... no one asked why didn't you die anything blue? There were also games and other things that help you to get to know people. You know, some of my best friends from university were in my frosh group. If I hadn't had that then I wouldn't have been able to get to know so many people.

For this participant, more advanced peers did not force her to participate. She not only remembered this experience positively, she stressed that there was no pressure to drink.

> One thing I'll say is that engineering at [undergrad university] is different because orientation week I didn't feel pressured to drink at any time and that wasn't part of the orientation events. That was after and people were invited but it wasn't part of it. We had like Frisbee-golf and scavenger hunts and stuff like that. And our engineering society we actually did a lot of charity stuff. We had a teeter totter-a-thon to raise money for the women's shelter. One day we went to the food bank and there were like 20 of us and we basically helped them re-organize their stuff. At Halloween we would go trick-or-treating for canned goods for the food bank. There was a lot of focus on community and stuff.

Perhaps the initiation organizers at this university wanted to combat the image of the all revered drinking and partying as essential to engineering. Interestingly, this particular faculty of engineering had a high percentage of women in their undergraduate programs. In sum, the practices of initiation served as a public rite of passage- introducing the neophytes to those successful engineering students who survived the necessary sequence of tests to be potential members in the culture of engineering.

Brotherhood.

The notions of intellectual challenge of the curriculum and the superiority of students were introduced early in undergraduate engineering.

> I think I realized pretty quickly that there was sort of a brotherhood in engineering. [laugh] It was certainly an attitude that attempts to instill in people even in frosh week that engineering is the cream of the crop-really a condescending attitude. And I think I sort of refused to buy into that because my closest friend in residence was in history and French so not engineering. She was my best friend and it seemed just ridiculous to try and isolate yourself in this one small part of [university] when you could have so many more experiences. Ugh, so that is sort of the initial introduction to engineering and the culture.

Membership into engineering and its benefits were described by this participant as a process of indoctrination. The tacit knowledge that the more mathematically-abstract disciplines of engineering were superior was conveyed by this professor.

> That is what you say about the whole engineers rule and stuff. I specifically remember my 2nd year economics class, they were telling us -the prof was describing what a, b, c, d, e, f, level engineers difference were. And I was being told that engineering was a great profession to be in, that we were great, smart, and we were really told like rah, rah engineering, we were awesome.

This notion of superiority was reinforced early in the undergraduate students training. Moreover, some types of engineers were seen as of higher rank.

> This prof made himself maximally unavailable, who would also use language to make himself sound more educated as well, and uncomfortable. It was obvious that he saw himself as our superior and that we would never attain his level. He brought a lot of funding

> in his department, and I think that the perception was at the time and he could do whatever he wanted because no one would put their foot down and say what you are doing is inappropriate. I think he was actually quite confident. Perhaps not at teaching but rather his area of expertise. He certainly gave that impression. The fact that he has maintained a high level of funding for his projects is evidence of his standing/stature in the department. I haven't encountered anyone who is really incompetent and trying to cover it up. This is definitely for intimidation purposes. At the same time, he is making himself available to other students who aren't mechanical engineers, but rather in engineering physics. There was this perception that they were also superior to the mechanical engineers.

Within the culture of engineering there resides implicit, tacit knowledge concerning engineering practices as well as the misconception of engineering as physical work.

> The perspective of the community- the engineering perspective in the community is someone doing physical work. That is what I have found. Actually one of our profs, there was an assembly or something like that. So we came to this, why we don't see female students or profs and he was complaining about this. People still think that if you are an engineer that you work in the field you do a hard job that is very much physical that you would think of. But this is wrong. It has changed maybe some decades ago. It is much more assimilation work right now. You hardly go to the field.

In order for the culture of engineering to remain relatively unchanged for decades, the full members- that is, those who have been approved based on their 'fitting into' the prescribed practices of the culture of engineering must apprentice those new engineers in order for the history of the practices to be passed on.

Iron ring.

Receiving the iron ring was a practice and tradition that united and reinforced the uniqueness of the engineering profession.

> I didn't find out about it until 3rd year when people I knew in 4th year were getting them [iron rings], and it was like weird. I think the ceremony is a bit silly. It's more fun because it's more secret society and you should feel special being there. At the time it was the exclusivity. You are only allowed to attend the ceremony if you are already an engineer and that is kind of --I see that as being silly now. I particularly didn't like the very male and very religious, I didn't like the wording of it. So when I did my quote, I changed it to female words and whatever I wanted. I guess I liked the iron ring as a sort of conversation piece. It's like hey you are an engineer! And it's a good way to get to know people.

Although she views the ceremony as ridiculous now, she recognized that the ring was a sort of status symbol. Similarly, another participant viewed the ceremony as disconcerting.

> And I found it almost disturbing when I got my iron ring [laugh]. And there are a number of professional engineers roaming around the floor and put the ring on your finger and shake your hand and welcome you to the profession. And that-it was like a secret society [laugh]. And it was just disturbing. Yeah, there is this whole ritual that you have to go through that seems utterly ridiculous. And then you are welcomed to the profession-it is like the godfather coming up. I don't know; it was just weird.

Her analogy of the 'Italian Mafia' was interesting and added a new spin to the notion of the 'brotherhood of engineers'. Engineers from countries other than Canada do not have this iron ring tradition but are characterized as follows.

> Umh, we don't have an iron ring or anything specifically that can show that you are an engineer- we don't have those things [in European country]. But in engineering it will tell. Because he is probably carrying a lot of books and if it is a female student there is no make up for sure. She is not wearing all those female [things] you know, she is 100% wearing jeans and sneakers. That is how you can distinguish.

In summary, the iron ring is a constant reminder of belonging to the brotherhood or profession of engineering in Canada. This symbol denotes not only ethical responsibility to the public and the profession but superiority- that all rites of passage have been passed within the community of practice.

Professors

Professors of engineering are the gatekeepers of the practice. They implicitly and explicitly decide who continues to participate and at what levels. The doctoral women voiced the tension of their trying to understand and negotiate the rugged terrain of academia. First, a description was provided of the 'boy's club' as conveyed by professors' treatment of their students, and how this affected the engineering climate. Then, I situated how women professors were viewed by the participants. Lastly, engineers having mixed feelings about their experiences with professors is presented.

Boy's club.

The rules of membership into the 'Boy's club' must be impressed by a more knowledgeable member. One participant who is not a B.Eng., recounted her impression of not being in the 'Boy's club'.

> Like that was the attitude-that I was outside of the circle and that I would never be. Like I have a physics degree so if I wanted to go and get a P.Eng. in 3 or 4 years after my masters' degree, like I would have no problem. So, it is just very negative. If you are not an engineer you are not in the club. Like I am a little bit closer because I actually have a physics degree. Whereas some of the other students in biomechanical have kinesology degrees or human kinetics degree so they are even more looked down upon as being not up to the task so to speak.

Male bonding was strengthened in this environment by disparaging females with innuendos and sexist jokes.

> One of the things I was uncomfortable with here when I was taking classes were the jokes. Like the prof, not all the profs but some, some of them say sexist jokes or thing that make you feel uncomfortable- but the guys love it. The students [males] do it among themselves. I still remember some of the profs making jokes about girls, I wasn't really happy to hear. I still remember those.

These doctoral engineers were not directly told that they did not belong but were given very implicit clues. Women participants were also excluded from the 'boy's club' when physical labor was involved.

> Okay, let me give you one example. If a prof is looking for a grad student, he wants to do some experimental work. And in mechanical engineering, extra work can require a lot of physical endurance. So he might decide to choose a male for that because like for

> example in mechanical engineering there are experiments on furnaces or building a set up that really need a lot of physical work. And if the prof doesn't have enough money to pay for a technician he will ask his grad students to do that. So he will prefer a male student.

One participant noticed differential treatment when her advisor expressed strong emotions and swore in the presence of male engineering students while being gentler with her.

> ...He is not as harsh as when he is with his male students. He is more relaxed, softer with me. His demands are the same but maybe he doesn't swear when he is with me. I know that he swears a lot when he is with his male students. But I have never heard any nasty things from him. He is always nice and polite. Even though when he gets mad he controls himself. I can feel that. But I am sure he doesn't when he is with his male students.

Although this participant didn't want to be sworn at, she could 'feel' the difference- that is, that she was not part of the 'club'; she was not one of them. Taken in isolation, any one of these small 'differences' in treatment may seem trivial. But still, this participant continued to believe that her advisor had no preference for doctoral students. "I don't know what he prefers male or female students. [laugh] I don't think any of the profs mind as long as the students produce something. They don't really care, male or female". Being excluded from the 'boy's club' of the basis of gender/sex by their professors affected how they learned to view both engineering as a profession and their research and learning.

Women professors.

Participants discussed women professors in the context of how they transmit engineering traditions to their students. Only a few participants have had women engineering professors as teachers and even fewer have had them as advisors.

> Some of them [women] are really tough. Like [an eng. professor at master's university] was like, she scares me. I could never work for her. She would cut me to pieces in an instant. She is cut-throat. I mean she was the only woman in engineering when she graduated [from eng.] when she did her bachelor's degree. I can't imagine what that would be like. I just can't image being one girl in a class of 60 men. And she looked like a Go-Go Girl. She was stunningly beautiful. And had to put up with the guys and how do you deal with that?

Another doctoral woman described three women professors, all of whom negotiated their engineering journey differently.

> Umh it is interesting there are 3 women profs in mechanical engineering right now [PhD university]...it is interesting to see the dynamic. Ugh, just the way they sort of fit themselves in or carved out a niche for themselves in engineering. One has very much assimilated with the 'boys network' and she is sort of gruff and rough and coarse. The other one is a feminist and that-she does research-she was [my friend's] supervisor [for Master's] and her focus is [female related issues]. So she is always working with women and promoting women's issues- [a particular sub-discipline]'s issues. And teaches courses on women in engineering in the department. And the third person is quite quiet; I wouldn't say she is a feminist per se. I don't know, she has always been quite receptive to me and seems to treat people equally well whether they are men or women and her focus is [a specific area]- which is not a female dominated area [laugh] of [a major discipline]

engineering. So she is kind of like a quiet leader-person to me. Umh, just because she is in that very non-traditional space but still very feminine.

Their different ways of conducting themselves perhaps dispelled the notion of a 'stereotypical woman engineer'. Similarly, 'models of possibility' were provided for students by 'visible' women engineers/professors at conferences.

Then when I was in 4th year, I went to the women in engineering conference at [an Ontario university]. That is where I met [my advisor]. She was an engineering professor and put 2 grad students in the session that she was presenting about engineering and I was just thrilled because I didn't know there were that many [women in engineering]. And so I sent an e-mail and I thought I had an idea all the way through that I would like research but I could never get a job through co-op at [undergrad university]. We don't have very good [co-op] programs. I got into grad school with [my advisor] and then after a year, I enjoyed it so much that I made this decision that I wanted to finish my master's degree first but I decided that I would start my PhD right after I finished. So that is kind of how I got there. I really enjoyed working with [my advisor]. I actually liked going to conferences and doing papers.

Mixed feelings.

One participant manifested mixed feelings towards her advisor and area of research.

I always had an interest in the medical end but it wasn't necessarily breast cancer- but he had money and the project looked interesting so that does drive a lot of research- Who has money.

Describing her relationship with her advisor as 'convoluted', this same participant attributed her advisor's 'good' behavior to his wife's participating in a non-traditional profession, as if a demonstration of progressive thinking.

> He is great. I have no problem with him. His wife happens to be a [professional] and she is very independent and smart. So he has no issues. Sometimes he will come over and make a remark to push my buttons but it is all joking and we all know it is joking. And if he is bugging me I will tell him to bug off. You know so it is that kind of relationship. But no, I have no problem with him from that point of view. But there were a few issues with the whole master's degree thing but that had nothing with me being female and him being male.

Similarly, another participant does not attribute her positive working experience to her same sex advisor.

> Well I know that I've had a really positive experience. I don't know if I would attribute that to the fact that it is a woman supervisor. I think that's why many men work well together- we work the same. She is not looking over my shoulder all the time and she says, "well it's great that you always get on a project and I send you away and you come back and when you need help. And you're very independent". And she really liked that. From talking to other grad students-- like their supervisors are hounding them all the time 'well do you have this done? Do you have that done?' I work very poorly if I get hassled like that and I'm less likely to do it. But if I do it on my own, then I'll get it done in half the time. It could be that we are both women and both work the same way. But she does have a lot of engineering qualities you know -- I guess it goes with the whole self-elected group. Women

are in engineering now because they have the qualities to survive.

Although she first denied there could be a gender/sex influence in their positive working relationship, she lauded their having similar working styles. She elaborated further by suggesting that these superior characteristics, their 'engineering qualities', could in fact determine who survives in engineering.

Peers

Peers provided a sounding board for many 'accepted' practices within the faculties of engineering. The 'actual practice' of learned behaviors, both intentional and unintentional, was reflected in these women's interactions with their peers. The women's 're-tellings' were overwhelmingly considered as constraints. Whether it was as 'social groups', our first theme, or the 'rapport' between men and women engineers, or 'contexts of harassment', -peers represented obstacles to women's full participation in the culture of engineering.

Socializing.

According to one participant, the salient act of inclusion by her engineering peers was that of socializing at pubs and bars.

> I was always included. At [Master's university] it was great. Four o'clock on Friday there was always some of the guys and it didn't matter, sometimes it was me, sometimes one of the guys- like one of us was always going around saying, "anyone want to go to the grad club to have a beer". And there would be, like I remember going out to dinner once- me and 14 guys at a pub. And they were so friendly about that kind of stuff. Here I go to a

much more multicultural university now [PhD] as far a graduates are concerned and a lot of graduates don't drink so don't do that here. It was very inclusive. I was the only girl really in the dept at the time when I first got to [Master's university]. And then when there were girls, us girls went out a lot and also took the guys with us.

In universities with a large ethnically diverse population, it was not always possible to socialize.

Graduate students, I would say about 65-70 % are international. And a lot of the Canadian students who are local are on part-time status now. And they have got real jobs and we are spread over 3 different buildings- there is the dynamics...So, I don't see the other, if you want to call it, white Canadian students. There are mostly international. And I am [involved with] the engineering graduate students society too. So, I should know everybody but I don't. So, [sigh] I find they have their own already established social group because they are all international students and they can empathize with being far away from home. And most of the young Asian females are married, almost invariably. And they are not into drinking. They do not want to go out for a beer on a Friday and they are not into what you would call the normal university social scene. They like, we have pot-lucks which go over really well. We will have about 50 graduate students turn out for a pot-luck. Which is really exciting because you get Indian food, Thai food, and Indonesian- Oh, [laugh] because [small university town] has no restaurants. So, they are great. ...But as far as having that regular 4 o'clock Friday thing, they are not into that.

Language was another factor taken into account in social networking.

At [Master's university] we had Canadian students and a big Oriental population. About half and half. And the oriental students hung out- they had their own little social group and

> then there were white Canadians students –and then they weren't all really white, it was all the Canadian students plus some of the international students who weren't Asian. So if you weren't Asian you usually hung out with the rest of the other group and the Asian students hung with their own group. And I think that was mostly a language reason like it must be very comfortable when you are away to be able to speak your mother tongue when you hang out.

Some international students associated only with 'their own'. "But I find the Asian females have their own little- I find they tend to have their own collection. And they are not as interested in getting to know others". Similarly, another participant remembered only having a few close friends.

> The other thing is in grad work it is different. In undergrad even in master's you are in a group, you are taking your courses, even when you are working on your master's thesis you have more friends. But when you come to PhD, you are on your own. I only had a couple of friends that I met through my courses. Other than that I didn't make a lot of friends.

Another participant recalled a negative experience with peers during her undergraduate summer placement as recipient of the Women in Science and Engineering [WISE] scholarship.

> ...With some of the other students it was a little bit different because you got comments, "Are you a WISE student ?" "Oh, you are one of those". Basically we don't believe that you should be here and you are taking a job that my buddy Dave could be doing so much better than you. [laugh] That kind of attitude which really undermines a person's self-

confidence. So in a way while WISE was promoting this positive attitude towards women in academia and excelling in engineering, at the same time your peers are saying-"you know you don't deserve it, if it were open to everybody and not just women- you know you wouldn't have that- Because men are so much better". So, you start to wonder-should I be here, do I deserve to be here? So and I got that attitude a bit with some of my peers in engineering but not to that great of an extent [at undergrad university]. Not so much blatant.

This same participant perceived her relationship with peers in graduate school as being less troubling.

... When you get into graduate school it is a smaller field and people who are there genuinely want to be there doing research and they don't really care. [laugh] As long as you really are confident, there is not so much resentment. I haven't encountered the same kind of resentment in graduate studies. But of course you kind of carry that little bit of umh questioning of one's worth from undergrad just wondering, "why did I get this scholarship"? [laugh] "Why am I getting NSERC?" "Did they make a mistake?" [laugh] "Are they going to find out?" But yeah it's, I think as a graduate student, I have probably asked myself those questions more than anybody else has. As an undergrad that is when that seed of doubt was sown though. And that was definitely external influences. But there are a lot of scholarships out there that aren't specifically for women scholarships and so on.

Conversely, one participant reported 'the tables being turned' so to speak in that her school of engineering comprised many women students.

Because the school of engineering is small, all the disciplines are mixer together all the time and so overall there is about a 50% average. Even my graduation total, there were more women in the photos than that. There are about 54% women. Of course, there were some guys who didn't' have their picture taken.

Socializing with peers provided a necessary bond amongst engineering students. It made them feel like part of the team. In some instances, 'differences', especially that of sex/gender, affected who was included in social situations.

Rapport with the opposite sex.

Depending on the graduate university and the discipline of engineering, some doctoral women had more contact with peers of the opposite sex than others. Increased amount of time spent together did not mean better rapport with peers.

Not my classmates, they didn't treat me as a person to date because I think they understood that the amount of time that we spend together that it would have just been too difficult if anyone had tried that kind of thing. As far as that goes, it wasn't really an issue but they didn't actually all accept me either. I do remember having in my fourth year- it was a 5 year program when I went through, my fourth year when I was really stressed out and everything. I was on the receiving end of some nasty jokes and comments and stuff. And I remember having nightmares about it.

Rapport was difficult in that it was not always clear how one was perceived.

But the women in mechanical, well I was treated really well. All the guys were super friendly. Once they found out I had a boyfriend they stopped hitting on me. One other thing, male engineers especially the ones in graduate programs lack in sophistication and social skills when they are working with their post-graduate counterparts.

When this participant was no longer considered dating material but an engineering colleague, she was treated as one of the guys.

> That is being caught in the club because now you are one of the guys in a way. So, now you have to put up with all of those innuendos because you are a woman. But you are suppose to be able to take it, isn't that what the phenomena is? I don't know, that is my take on it—that you are suppose to be able to take the abuse because you are one of the guys. Just the abuse is a different form. Oh yeah, guys are pretty disgusting to each other.

This same treatment as men can be as upsetting and viewed as inappropriate treatment. Of course, it all depends on how it was perceived and intended.

> And some of the guys that I would go and have a smoke with, you know we would be talking about an assignment or a question or a test or whatever, and I would say what I got. And unfortunately there was more than one occasion where it was said that I got it [good mark] because I had spent time in the prof's office on my hands and knees. But there were people there that were my quote, unquote friends. Right. And I am sure if those friends had heard anyone say that to their sister, they would have killed them. But I was supposed to be able to look after myself because I chose this, it was my choice to go into this, it was all guys but I picked it. So you fend for yourself, girl. I just think it was that I was kicking his ass in one of these courses and he didn't like it. So he was trying to put me in my place.

What appeared to upset this participant the most was her friends' silence when listening to these sexist comments. The notion of choosing engineering, a male domain, was justification for the disparagement of women who 'threaten the male superiority' of some students. It was 'par for the course'; the expected camaraderie was difficult to distinguish from harassment.

Harassment.

The participants spoke kindly of most their male peers. What upset some participants were the few who were 'allowed' to display inappropriate behavior, and other male peers who watched and chose to be silent.

> And actually that same comment [that women before made it easier] was made to me by older- by women of the older generation was that as much as there was stuff said to me that I didn't like, I still had it easier. It is a process, right? I think it is important that people don't forget that that does happen and had happened, and can happen again.

While some inside and outside engineering faculties thought the issue of harassment and inappropriate treatment had gone the way of the dinosaur, new and 'seasoned' women doctoral students 'begged to differ'.

Harassment was manifested by inappropriate comments and behaviors.

> Well he made innuendo comments about me. And, after that I wasn't comfortable enough being in the lab alone in the evenings with him because he shared a workspace with us. And if it was getting late- I would leave, I would go home for the rest of the evening and work because I didn't want to be alone in the same room with him. It just felt too uncomfortable and he 'hit on' another one of the female grad students who was actually a lesbian, which we never told him... And calling in such a way that kind of –and leaving gifts for her and she was purposely trying to avoid him like any other normal guy would caught on that she wasn't comfortable with that but she also wasn't comfortable outright saying, 'you are a jerk, leave me alone'... He was pretty much harassing her, and I didn't feel

> comfortable being alone with him either. We would both skip out if he was around... he was a jerk... I have heard the way he talked about other women on occasion and I just like, no you just don't say things like that. As soon as [he] went to [European country] to finish off his research, I hung out in that building, I spent whole nights in that building and I was never really nervous.

Feeling uncomfortable ultimately affected some participants' learning and how these women reacted to their male peers.

> I think most of the guys, a lot of them I considered myself friends with, you know I hung around them or worked on assignments together whatever. But out of a class- out of 45 it only takes 5 assholes you know to make comments. To make sexually degrading comments to me to make it uncomfortable. And actually for a while I was angry at them but I was also just as angry at my so called friends for never saying anything.

In sum, positive rapport with peers, same-sex and otherwise, was often difficult especially in a program that demands communication and group work. Feeling comfortable and accepted by your group members was essential to learning in a program that demands competence and problem solving that cannot be completed alone.

Secondary Themes

Not all of the secondary themes were experienced by all of the participants. Nonetheless, they were voiced as salient for some doctoral women. The theme of 'Difference' in the culture of engineering will first be discussed. Then, 'Non preparation for the industrial workplace' will highlight some of the problems the women faced. Finally, 'Engineering associations' will illustrate how women engineers had many roles and expectations to fulfill within and without the culture of engineering.

Difference

Sharing a similar 'culture' bonded engineering students together. Many disciplines of science tended to attract people who were like-minded, who had similar abilities, interests, and ways of solving problems. We found 'sameness' in how engineers should dress, in the 'look factor'. This issue will be addressed first. The remainder of the section addressed the 'difference' factor with regards to disciplines of engineering, gender, sexuality, and international students.

Appearance.

When describing the characteristics engineers shared, one participant first talked of their choice of dress.

> For example me, when I go to school I never wear the things the other social science students wear because I think, during my undergrad, half of the day I was in the lab working with acids and things like that. And you don't want to ruin your clothes. Even you don't wear your nice jeans, you wear your old jeans that is another thing. But here [PhD] when I go to the other campus, the things the female students wear there is so much different than the female students you see at our school. We are wearing jeans or sweatpants. And the thing is you- I think it is also coming from the guys- they come to school with awful clothes. Even the engineering male students they don't wear their nice

> clothes. It is different. I think the workload is more [in engineering] than the social science students. Making your deadlines is much more important than how you look.

Not only did women engineers 'perform' society's notion of the stereotypical, hard-working student, they also, as the males, put less emphasis on their appearance. Another participant clarified, "Plaid shirts and jeans, but I think there is a certain amount of apathy towards one's appearance in engineering too. Perhaps there is a little bit less individualization". Adopting the dominant group's practices, at least in appearance, was one way to be part of this culture of engineering.

Disciplines of engineering.

Disciplines within faculties of engineering were implicitly ranked based on perceived levels of difficulty, that is, some areas held greater prestige. In the past, these disciplines did not often work or socialize together. "You won't get mixing of mechanicals and electricals. Electricals don't talk to mechanicals, who don't talk to civils, who don't talk to 'nevils'". Some faculties of engineering had more traditional divisions of disciplines. "I do remember comments being make about chemical and industrial, well they were easy so chicks were in it right? There is very much a pecking order". Similar divisions prevailed in other countries.

> And at my university it was very different from here and there were a lot of women profs. That is, what I want to say, it is different here [Canada]. Here we don't have any in my department. Of course if affects on the decision of engineering. You will see a lot of women in chemical engineering, environment engineering, and maybe less women in

> mechanical and civil engineering. But in industrial there are a lot. So, I think it is similar to this but you still see a lot of women profs in all departments in [European country]. That was the main shock for me when I came here. There was none in my department and there is one in chemical right now, a new prof came this September. And one in civil, that is all.

Since there were few women in some disciplines of engineering, it shouldn't be a surprise that there were even fewer women professors in these same disciplines. It seemed that the participants who reported their doctoral institutions as very traditional in relation to disciplines of engineering, also employed fewer women professors in their electrical and mechanical departments.

Gender.

First of all, some participants reported stereotypical notions that affected not only their work but also their peer relationships.

> Well, the thing is I wouldn't like to walk home alone late at night so I would leave school early. But guys would stay until midnight and finish their projects, but I had to leave because it doesn't feel safe to walk. So that was the thing I was probably missing... guys can walk home any time they want. Maybe it is my thing I was told it wasn't safe to walk home after 11 o'clock alone. So I would leave the project or assignments and then go home. But they would continue of course.

This stereotypical myth, similar to Cinderella's curfew, dictated when this engineer returned home from school. Why would it be any safer to walk home at 11 o'clock instead of midnight? Similarly, another participant speaks of 'the good female student' stereotype, asexual and adhering to the unspoken rules of staying within one's group.

> Umh, there was a lot of girls in undergrad when I was in classes with engineering students, the girls were umh, like the girls were one of the guys. I don't think there were too many relationships between the guys and the girls in engineering. Ah, because the girls in engineering were typically really good students, and I think that the 'good female students' were always willing to help other people-and they stay within their own group in engineering.

The discussion of dating was very ambiguous, with few comments. Interestingly, all of the participants briefly mentioned either that their current 'significant other' was an engineer or that they dated engineers in the past.

Sexuality.

When participants were asked if they knew of any gay, lesbian, bisexual or trans-gendered students [GLBT] within their faculties of engineering, some participants responded directly while others appeared to skirt the question. One participant highlighted that women who chose non-traditional paths such as engineering may not be conventional in their sexual orientations.

> As far as women in engineering, women who are in engineering are not your average women any ways. Right. So, you are getting different people. [This Ontario university] is a very open university; I didn't think that when I was there but in hindsight.

The notion of 'people of difference' being attracted to a university that was freer of stereotypes or more accepting of particular 'differences' was salient.

> She was very private about it. And it wasn't- we knew that she had a girlfriend we just didn't talk about it. She was very private about everything not just about her sex life or her gender or whatever you want to call it. ...She was private about school, her grades, research, her hopes and aspirations- she was just one of those very quiet people. It was never one of those things she went around- like I have had gay friends who were like talked about their gayness and it was like dinner conversation the same way I would talk about my straight relationships. But not with her, that was just her. I don't know if mechanical engineering is very- I don't know I never have met any other guys in mechanical engineering that were gay. She is the only lesbian in mechanical ...I know people who are bi -[sexual] but that is different too.

In fact this particular research lab was an all-female environment where relationships among other things were discussed. This unconventional setting may have allowed the members of the research group to be aware of each other's sexual orientation(s) instead of the assumption of heterosexuality.

Another participant recounted her gay roommate's experience of 'coming out' to other engineers.

> Yeah, I did know of some. Actually I lived with one, my housemate for 2 years. There were gays, both men and women in engineering. They were quite open about it, at least 2 that I know of for sure. [They were] just open in general and active promoting awareness. So, I know that one was a close friend of mine and he was really afraid of coming-out to the engineering society which is kind of the big brother of the 'brotherhood' on campus. And promoting frosh week and things like that and that attitude that pervades us- we are the greatest attitude. Umh, he was really afraid of how they would react and he was surprised

> that they were- I don't know if they were welcoming- I wasn't there when he 'came out' to the engineering society and started talking about the awareness but umh he had a really positive feeling coming out of it. And I don't recall any negative things being said to him by other engineers. I know there was certainly homophobia around but it wasn't expressed toward him or him directly.

The climate in engineering at this particular university was such that there was at least a discussion of 'awareness' issues that took place relative to homophobic attitudes. Moreover, this same participant remembered her first encounter with 'sexual difference'.

> Coming from a small town, [laugh] they have narrow-minded ideas. Actually my first exposure to a different sexual orientation was when I first arrived in [university-town]. My parents had driven me up and we got to [the university] and wanted to look up a friend of my parents' who had lived in [my province] and now lived in [in university town]. She is a prof at [my university] and we had gone to visit her and it turned out that her phone number was unlisted, so we had her address and dropped by. And found out that she was divorced from her husband and living with another woman. And that was, it was [pause] my first exposure and I think my parents' too. So, it was kind of a surprise and I remember going back to the hotel with my parents that night. And thinking, you know she is still the same woman we knew in [hometown] and there is no reason to treat her any differently and there is no reason to think that this is anything bad and that was just how it was. So she was still the person we knew-we just knew more about her. [laugh]

Conversely, not all participants attended more progressive, inclusive universities.

> I can imagine, I mean I CAN'T imagine actually. I mean it is hard enough being female but like being gay, in a homophobic society that we live in- it would be worse. Unfortunately

> when we talk about the whole engineering society it really reminds me of the military. And I think- I don't know whether it is the nature of the job or just that it has been male for so long- but that is really what it reminds me of you know, 'we are the best of the best of the best kind of guy- only if you are a guy and white. To be honest with you, I hadn't [thought about it before]. But you are right statistically there would have had to been. But the climate, Man! I guess I would be happy if someone had of 'come out' because then they would have been treated worse than me [laugh]. That is awful but.

The notion of the 'dominant engineering culture' being represented by whiteness, maleness, and heterosexuality was a deeply embedded stereotypical ideal that seemed to pervade the university institutions of engineering.

International students.

Being visibly different, and usually not eligible for Canadian scholarships or part-time employment, international graduate students abound in schools of engineering.

> ...In undergrad you only see a few international students who are undergrads. In my university [doctoral] there is only one or two who are international students because it is too expensive and they don't get scholarships and other things. But in grad school, you see a lot of women international students. There are many reasons for that. One of them is that people want to live in Canada that is why they first come here to study. It is easier for Chinese or other people to get a VISA and then to start a new life. So women prefer to come.

One participant alluded to international students choosing nontraditional engineering disciplines ultimately as a way to gain citizenship.

> I guess I can understand in undergrad why some female high school graduates don't prefer to go into civil or mechanical because the working environments are not as suitable as other disciplines. But in grad work, it is all research. And actually there were no Canadian female grad students in my department, they were all Chinese- Me and the Chinese. [Chinese are master's] I think when it comes to research still international students or 'other' students want to do it because really they don't care about the discipline of engineering. But after graduating, when you are done with your grad work, and you start to apply for a faculty position I don't know why it happens but we don't see any females. But still I would love to see a woman prof. in my department.

Another participant described another stereotype persisting in engineering.

> And I think there is also the assumption that, at least at the graduate level, if you are a female and you are from another country then you are probably pretty damn smart to get over here. And you have resources, and so on. Whereas I have to admit, I am pretty sure I am the only white female graduate student in the electrical department now. And I get a few looks, "who the hell is that". But it is kind of ironic in the sense that we like to think we are so liberated over here. And most of the graduate students that are female are foreign.

Again the notion of 'foreign females' choosing nontraditional areas of engineering, as the only way they could get funding, was overlooked by this participant. In fact, she conveyed a widespread stereotype, that of international students having the resources to survive when they arrive in Canada. Another participant concurred with this assumption of resources.

> It is a white school [master's]. There is a large Asian population and some of them are foreign but financially some of the best off students at [Ontario university]. Like they have cars and new cars. [laugh]

Homogenous populations in engineering faculties perhaps contributed to these unexamined assumptions concerning foreign students.

> And see like my undergrad was so different in that, we had if not a 'white' community, it was mostly Canadian people: people that were born in Canada, raised in Canada. It didn't matter what their race was. They were raised in Canada so it was purely Canadian people and very few international students so it really wasn't any distinction of your race or religion or anything like that. Again. We didn't have a lot of people- not many mature students in our class. I mean we had a few men but no older women to do more or something like that.

The sameness of this 'white, Canadian' undergraduate class bonded them together but at the same time may have instilled an 'us' and 'them' syndrome. Another participant also used this language of 'difference' to describe 'other' groups of students.

> I have observed that in our undergrad program we have a lot of Arabic students, they always work together- male or female. Like I say 50% -half and half, they always work together. And Chinese students, they always work together. For Chinese I am sure it is language but for the Arabic students, they are in undergrad so most of them have good English. Maybe they weren't born here, but I am sure they have their high school diploma from [this province]. So, I think it is a more ethnic thing, yeah. Maybe they speak Arabic among themselves. They help each other. They work together. They make themselves isolated from other groups so I don't think it is healthy.

Since many international students shared a common bond of language and 'difference', it was no wonder they worked and socialized together. In fact, it appeared that gender/sex was 'forgiven' for international students, since they appeared to be 'marginalized' already.

Non-Preparation For the Industrial Workplace

While some of the participants had experienced working in industry either through summer jobs, co-op placements, or industrial engineering positions, all of the participants reported that they were not prepared to work in industry and that industry may not be appealing.

Becoming aware of expected salaries for new engineers in industry was disappointing for one participant.

> I am sure there are exceptions, but normal engineers –like mechanical engineer undergrads- after they graduated the average annual salary is $ 45-50, 000. And commerce students or business students will get maybe $38-45,000. But at the end of the month with the taxes deducted, the difference will be $200-300.

The ordeals that some women endured to survive in engineering programs seemed less appealing after learning about the salaries offered. "So why go through the nightmare of 4 years, no parties in undergrad education, and they [women] will probably prefer to study something easier and more fun". Her work experience in industry provided a clearer picture of what was expected and what was more important for this same participant.

> In my mind, industry is very harsh. In terms of workload, academia had more. You work more in academia for sure and you are paid less. But you are totally free, that is the main thing. But in industry they tell you what to do, I think that was the main thing. And your aim, your success is equal to how much your boss makes, the amount of money he makes. So, that is what you work for. I think that was the main thing for me. You learn and you work on something for yourself. In academia, you read an article because you want to learn it. You want to expand your information on that subject. You don't want to use it to make someone richer. You use it for yourself.

In conducting research with an industrial partner, another participant talked of ethical dilemmas she faced.

> Obviously, in biomechanics if an engineer is designing something to help a person- than that is their goal. Obviously you want it to be successful and help people and in a way - I start to see the lines being clouded a bit between profit and helping people clearly. Walking down that ethical line and saying that this has been well tested and you know it works. This is right. Umh well as, 'we think it works, surely this time, it will be fine'. Sending it out there too soon so you can say 'well we did it first'. A certain amount of that I have encountered and that attitude. So it's, ethics has been on my mind because of that and because of the practice. Because of the potential to really hurt somebody while telling them at the same time that we know what we are doing—'we have never actually tested it but we know what we are doing'. [laugh]

This participant chose engineering in order to help people and make a difference but understanding the industrial philosophy of profit margins caused her to rethink where she wants to be in the future.

Having worked in industry for numerous years, one participant believed there was a need to teach communication skills early on in their training.

> They are finding that this is a problem in the sense that you go out into the real world and you have engineers on teams, and they are not talking to each other. There is the elitism problem. My experience with most male engineers is that most of them do not have very good personalities in the sense that their sales and social skills are lacking. But there are more and more employers that are like it doesn't matter if they can put together the formula they have to talk to the client.

Perhaps some of the skills learned in the classroom setting were less useful in industry and in dealing with clients. Another participant felt that professors who worked for a time in industry learned more appropriate communication skills.

> My supervisor specifically is not a good manager. And I think people who have worked in industry actually seem to pick up better managerial skills and if they have been to industry because their main goal is to get projects done and out the door and to keep people motivated and working. I think that really lends itself to teaching people how to be good leaders or perhaps better at teasing out who is a good leader and who isn't. It seems that academia tends to get a lot of people who are not good at interacting with people in engineering. It is as though they did their master's and it was a project they did on their own, by themselves, with minimal interference or input from their profs. And they went on and did a PhD and again on their own, in isolation and then all of the sudden they got all these students who are looking to them for guidance. And they say, 'well I did this on my own so you go on your own' and I don't think there is enough interaction, to really perhaps start from there.

The need for improvement in communication and managerial skills was also visible to others in the university. She continued

> They do seem to be related [power and external funding] from what I've seen. People are very cautions about things... It seems that since they bring in more funding then they have more power. My professor brings in a lot of funding and the university caters to his every whim. It surprises me sometimes the things he gets away with because of his standing in the department.

Another participant suggested that some kind of formal program or sharing of information/expectations from industry to academia would be beneficial.

> I think that would be beneficial to have some liaison between industry and academia, and knowing who to approach and how to approach. And even just going though PhD scholars and women. I wouldn't say it's necessarily harder than for a man, but it is very much unknown until you are in the middle of it and even then, it feels as though you are less without any form of life support-just to know what to expect would have been really helpful. I've been talking to other graduate students before I started my PhD, they said well--you have to really want it. Well that didn't really tell me what to expect.

Co-op work placements, and industrial partnerships were experienced by a 'lucky' few of these doctoral women, but these options were not proposed by all universities and engineering programs. Unfortunately, there were no common guidelines for academic/industrial partnerships that truly prepare engineers to negotiate the workforce, especially with people of 'difference'. While these women engineers were students in faculties of engineering, they excelled academically and their skills were appreciated by their working-groups. The "harshness" of industry required and valued a more masculine approach.

Engineering Associations

A few of the doctoral engineering women participated in graduate engineering associations, and professional engineering associations at both local and provincial levels. In fact, this minimal participation was definitely considered a constraint. Of course, it must be remembered that only a few qualified for their P.Eng. as they had little work experience. This would inhibit many from participating provincially and nationally in engineering association conferences and 'gatherings' designed for women, or perhaps even knowing that they existed.

The professional association for women engineers in this province was not viewed as very demanding.

> Umh, let me see the second job I had. At that point I would have been 26 or 27. I decided I was going to get a little more involved with the professional association and in doing so I was join the women in engineering group. Because [my province] has had one on and off and it is very ineffective and anyway not much came out of it. So, I joined that and I think I went to meetings for 6 months and every woman that was on the committee wanted to do something but because they were all so busy between jobs and kids that nothing really got done. And then the woman who was the chair at the time, got a new job, a vice president of one of the universities in the province. So, she became too busy and never relinquished--like either she never gave up the position or [association of profession engineers of

> *province*] didn't have the interest to try and fill it with somebody else. And she didn't participate, nothing happened with it.

The issue of women being too busy, that is, having many roles to fulfill in their lives while trying to pursue professional careers was salient. This same participant was asked to be a representative at a national conference but received no worthwhile support from this initiative.

> So, then last year, there was a conference in Ottawa put on by the Canadian Council of Professional Engineers. And because I had been involved with Women in Engineering and because someone in [provincial assoc.] remembered that, they asked me if I would go over and represent [my province]. So, I did. However, the most that has come out of that is that I have provided them with a summary. And a willingness to participate in something you know- as I have time. Seeing as I am in school, I don't have a lot of time. But I was interested in doing something. And it is not important to them. It is not only not important to [assoc.] but before I went to the conference last February, I let the student newspaper know I was going and asked them if they were interested- you know a paragraph- to put it into the paper. I never got a response. It is a non-issue. It is not a problem- or it is not a talked about problem. There is no problem. So you know, go away you feminist- that is how I felt anyway.

Although she went to the conference, it left her feeling frustrated since the association had done little with the summary of recommendations she proposed. Moreover, the disinterest by the engineering student newspaper opened 'old wounds', that of the invisibility and silence of women's issues in engineering.

> And my experience with, when I was going to [undergrad university] and there was the Montreal Massacre, and there was all the talk about how women were treated in engineering. There was a bit of a backlash in the school at that time. Because the guys were like, this was one cycle- there is no problem. I think the backlash has been a problem.

This notion of 'backlash' was not only present with her male peers in graduate engineering school. She also perceived that some of the women at the national conference thought discrimination and poor treatment were a thing of the past.

> There are many women involved with it [CCPE]. Okay, my experience, I know that my experience is unique. ...I come from a smaller part, less populated part of the country. I am in electrical so naturally there are fewer women and so forth, I just found that I felt like I was regarded as 'the one with the black cloud on her head' the very negative person. Whereas, I was just interested in saying, this happened to me don't think that it is not a possibility.

Having encountered disappointment and resistance from women in engineering associations, as well as the 'usual' exclusions by some of her male peers influenced her participation.

> So my experience with [engineering association] and trying to change the way things are for women in engineering- or girls that may go into science and engineering- have been very unrewarding. That has been my experience with [this association], and I have come to the conclusion that I am better off to just stay away for awhile because it was making me upset.

Conversely, another participant recalled the student engineering society as being a popular thing to be involved with.

> A lot of people participated in the engineering society which was more or less a popularity contest. I guess that sort of lent itself as a forum for, perhaps, boosting one's ego. There was definitely a clique associated with the engineering society. Only certain people were recognized by them. You get voted in by the engineering students. And they were in charge of ...a student government but they were also in charge of the engineering student pub so it was also run- that was king. So that was kind of associated with the 'man'.. it was a very cool thing to be involved in.

This student association had a long history of male participation where 'dominant', popular male engineers decided who could participate and to what extent. Associations for women were not active at her university.

> I haven't had much interaction with professional engineering organizations at this point. Well, I had decided a couple of years ago that I would like to be active with WISE. There was no way of getting in touch with them. Their website was outdated by 6 months at that point. Sending e-mail to the names listed on the website generated no response. And I asked one of the profs at [this university] if she was active with it... and she wasn't. So I didn't really know where to go from there to try to find out.

This pattern of women engineers being so 'busy', was seen in their WISE website being obsolete and the student group not being active. This example carried itself into their professional careers. Perhaps women engineers cannot 'do it all'; yet without their unique voice being heard and being represented in associations, how will change occur?

This study explored the sociocultural influences that affect choice and participation of women in engineering. It aimed to understand how the learning context in faculties of engineering impacts on what is actually learned and how this affects the achievement of women in science/engineering.

CHAPTER SEVEN

Research Question Four

4) How does the female PhD student's non/participation in engineering affect their identities?

A self-proclaimed identity has two main facets; how one chooses to talk of oneself, on the one hand, and how one recounts others' descriptions and behaviors on the other hand. Moreover, doctoral women's participation in engineering with regards to environmental influences affects how they speak of themselves, revealing thus, components of their identities appropriated and resisted from the sociocultural milieu. Salient ways women spoke of themselves were categorized according to 'Self-definitions', that is, how the women spoke of themselves. Next, 'Performance of identities' was described along with how the engineers viewed their 'Future goals'. Finally, the importance of 'Role models/mentors' for others was revealed while 'Socializing/intimidation' with people outside the engineering faculties was discussed with regards to feeling 'out of place'.

Self-definitions

How the doctoral women described themselves cannot be differentiated from the context of their 'talk'. Their perspectives of 'self or selves' addressed their 'Personal characteristics', 'Conditions to become an engineer', and key 'Life experiences'.

Personal characteristics.

Although there are many different ways to arrive at a doctoral engineering program, participants spoke of common characteristics that proved helpful.

> You have to have good time management skills and be able to prioritize assignments and stuff like that. I guess one of the things I learned going through my undergrad was I actually found high school very easy. I didn't study much for exams, and did really well. Then I got to university, and I remember studying for my chemistry test and it was only the 3rd week of September and I thought a midterm? We've only been in class for 3 weeks! And a week of that was review so I thought aw well -I normally study 2 hours for an exams... And I think I studied until about 4 in the morning and got through half of the material and was just appalled by how much stuff we had learned in 3 weeks and got introduced to failing-not courses but exams and such which I had never done before in school. Well I just realized that it's all about perseverance. I know a lot of guys fail a lot of courses and you know, entire semesters and they'll come back and continue their studies. I don't know if I would have failed courses- if I would have gone back. [If I had failed] I think I probably would have thought that I didn't study enough; self-confidence that you can stick through it.

For this participant, failing an exam provided incentive to learning subsequent time management and study skills, in addition to calling upon one's perseverance. Similarly, another engineer affirmed

> Patience, and should have the guts to work long hours. That is the main thing. And [especially] patience because if you do modeling, you do it once, it doesn't work, you try

again, and again, again you shouldn't give up. You should continue working on it for long hours until you do it.

Another participant elaborated on why patience was required and fostered open-mindedness.

Oh, you have to be very open to interdisciplinary-you have to be very willing to learn things that are outside of your field. You have to be very accepting of the fact that you are going to have to know physiology, you are going to have to know anatomy, you are going to have to know metallurgy, use computer programs, you are going to have to be able to say I am willing to learn about a bunch of new things that I didn't know. Usually, researchers go into a field and its get narrower and narrower the focus. But it seems in biomechanics the focus has to get really wide before it can get very narrow in graduate studies because you have to learn so much about other fields before you can back into what yours is. I am doing course work that is epidemiology, anatomy, I've got linear transformation techniques, 3D motion tracking, and I've got so much other stuff that I have to learn before I can get to my stuff. That is not in most other research fields where you just get to focus much more rapidly on your stuff.

According to this participant, it was necessary to know what career area motivated or interested students, either solving current applied problems or examining creative theoretical research- because different skill sets and personal qualities were needed to be successful.

To be an engineer.

Some doctoral engineering students came to the program from other disciplines of science and quickly voiced that others in the field disparaged them. A participant confided, “I’m not really an engineer”. One participant had adamantly been told that she would never be an engineer.

> I am not an engineer so maybe I notice it more, because my area is physics and biology, so I don't have an iron ring. When I first walked into the office of the head of grad students in mechanical I was given a stiff lecture about how I wasn't an engineer and I wasn't allowed to call myself an engineer and how I would never be an engineer. And I was walking in with full NSERC funding; it was the most negative impression I have ever gotten at the department. Like all the other profs were very nice but this one left a sour taste in my mouth.

Expectations that one should be an expert on certain subjects in order to call oneself a ‘true engineer’ were expressed.

> My [doctoral advisor] gives me a hard time every so often because I don't have, like I am not an engineer. So I don't know anything about fluids. And I am not a computer scientist, so I don't know anything about the guts of a computer. And I don't think I should have to. I know about what I know which is my field, which is ergonomics. And I am pretty good at that and I don't think I have to be an expert on everything. People always make you feel like you are so incompetent if you don't know everything about everything.

Although this participant realized that she was competent in her discipline and had been recognized with national scholarships, the seed of doubt persisted as to her status. Another participant self-defined as an engineer because of her engineering expertise.

> Sometimes I say that I'm a PhD in electrical engineering and people say, "Uh".
> And sometimes I say that I'm a PhD student in computer vision. Because that's my field of expertise and they also say, "Uh". I think that they can relate more with the computer vision

> because electrical engineering for them is really someone who is into electricity and circuits and stuff like that and it's totally not what I'm doing. So that's why usually I prefer to say that I'm doing computer vision instead of electrical engineering.

Another participant was very confident in her choice and identity as an engineer.

> Well then I would definitely say I'm an engineer. That is the one thing that I've recognized over the years, is that I was destined to go into engineering because I have every characteristic of an engineer. I'm organized and detailed-oriented, I like figuring out things. I was always the one who hooked up the VCR to the TV so you can videotape. I put together my bike on my own. Stuff like that. I like science all the way through. I really feel like if would have gone into anything else, I wouldn't have been in the right field. I think I'm in the right spot. Like I feel like I'm really interested in what I am doing. Especially getting into research. This is definitely the place for me.

Interestingly, not all participants viewed themselves in this way. Another participant confided, " I guess I would call myself a mechanical engineer. Umh, although I feel less identified with that". In sum, those engineers that came to the doctoral program with a B.Eng. had the ability to choose more freely how they spoke of themselves. Other doctoral women had appropriated the labels given which hindered their expressions of identity.

Life experiences.

In order to complete a doctoral program, many life experiences had to be delayed or forfeited, from things as simple as living conditions, to relationships, to the decision to have children. Comparisons with others in her peer group was disconcerting to one participant.

> I feel like I am a grown-up student, I feel like Peter-Pan. I haven't really grown up because I live in a student apartment with ugly furniture and ugly carpeting and none of those nice consumer goods that everybody else I would have gone to school with would have right now. And I haven't gotten married and I am not planning my retirement, not that a 25 year old should be thinking about retiring but they know- they have got all their RRSP contributions MAXed out, people I would have gone through undergraduate with. Although most of my friends are in professional programs or in graduate school, so I don't know. I just went to a wedding on the weekend with a bunch of 30 year olds so I am feeling a little bit like "oh, okay".

This participant viewed her journey and life project as an adventure.

> I am pretty happy with who I am. I am confident in most of my decisions. Sometimes I have regrets but everyone that's grown up has regrets. And umh, 'who am I'. I am a very happy 25 year old woman who has the whole future to make other decisions and make mistakes and do something different if she decides that isn't what is for her.

Aware that she is still young, she might have another path if she is not pleased with her choices. Another participant stated, "I am not a typical PhD student, I am a little older". She worked in industry before returning to complete her doctoral program, and has had time to consider both her personal and educational needs.

> Well, I realize that I am not happy to stop learning. Umh, I realize I am someone who has a quest, a search, or a longing to keep learning. Umh, I am someone- I am trying to take this into perspective with the whole PhD thing- but – [repeating the question in lower voice]

> who do I see myself as, who am I. Umh, I am still searching for the right direction. I don't have a whole lot of people in this profession that I consider mentors. So, at times, although I know I want to do research and I know that I want it to be medical and have certain flavors to it, I feel a bit like I am floundering, and searching, still trying to find that sense of direction. But that could also be a reflection of me personally rather than anything education-wise.

Questioning her personal direction allowed for the negotiation of her need for learning and research that reflected an ongoing constructive perspective on life. How women doctoral engineers appropriated and resisted societal expectations to fulfill their educational needs on the one hand, and relationships on the other hand, was challenging.

Performance of Identities

How an engineer performed her identities was an adjustment process that she enacted, on the basis of explicit and implicit sociocultural expectations. In the academic setting, negotiating the many roles of a doctoral student often collided with the expectations of her advisor. One participant in particular, shared her perspective.

> I am trying to figure out what roles he expects me to play and how aggressive- like when we meet one on one. I am much more aggressive than when we meet with other people- other members of the group. Mostly, because I don't want him to be concerned that I am disrespecting him because he is an older male and he is European. So, trying to figure out the right- there is a whole bunch of different answers and depending on the situation a 'certain *Anna*' kicks in and behaves a certain way. And I haven't figured out the appropriate *Anna* is to use with [doctoral advisor].

Many identities need to be assessed.

> There is a whole bunch [of identities]-depending upon who I am interacting with I will use a completely different- If I am interacting with males my father's age or older-depending on the situation, if I feel that I am being treated like a flake than I will get more aggressive. And if I don't want-Have you ever acted like somebody's daughter just so you could avoid the fact that they might be hitting on you? That is what I do, and if I feel uncomfortable with the situation like that I start to make comparisons. "Oh you sound just like my dad, or my dad would have said something just like that". And try and remind them that there is a 25 year age gap.

This assessment of the context required sensitivity to the feelings and perceptions of an industry/research partner for this same participant.

> Or there are situations where I scare the engineer from [a company] pretty bad. And then I started to say, Ok he is nervous about me coming into his plant and screwing things up. So I want to reassure him that I don't want to do that and that I need to learn from him. So, make it the purpose of being the keen, really interested student that wants to use all of his experience and knowledge. And that was the *Anna* that works with *John*. And that is the *Anna* that I have to use with *John* now that he needs to be reassured that I recognize that he knows more about this than I do and that I want to learn. Instead of him being intimidated by this little PhD who wants to come in and destroy his plant.

The privilege to conduct her doctoral research in an actual industrial plant was seen as a rare learning opportunity that she needed to protect. Making the plant owner feel in control, instead of intimidated by her was a primary concern. Moreover, she recognized that all performances were part of her 'identity'. She explained

> I am very conscious of my behaviors. And figuring out which behavior works well with which people. And I make, depending upon the situation, I make a conscious effort to be that aspect of myself, like they are all me. I just make sure certain parts of me are more apparent and that is what works with certain people. But [another prof] expected such a high level of performance of me that I became this super student and I made sure she knew that I was working hard. ... So, I became super student. I was there between 8 or 10 o'clock every night working. And that is what she needed and wanted from me...I make a conscious effort to be whatever I have to be to get the job done. And being the pushy aggressive student with certain profs because they need to pushed and driven and guided through a process of whatever works. And then being very passive, "ok if that is the way you want it that is fine with me". Works with other people. And you negotiate, you find out what the person you have to be is and get the work done. And you make a conscious effort to be that person so things run smoothly. I sound so manipulative don't I?

This participant explicitly described how and why her 'performance' choices were made. Getting the research 'done', as well as having things run smoothly were important aspects for this participant.

Participants must be viewed as competent, that is, able and confident by their research group in order to gain respect. Adopting male-like behavior of aggressiveness was necessary to this participant.

> It happens when people don't know each other... Sometimes people don't know me at all, especially I look not so big. [Asian] women are relatively smaller. And they tend to think I'm

> nothing. Even in [Asian country] it happens, when they look at guys they tend to think that they are in charge of things although I was in charge of things. It happens very often. They usually think women are the followers. I feel it's much more difficult for a woman to prove themselves to show their ability. They have to be a bit aggressive. Actually I have to purposely show off a bit for people to notice my ability. But it's difficult [at] times.

The 'performance' of masculine behavior was reinforced and necessary for this woman engineer. Another participant received a remark, - "You are just one of the guys". Moreover, an additional behavior was identified with another aspect of her male peers. " [T]hey are all very 'geeky'. But I am very 'geeky', I guess". Acknowledging 'difference' in engineering was also voiced.

> I just recently became engaged a few weeks ago, and we were talking about rings and dresses and I said, " enough of this she-she fou-fou stuff". And *Cathy* said we are female engineers, I think it is important to be as she-she fou-fou as we want to be. [laugh] She thinks that is the ultimate expression of feminism in engineering. And I have to agree with her. We are not trying to be male engineers. I think it is important to define ourselves as women in engineering perhaps different than men engineers but we bring something to the table to offer that is a different perspective. I think that is important-not to try and homogenize everything.

Although acceptance by her peers and research group was important, she had not lost sight of her 'other identities'.

Even more affirmatively one participant sees herself as a feminist, one who questions the harmful statements of certain male colleagues.

> I am a feminist. Isn't feminism the notion that all people are equal regardless of gender, race, or age. Yes, I am a feminist and I think most people are feminists. But everybody is scared shitless of bra burning feminists. And I don't think that most people have a problem with believing that women can do anything that men can do. But I just find that white males are a little bit sensitive to anything that anyone else wants to do. Like they take anything like -white males take as an attack on them...I don't know why they have to perceive everything as being a criticism when it is not. They like the status quo. And they don't understand whereas if you explain to them, would you go and intentionally hurt anybody? Most of these people wouldn't intentionally go and hurt someone. Well, if you knew that something was going to hurt someone would you say it? Well, probably not. Well then why would you make those jokes? And that is the only way to get through to them, is to break it down to the simple concept of hurting someone else's feelings. You wouldn't intentionally do that if you were a normal person.

The lack of acknowledgement of the multiple identities and roles of women, as well as 'other people of difference', in engineering may have contributed to the current homogeneous population.

Goals

The process of becoming a doctoral engineer can be qualified as a challenge. Entering engineering to 'Contribute to society' was a goal of some women engineers. After participating in the culture of engineering, some participants re-negotiated their goals with more realistic notions, while others contemplated leaving the field, or just 'reaching for the sky'. In practice, most participants are still weighing their options, their identities being 'liquid', not yet fixed. Finally, as an afterthought, many participants experienced intimate aspects of their identities, that is their 'Personal lives' and how these complemented or conflicted with their goals.

Contribution to society.

Some participants felt compelled to help people and contribute to society.

> I wanted to do something that I felt would contribute directly to society. Unfortunately for some of us it takes a little longer. It takes some of us like 8 years to figure that out. My thing was that I didn't find the [industry] work challenging, I didn't get any mental or emotional reward out of making a conveyor belt work better or a motor work better, or an elevator work faster or whatever.

Another participant gave a vivid account of how she wanted to help others.

> My original interest in [sub-discipline of engineering] came from actually when I was in grade 7. I went to a WISE [presentation] basically to give young girls an exposure to areas where I guess women were underrepresented or non-traditional roles. So there were a number of people giving presentations from various areas, from chemistry and so on. There was one presentation on [sub-discipline of engineering] and it was specifically on artificial limbs and the demonstration was with sort of a bioelectrical arm. And that was my initial exposure to it. Ironically it was the only presentation given by a man. [Laugh] I had always been interested in science and then ...realized that what I wanted to do was help people directly and get that immediate feedback and be able to see the impact that you could have on their lives-the beneficial impact. So, I realized that I wasn't going to get that from an undergraduate degree in engineering. So, I sort of thought of my master's as

> specialization in [sub-discipline] engineering. So that was my [sub-discipline] specialization and the project I was working on-I hadn't really tied up all the loose ends so it was kind of interested in continuing on with it at the PhD level. Plus, I was able to get funding to continue at the PhD level and my parents were very keen that I don't pass up this opportunity. So, I guess those were the main contributing factors.

For this participant, a presentation by WISE was perceived as encouraging and it allowed her to plan for ways to combine her interest in science with her desire to help people.

Weighing their options.

One participant considered the jobs she liked to do and how they may translate into her future plans.

> Well, I hope to finish my PhD in 2 years. In 2.5 years from now, I want to do maybe a fellowship or two somewhere abroad, hopefully Australia that is my first choice. I want to work with a former colleague and a future colleague too. And then I have- [a university] has offered me a tenure-track teaching position when I finish my PhD. So, I might go back there and teach as a prof in the human kinetics/kinesiology dept. there. And I want to start my own consulting business... And instead of doing pure applied lab research, I want to take my industrial contract and make that my research. ...And I would probably like to stay in Canada. And if I do take the teaching position ...which I am not 100% sure because my family has pretty much moved [out west] except my parents... I would like to go back home but I don't know if I have out grown it or not. And I cannot live in cities; I hate cities. So, [this particular university] has that combination of being a small town you can live outside of. So, maybe another small university like Laurentian or somewhere like that. You can

teach a course or two at a small university and then work at a small consulting company that I hope to make bigger. That is my career path right now.

Although she was at the beginning of her doctoral program, she had considered her future options and how they fit with her perspectives of 'self' and her engineering ambitions.

Having had many engineering experiences inspired one doctoral woman to envisage her future.

I think I would love to be teaching. I would love to have a faculty position teaching. That is how I see myself. Actually, I have my undergrad in environmental, so I am not a real hard mechanical engineer. My husband is, he- I am sure he would love to work at another university who is extremely good in his research. But for me I would love to work- I don't have a university in mind but a university where they have a good [program] in environmental research going on.

Although she knew she aspired a faculty position, she was not set on a particular university. In fact, this may be helpful since it is difficult for two PhDs to obtain faculty positions in the same university and even less likely in the same department. Another participant considered a management-engineering position, one that required more responsibility.

I'm still in the process of thinking about it. I really don't know if I'm going to be a university professor or a researcher for a company. I absolutely don't know right now. I certainly see myself doing research. I certainly hope so. Presently, I also may see myself passing more responsibilities whether it be on the side of management or human resources or stuff like that. I hope I can do more research. I think it's the opportunities after my PhD which will really decide the offers basically. Because right now I don't think it's the time for me. I still have a year and half to do. It's not worth it right now to decide where I want to go. If it turns out that it won't work in a year and a half well I don't want to be disappointed so I really want to keep the doors open. Anyways, I think I could be happy in both sides, whether it be industrial or engineering career. I think it's the opportunities after my PhD if a person offers me an interesting research job with a good salary, I would say yes.

Although she said she would be content in either industry or academia, she did not want to be disappointed if her choice did not materialize. Keeping her options open, for now, was her current strategy.

Conversely, some participants' were in the process of renegotiating their career goals after experiencing what they perceived as constraints in the doctoral program.

I was thinking about being a professor before I came to Canada, because I like research and I thought school [would] give the most flexibility as a professor. But the problem is I don't want to go back to [Asian country] to be a professor because they get very low payment, like it's really unfair. But then when I look at young professors in our lab, I feel it's really a tough job. They are so busy and I feel even if I want to, I feel my health is not up to it. That's the main concern these days I realize. I also work hard and then I get sick. And then I have to stop for a few days. ... So I find that maybe that my physical limit- that I just can't do so much. That's why now I change my mind, I would think about working probably in a big company... If you work there in the future, then you really just hold on to the research part. You don't have to deal with all the technical stuff. And that's the thing I like so I can really make use of what I know, do what I want to do. That's the reason why I think I wanted to get a PhD, so that I can show that I'm special, [my] focus on things. So

> that's what I'm thinking now. In the long run maybe I would also try to maybe change a little bit my career later. I don't know, maybe, I was thinking about some other fields I have interest in which has nothing to do with engineering.

Having to do both academic teaching and research in a lab was thought to be too demanding on this participant's health. Only after participating in this environment did she realize that perhaps working in industry may be better suited to her limitations. Becoming disillusioned with a research lab and the process of 'becoming a doctoral engineer', another participant was in the process of questioning her future prospects.

> I really don't know. That is something that has just over the past couple of years become less and less defined and less and less clear. Umh, I was really disillusioned with my project and with my prof and with things that were going on about a year ago. And well, even six months ago and I basically decided not to look too far just because I found it really hard to get excited about doing what I was doing which made it so much harder to want to finish ... I decided I should focus on my immediate goal of finishing and then think about the rest of it after that ...Working on low cost prosthetics for land mine victims in third world countries, that was what I wanted to do. I had all the [brochures] on organizations when I was coming out of undergrad and I was really excited about working on things like that but there was just no opportunity when I started my master's and again when I started my PhD actually... And I said we [she and fiancé] will just have to start our own company kind of half jokingly and at the same time thinking, hmh-how do we do this? So, I am feeling a little more excited about that prospect and about having more allies in a way and perhaps the possibility of creating a niche that if it doesn't already exist the possibility of create something that is right for us.

Returning to her initial intention for becoming an engineer, that of helping people, she reported feeling more excited about her future in engineering. She also considered the possibility of applying for a teaching position.

> But yeah as far as 10 years from now I don't see myself in industry to be honest. I would like to consider teaching I don't know if that would be at the university level or in public schools. Umh, but I am kind of disillusioned [laugh] with academics now but if I do come back to it I would like to have a really firm grasp of what is expected and required in industry.

This participant wanted to experience and understand the requirements of industry before teaching engineering students. Similarly, another participant spoke of the tensions between the political climate of many universities and her research interests.

> I have been wrestling with that one for a while. Umh, I know I want to do research. I am not so sure that I want to go into the university environment. And maybe it is just my experience at [this university]. Umh because I see an awful lot of 'politicking'. I see how much time people spend arguing with administration, petty fighting over lab space, begging for money. In the university setting, I am a little disillusioned. However, I don't know if I will be able to do the type of research I would like to do in industry. And so, unfortunately I have really high ideals for what a professor should be. I think that for me to finish this in two years and to be [thirty-something] and have had [approx. ten] years of industry experience to me doesn't seem enough.

Another participant considered her future and engineering goals as follows

> I was just asking myself this last week. I'll be honest. I have pretty high goals. I'll tell you

> what I was doing. I was trying to figure out what I wanted to do with my life. What sort of things I think would be sort of cool things to do. Because I really like to organize things, I'm not so sure that I like doing-- well I like doing the engineering part of design but I like the side of organization and I like supervising the students and stuff like that, supervising people. Well I kind of thought that I would like to be the dean of engineering, yeah so that is one of the things. The other goal a few years down the road would be the president of the university. I don't know, you see the thing is that- the whole problem with all these career goals is that I have no idea how to get there. Of course, the other one is that I'm the chief researcher at some industry but again I really don't know. I was trying to write down how to get there. I think the president of the university has an MBA somewhere along the line and probably maybe have to be a dean and maybe a place rector or something; I don't even know what they do. I really like organizing things so I would like to be a manager type.

This participant considered the tasks she liked to do and their relationships to the job 'titles' she had been considering. Interestingly, she does not know the exact job description or how to attain these goals, - a situation similar to her initial description of selecting engineering.

Personal life goals.

Most doctoral engineers reported that they lived 'unconventional' lives. These women did not only focus on their doctoral research, but also experienced a tension between societal and engineering role expectations.

One participant thought academia was great for women but acknowledged that the long work hours may negatively affect family life.

> So, still I think for a woman, if you are asking for a woman engineer, for academic life I think it is wonderful. Still you have to work at night and on the weekends, but the stress is still low. You don't have a boss on top of you, to tell you to do things, you are totally free, you do whatever you want. You teach however you want to do it. So, the stress is low that is one thing. So I think it shouldn't really affect any female engineers that choose to do academic work. Their family life shouldn't be affected. That is what I think.

She was not aware of this commitment as an undergraduate student.

> Well, it is hard to say when you are an undergrad. When I was an undergrad I never thought of family life. [laugh] You don't really make your plans on your future family life, I never thought of it. But ugh, I think it also depends on the person who you are sharing your life with- if they are understanding. Like I don't think it is going to be an issue for us- to work extended hours or to go for business- conferences and things. I don't think it will be an issue for my husband and me.

Choosing a supportive and understanding partner was one influence that this participant considered as salient. Since she married a fellow PhD candidate [now faculty member] she was confident that their 'partnership' would work as they have already negotiated their work/family lives.

When contemplating having children, she pondered whether she could stay at home and be a 'traditional' mother for any length of time. Although not an immediate concern due to her relatively young age, the pressure to have children has been lessened because her parents already have grandchildren in the family.

> In 10 years, I don't know if I will have a family but I do want to have children but I don't know if I am going to. My sister had a baby recently so that has put off any pressure that I

> might have perceived of having children any time soon. So, at 25 I figure I have got 10 years where I can say either there isn't going to be children or there is going to be children. So, I am not sure-I am not 100% sure if I am going to be a parent. I might think about foster kids or adoption later on. I don't know if professional engineering does like in the workplace but academia certainly lends itself to having, I think, a family. Because the work hours are so flexible that you can work things around- I know lots of people who are parents that- you can do the from 8 am to 8 pm, twelve hour day as an academic ... but you can burn yourself out trying to become the super prof, working 12 hour days and I have seen it and not know your kids, or you can be a person who takes advantage of the fact that you only have to be in school at certain hours or a certain number of hours a week. And set your office hours and do your research-when you can make time to do your research. It is much more flexible- it is even more flexible than being a teacher.

Interestingly, some doctoral women engineers made personal decisions despite the environmental pressures. They are following their own paths.

Role Models/Mentors

'Having' and 'being' role models constitute identity building blocks. Role models and mentors were both identification figures and examples of strength for some doctoral women. Although not all the role models mentioned were engineers, they nevertheless modeled creativity and perseverance. Women who reported having role models/mentors also spoke of wanting to be one for others.

'Having' a role model or mentor.

When considering participants' non-traditional choices of pursuing a career in engineering, recognizing the influence of role models was salient

> I moved around a lot when I was a kid so I think the closest thing to a role model, the person I had as a role model was my aunt, my mother's sister. She is very independent, she went back and got a commerce degree when she was 35 and did it all through night school and spoke her own mind and was a strong person. So, from a personality point of view she was a role model. But as far as science and technology goes, no- no one.

Although this participant did not have a mentor to guide her through the process of becoming an engineer, independence and drive were modeled for her. Similarly, another participant remembered her grandmothers as being creative and solving problems.

> I think I realize too that neither of my grandmothers could have been engineers that [they] didn't have the same opportunities that I have. And my grandmother, my maternal grandmother especially, she was always fixing things. And just thought nothing of- if it was broken she would take it apart and figure out what was wrong with it and fix it. And she never thought of herself as an engineer or good at math or anything like that. And she was always very creative too and designing clothes and figuring out how much material. So, I want to finish my PhD in honor of them. And I always thought I would dedicate my dissertation to them because I always thought they were really two of the major influences in encouraging me and showing me I could do whatever I wanted to do.

Acknowledging the lack of opportunity for her grandmothers' made this engineer want to dedicate her dissertation to them. Their encouragement not only consisted of words but was an exemplar that she could achieve whatever she set her mind to. Another participant remembered women engineering professors as powerful examples.

If I go back to [undergrad university]–I felt it was pretty women friendly university. But then if you look back, we really only had 2 or 3 female profs which may be a lot more than most people, but it was still a minority of women professors. I guess too because I'm involved with the WISE organization in [current city], so I know a lot of women in academia and women professors so to me there actually seems to be quite a few. I can't say that I've actually sat down and talked to a lot of them and talked to them about how they got to where they are. Or things like that. I have talked to a few. [My advisor] invites me to lunches and stuff. I was actually invited to one last year where it was the university professors in her department and they were just discussing about what they liked about their job and what they didn't and the difficulties of getting tenure. And that one of the profs really liked teaching and she always got great reviews from her students, but she wasn't able to get tenure because she hadn't had as many grad students and had as many papers published but she was a great professor, and talked about the frustration of that. I really haven't used any of my networking to find all this information out yet.

Seeking out a woman advisor for both graduate degrees allowed this doctoral student to see and experience closely a woman's perspective of 'doing' engineering. In addition, participating in the local WISE group, as well as attending functions as a colleague with her advisor encouraged this participant to see the power of networking within academia.

'Being' a role model.

The importance of being a role model for other females was an identity marker.

But here the female students they really like to see, like PhD students, they are not used to – I am not TAing right now, but I used to 2 years ago and did some lecture too. And the female students, and there were only a few in my class, they were happy to see me. And

> they were asking me questions, why I chose to do grad work. I think I was a real role model or something but they were happy to see a female in the department.

Another participant acknowledged being a guide and role model for another student in her discipline.

> Ugh, that is very flattering but I guess I am one of the-we know very few other PhD candidates, so it is kind of, perhaps in a way I kind of played a mentoring role to her because I had been through what she was sort of going through with her master's.

The notion of being 'only one' of a few doctoral women engineering led some participants to encourage more females to continue with science. This participant acted as a sounding board and guide and hoped to provide support similar to what she received as a young girl.

> I sort of always wanted to see myself as a role model for my cousins- you know you can do anything. But I am afraid that in trying to do everything-some of them kind of feel- this is what I have to follow? So. I don't think I have totally succeeded in that. Umh, I don't know. Umh, I guess it made a difference growing up believing I could do whatever I wanted, and that I didn't have any boundaries. Umh, and I guess seeing some of my cousins growing up and saying "I just can't do math". And wondering what do you mean 'can't do math'? There has got to be some way that you can understand it, maybe it has just not been explained to you right. So that's, that is where the role model thing and the fact that my grandmothers were both strong role models in their independence ugh, encouraging me to do whatever I wanted.

Although she hoped to be a role model similar to her grandmothers, she questioned what she had actually modeled for her cousins. The notion of accomplishing a great deal, that is, her doctorate in engineering, may actually 'set the bar too high' and discourage the very people she wanted to encourage.

Socializing & Intimidation

In their relationships with acquaintances, more specifically those outside of the engineering field, woman engineers reported feeling strange or weird, while their audience behaved as if they were intimidating. One participant was displeased when people expected her to be good at everything.

> Like how many times have I played pool and I 'suck' at pool. And somebody will say, how come you can't play pool don't you have a physics degree? I am like yes, that is called quantum mechanical theory and basic dynamics and this is the real world. Like the two do not -that happens to me all the time. Like everybody expects because you are a PhD student you are expected to be the next walking genius and you are not.

The response of people with less formal education tended to make the participants feel a lot 'different'. Conversely, educated people might feel threatened by the competition; that is the level of difficulty associated with doctoral engineering.

> People's reactions are not always favorable. They expect you to turn around and all of the sudden have some big horn come out your back. It can be a little bit odd. Or the other end of it is if you end up a cocktail party with a bunch of professionals who are all like stroking their own feathers, their response to you isn't any better because it is a little intimidating- they are intimidated by what you do. You bring it down a notch I mean. There is that

> expectation ...about of knowing- or being a general expert. Or worse yet, I am supposed to know everything there is to know about electricity and be able to fix your toaster. Sorry. If it is not working, throw it out.

The notion of being 'odd' or 'different' resonated with most of the doctoral women. Intimidating people while socializing was upsetting for the following participant.

> I hate it! I really have trouble with that. To the point... it's interesting that you bring that up. Because just last week I had my '10 year reunion' from high school so obviously that was the question of the evening. And I say I'm a PhD student and people are like WOW, and that is SO incredible and you are so courageous. And it's like any other work. First you do your Bachelors, then you do a Masters, and then you do a PhD. People really look at you like you are an alien. Like you are one of 'those' people and I don't feel so bright personally. So people are really intimidated.

She did not see herself as exceptionally smart just hardworking and persevering. It appeared she, like the other women, did not know how to handle these social situations.

The 'performance' of one's gender/sex in social situations profoundly affected how they saw themselves and what they 'do', that is, doctoral research in engineering.

> Also, I found in social situations, especially in rural parts of Canada, I am assuming that other rural parts of Canada are similar to [this province] in that you go to a party and the women go to one room and the guys go to another. And so generally I found I didn't have a lot in common with the average women in that environment. So, I would go in with the guys and some of them were pretty outright making it clear that I wasn't welcome. They wouldn't actually say anything to me but I would get the glares, I would be ignored, you know trying to add to the conversation – that is a little outright. And then some of them

> actually talk technical stuff and I can actually add to the conversation and you can kind of see some squirming in the seats. Because I think the guys have a tendency to bullshit. Let's put it that way. You know, talk a little more of the jargon than they actually know. And then when there is someone there that can actually call them on it, and is not afraid to- and especially being female, I think it is a little intimidating.

Having a woman intrude on your masculine space and then expose your lack of knowledge, or 'talk' chosen to exclude the intruder, was thought to be intimidating by this engineer. Another participant thought that her choice was weird, off-track and to a certain extent, intimidating.

> Although it's true that some people thought that was very weird, it's true that officially when I was in high school some people would say: well you have good grades; how come you don't go in medicine, for instance. And you know, sometimes it's really weird for them a girl in physics and those kind of very abstract kind of fields. And I think when I was in astronomy and I told people that I was going into engineering, some people were kind of maybe disappointed in some sense, because I guess they probably understood a little better what does an astronomer with respect to what does a researcher in engineering because it's a very technical thing in that you can't explain. They were supportive but I guess you could see in their eyes that: wow! That's weird!

Her not following a traditionally feminine path allocated for women of high ability seemed strange for some people. The notion of being 'weird' and intimidating others were salient themes and perhaps one reason why many doctoral women reported feeling isolated and 'different'. The themes discussed in these four chapters of findings will next be related to the literature review and an interpretative frame.

CHAPTER EIGHT

DISCUSSION

The participants' stories emerged as a 'reconstruction' of how they came to be doctoral engineers. From a sociocultural perspective, the tension of participating in social communities was an indicator of mediated action. "From this perspective, speaking, thinking, and other forms of human action are taken to involve an inherent, irreducible tension between agent and cultural tools such as language and narrative texts" (Werstch, 2002, p.6). The main tensions, or units of analysis, that emerged from the doctoral women's narratives are first discussed. Then, affordances and constraints are presented as they are related to the four research questions. Finally, the composite sketches of doctoral engineers are described along with a synthesis statement on this study.

Tension

The participants recounting their engineering experiences were fraught with tensions and contradictions. Many women started a particular 'theme' of their story by recalling the positive aspects of their experience but this description included contradictory statements that illustrated negative and differential treatment if not instances of exclusion. Fletcher's (1999) notion of women performing 'relational maintenance' was apparent, that is, their taking on the responsibility of keeping the peace within their work environments even when their remembrances comprised a parallel statement of this reality.

The main tensions which emerged from the doctoral women's stories were: 'Altruistic motives versus Elitism', that is, how the women's motivation for choosing and staying in engineering collided with the notion of superiority within the culture of engineering; 'Competence' as a measure of engineering ability; 'Exclusion' versus becoming one of the guys; and, 'Sameness versus difference'. These tensions inter-connected the context of their remembrances.

Altruistic Motive: Choice of Engineering/Elitism

In discovering the 'plot that links the elements' of the stories in my narrative analysis, I was drawn to the recounting of altruistic motives of most of the women engineers (Polkinghorne, 1995). Although the ages and educational levels of my participants differed when their epiphany took place, the women remembered knowing that they "wanted to help people" or they recognized their need to "benefit society". While many studies reported females choosing science and future careers based on wanting to help people, most girls chose paths more in keeping with traditional sex-roles such as teaching and nursing (Subotnik & Arnold, 1997; Kerr, 1995) while some females were able to combine their outstanding abilities in science with stereotypical notions and sex-roles for women such as pediatric doctors, biologists, etc (Bandura, 1997; Wood, 1999). Doctoral women engineers' altruistic motives were novel in their 'vision' of engineering as a venue for helping society, and at the same time, reducing the influence of these stereotypical sex-roles or not allowing them to alter their career decisions. Interestingly, many women engineers made last minutes decisions to select engineering programs at the undergraduate level and were not knowledgeable of engineering as a program or a profession. Moreover, once the choice of engineering was made they were committed to their path. While deterrents in the learning environment and culture of engineering were reported, they maintained focus in their engineering studies. Unlike the women in Holland and Eisenhart's study (1990), the career interests of the doctoral women remained central and not marginal. The 'traditional culture of romance' and stereotypical sex-roles were reported to have some effect but more often partners shared their interest in science, and were perceived as less 'problematic' to their completing their doctoral studies.

The altruistic motives of some of the doctoral women were frequently in tension with the notion of superiority often promoted within the culture of engineering. The doctoral women remembered first encountering this notion of superiority during frosh week with the songs and chants that cheered, "we are the best, of the best". When examining attrition rates, Anderson (2002) found that women engineers were uncomfortable with the male dominated culture, especially the attitude of superiority and elitism. Moreover, the very public and unique traditions of frosh week, coupled with the other traditions such as the engineering jacket, iron ring, and the oath of obligation, helped set engineering apart from other university faculties. No other faculties went to such elaborate lengths to demonstrate their uniqueness. This notion of uniqueness concurred with Drybrugh's (1999) notion of 'affiliation with the profession' thought to be a 'necessary' bonding process in the culture of engineering.

The dominant population in engineering was elitist for those whose performances best reflected the 'play hard, work hard' culture of engineering (Dryburgh, 1999). They were the "kings", according to one participant. Being most popular, they also were elected to positions of authority in such hierarchies as engineering societies. They determined which engineering peers got to participate fully in the social aspects of engineering. For those males who did not live up to this elite reputation, the label 'girl' was bestowed upon them. Henwood (1998) and Hopkins (1998) also found that when masculine identities were threatened, gender differences were reasserted in order that the 'natural order of things' be restored. Therefore, those males who did not perform masculinity correctly were belittled. As well, a clear message was sent to the women. They did not belong to the 'brotherhood'; they were peripheral participants in the masculine culture of engineering. Hopkins (1998) examined the use of " 'Girl' as an allowable, non-profane substitute for 'faggot', 'homo', and 'cock-sucker', mirrors and thus reveals a common essence of these insults. It signified 'not-male', and as related to the male speaker, 'not-me'" (p.169). This and other insults suggested a failure of living up to a gendered standard of behavior and a gendered standard of identity.

Although doctoral women first remembered elitism with their peers, the classroom environment also incubated this notion of superiority. Professors not only told them that they were the smartest, but also demanded that they accomplish tasks independently. Asking for help or clarification in class was perceived as a weakness. In many instances, the person asking for help was reprimanded and humiliated. Questioning in class was appropriated as a 'performance of posturing', that is, asking a question where students could demonstrate their knowledge and competence. Most frequently, this performance was reserved for males. Only one participant reported "acting aggressive" in her research group in order "to be noticed", but not in the presence of a professor. In agreement with Dryburgh (1999), engineers, especially women, must learn to perform confidently and competently when unsure of themselves.

In addition, engineering professors were thought to affirm this notion of elitism in class when discussing salaries and levels of engineering as well as management positions. Based on data from the majority of males in engineering, entry-level salaries are high for a four-year program and promotions can be frequent (Industry Canada, 1999; CCPE, 2002). Starting salaries of women engineers to date are at par if not greater than the men, and women are usually hired first (Kemper, 1990; McIlwee & Robinson, 1992), although this gender distinction was not reported to be made by professors.

This notion of elitism in the culture of engineering overflowed into the work place. The doctoral engineer with industry experience felt that elitism in the workplace inhibited communication within the team. Although not new, teamwork is now more valued in engineering schools since industry often informs change in programs of engineering. Kemper (1990) affirmed that more emphasis was placed on teamwork and communication in American engineering schools but he made no mention of addressing 'differences' in the group, or overcoming the notion of superiority that affected the behavior of some engineers.

In summary, both in the profession of engineering and in the public, what engineers actually "do" appeared to by unclear. Elitism appeared to be a façade, an elaborate practice/reaction that may be related to engineers' non-specific job description (Dryburgh, 1999). Another rationale was the perception that the American public does not value their 'contribution to society' (Kemper, 1990), yet according to the CCPE that was not the case. The manager of communications of the CCPE asserted that the

Canadian public generally had a positive image of engineers and they were reasonably well informed about what engineers do in certain disciplines of engineering (Kowalenko, 2000b).

Competence

Competence can be seen as the 'currency' of engineering. It is highly valued and must be acquired at all costs. Doctoral women spoke of 'competence' when describing their work; competence was viewed as being able and confident to solve engineering problems, as well as gaining respect in their community. When describing some male members of work groups, the notion of 'posturing' emerged. In posturing, one asked questions in order to demonstrate one's dominance in a subject area already mastered in order to deflect attention away from those areas where one's knowledge was weak. This performance was necessary to ensure that one was thought of as being competent. Regardless of gender/sex, engineers were reported to be constantly evaluating others, as well as being evaluated on their competence. One participant talked about a woman in her work group as being incompetent because she was not doing her share of the work and asked "dumb" questions. This same participant thought that she wanted to work with more peers so that she could work out some of the questions and issues in her research and not be afraid to "ask dumb questions". The performance of one's competence can be undermined by asking questions, but that was also viewed as important to learning and problem solving. This tension between performance of competence and questioning during learning strikes at the heart of how engineers view themselves and measure others in the culture of engineering

Dryburgh (1999) also found that women engineers must learn to portray their competence to others. This portrayal of competence appeared to be quite unnatural for most women as it was not in keeping with societal gender/sex-roles. In fact, one international participant in this study who described herself as being physically small and viewed by others as 'subservient' due to cultural and gendered stereotypes, found it necessary to "act aggressive" in order to be recognized as leading the research in her group. She pondered that it was perhaps more a gender issue than a cultural stereotype. This performance of competence can be misconstrued as an attitude of elitism. While this was in keeping with Anderson's (2002) line of argument that women in engineering were uncomfortable with the culture of engineering which included an attitude of superiority, Dryburgh (1999) explicated this performance as part of 'solidarity with the profession', that is, being able to solve ill-defined problems with confidence—or at least appearing to be confident.

Exclusion vs. One of the Guys

Through the women's stories, it became apparent that many were in fact excluded from both learning and social situations. Of course, this exclusion was disguised in various ways and degrees. Classroom discourse and its related learning activities were thought to take place in phases such as authoritative discourse, internally persuasive discourse (Bakhtin, 1981), and genuine dialogue (Sidorkin, 1999). In the engineering classroom, many professors were reported to teach using long-winded lectures that were poorly understood. In this instance, the professor in authority was seldom challenged, as this would bring into question 'his' competence and 'his' power. This was in keeping with Bakhtin's (1981) 'authoritative discourse' where the knowledge 'taught' was accepted or believed on the basis of the performance of the authority figure.

When this new knowledge must be applied during group assignments, members reconstructed their understanding of this knowledge through dialogue and negotiated meaning and application. This reflected Bakhtin's (1981) second mode, or 'internally persuasive discourse' and was thought to be particularly useful in classroom settings where language and cultural differences impeded understanding lectures as the main approach to teaching. As captured in the women's statements, learning also appeared in social situations such as sporting events, drinking activities, or just over a 'bite to eat' all of which can excluded some women. If participants did not share the same interests or if the 'events' were deemed inappropriate because of gender/sex stereotypes, cultural/ religious restrictions, they were not included.

A third discourse provided the opportunity for "genuine dialogue to happen" (Sidorkin, 1999, p.136) and refered to Bakhtin's (1984) notion of carnival. Members of the group know each other informally and feel 'free' enough to openly make sense out of classroom 'talk'. This third discourse has not been given enough weight when evaluating learning environments for women. It is in these situations of informal conversations that male members decided who was competent, who had demonstrated their affiliation with the 'work hard/ play hard culture of engineering' as proposed by Dryburgh (1999). As detailed by one doctoral woman, there was a relationship difference when working in groups, "when men decide they don't like that person, they DON'T like that person".

Courses or programs often relied on group assignments, but did not take the time to explain the learning strategies or expectations such as identifying what you already know, what you need to know, and how you are going to learn it, as well as distributing the work responsibly. It was more often assumed that the members knew how to work it out amongst themselves. Participants experienced group work as a constraint, without an awareness of the inequitable societal structures comprised in their explanations. Who gets to decide who is marginal, peripheral, and dominant- or are there multiple influences at play within the complex culture of engineering?

In the classroom and in the engineering culture at large, women engineers experienced various degrees of exclusion even when judged as competent. Appropriate displays of competence, such as being awarded a doctoral scholarship often resulted in jealousy from their colleagues. Male peers questioned the scholarships obtained and this judgment sowed the 'seed of doubt' that still follows some of the women engineers. The study of Noble et al. (1999) posited that successful women still carry with them this internalized gender inferiority, questioning themselves and wondering if they are imposters; these feelings were reflected by the participants of this study. In a similar vein, women doing well threatened the 'masculinity' of some males. Some male colleagues made negative comments in order to reinstate male dominance or the 'natural order of things' (Henwood, 1998). One doctoral woman explained the sexist comments she received after comparing her higher marks with the 'guys', with the words, "he put me in my place".

Conversely, the participants were often labeled 'one of the guys'. Herein lies the tension. The males in the class often wished amongst themselves for more women to date. The doctoral women remembered having conflicted feelings towards this. On the one hand, the statement can be seen as a compliment- they are competent enough to be considered 'one of the guys'. On the other hand, they questioned why they are not seen as a 'woman', as a dating partner. 'Woman' and 'engineer' were seen as polar opposites. To be one was to deny the other (Dryburgh, 1999; Henwood, 1998).

According to Butler (1999) this denial of 'who they are', in which "persons only become intelligible through becoming gendered", has caused the women to question their gender performance and its relation to heterosexuality (p.22).

Interestingly, most doctoral women ended up dating other engineers, so obviously some men made the mental leap and disregarded this 'gendered dichotomy'. One participant recalled one of her male engineering friends thinking it was too difficult to date women engineers because they were too argumentative and competitive. Apparently, women need to maneuver through both their public and private 'selves' and through the societal expectations associated with each.

Sameness versus Difference

While 'sameness' and 'difference' appeared to be contradictory terms, they reflected the ongoing struggle for neophyte engineers becoming affiliates within the profession. It appeared that 'sameness' and 'affiliation' had similar meanings in the culture of engineering. 'Difference', on the other hand, was more fluid; less defined, predictable, or accepted. In the narratives of the doctoral women, 'differences' were expressed in relation to 'Sex-roles' and other related differences such as 'Ethnic/cultural differences' and 'Language', and lastly, 'Sexuality'. Each of these 'differences' are discussed in the context that they emerged in the women's talk of how they came to be doctoral engineers.

The notion of 'sameness' was reported in various contexts by most doctoral women. Common characteristics that seemed to be reinforced in the university culture included perseverance, patience, self-confidence, and time management skills. Some doctoral women even felt that a dress or appearance 'code' characterized all engineers, male and female. The level of difficulty of the engineering workload left little time to be spent on appearance. Lab work required that comfortable, worn clothes be chosen. This notion of a 'certain look' in the 'work hard' culture of engineering was in keeping with Dryburgh (1999) who asserted that compliance with this dress code, if you will, also demonstrated 'solidarity with the profession'. Interestingly, the importance of the choice of clothing was most strongly voiced by international students where this was perhaps, one of their only shared 'symbols' of belonging in engineering. One doctoral woman attended an undergraduate program where the "sameness of students" encouraged a strong bonding of their class because students were of a similar age, nationality, educational experiences, and most were living in residence. An affiliation with the 'play hard' and 'work hard' culture of engineering prevailed (Dryburgh, 1999).

In the culture of engineering, certain shared experiences bonded engineering students together, for example the learning environment, their treatment by professors, and the affiliation with the profession which was expressed in the symbols, history, and traditions of the practice. Many doctoral women spoke of poor teaching and negative treatment coming from their professors. This 'shared culture of hardship' both in relation to treatment received and the difficult workload strengthened their relationships (Dryburgh, 1999). Other shared experiences for Canadian engineers were the engineering jacket as a symbol of affiliation with the 'work hard' culture. Only after completing the first year of the program was the leather jacket allowed to be worn. This was particularly important at one university where the beating of the engineering jackets on the ground, to intimidate new frosh, was essential to belonging, to passing on the traditions. Another symbol of 'solidarity with the profession', the iron ring, transmitted the traditions and history and was perhaps, the last rite of passage for the engineering student. The ring was a constant reminder of the engineers' obligation to perform well, that is, with competence, diligence, and confidence (Dryburgh, 1999). Moreover, the 'common oath of obligation', commissioned by Engineering Institute of Canada in 1922, along with its formal [secret] ceremony was crafted by none other than Rudyard Kipling (Corporation of the Seven Wardens, 1991). As part of the ceremony, 'the newly qualified engineer' recited the common oath to a more experienced engineer- a type of apprenticeship into the 'brotherhood' of engineering as participants called it. All of these symbols of traditions acted as a bond, a sameness of identification with the culture of engineering.

Although sameness was celebrated, differences abound in faculties of engineering and this created tension. Many doctoral women chose alternate paths before selecting engineering. With the exception of one, all the other participants completed their undergraduate degrees at different universities perhaps giving them a diverse perspective of engineering education and preferred practices. A few of the women have completed consecutive degrees in faculties of engineering, while others reported leaving engineering during their Master's degree for more applied research in science. Furthermore, some of the women were new to faculties of engineering, having arrived with science degrees from other departments.

Thus, the notion of 'sameness' was important in engineering. Common characteristics, a similar dress code, and other symbols of 'sameness' identified those engineers who have affiliated with the profession. Even the 'shared culture of hardship' acted as a method of bonding engineering classes together. Unfortunately, sameness as an ideology failed and some 'differences' were more easily overlooked than others. The following sub-themes are fraught with tension and emerged when considering 'differences': Sex-roles, Ethnic/cultural difference and language, and Sexuality in the culture of engineering.

Sex-roles and other differences.

Doctoral women reluctantly described their differential treatment with other colleagues. Some participants disclosed they were teased, and downplayed these behaviors, while others admitted being harassed or being consulted only when their contribution was essential. Some women were verbally harassed for doing well and not being a man. The gendered performances of students as well as their individual personalities affected the division of labor during group work. Some women were told what they could do, while others reported that males claimed the 'real' work for themselves and assigned to the women roles that required softer skills such as the presentation of their assignment. When the number of women in the groups increased, participants reported more sharing of the workload and enjoyed it. Not all males were prepared to handle the difference in interactional styles practiced in female dominated groups. The female groups tended to follow a less linear plan and were more 'relational' in addressing the problem to be solved as well as the needs of the group members.

Professors of engineering reminded doctoral women who were new to engineering of their outsider status, that they were not really engineers. They had not partaken in rituals and symbols, or the competence testing of the undergraduate program. They were not part of the 'brotherhood'. In fact, professors at some universities excluded doctoral women from their particular 'language of bonding' that is, swearing and cursing with their male graduate students. Other professors refused to hire women doctoral students just in case they needed heavy lifting of mechanical parts and couldn't afford to hire an assistant. Professors acted as the 'gatekeeper' of the profession by determining who was included into the culture of engineering (Dryburgh, 1999). In my study, exclusion was based on difference rather than a lack of ability. Women spoke of not wanting to be sworn at but yet "felt" the difference- they wanted to be valued for the qualities and abilities they brought to engineering, but 'difference' here meant exclusion.

The tension of feeling different, along with the subsequent differential treatment, did not occur only in the culture of engineering. Participants described being treated 'differently' in social situations when acquaintances learned of their educational/occupational choices. Most doctoral engineers attempted not to reveal this information, or tried to make engineering sound less intimidating. Only one participant proudly exclaimed her choice, but noted importantly that she used non-technical, very plain language in her description. Although all of the participants' families supported their engineering choices, not all of them understood what their daughters 'did'. In some instances, this lack of understanding caused some parents to treat their daughters a little differently. Their advanced abilities in math and science left them a little confused and awestruck. It is thought that when women choose new ways of 'being and knowing' they often feel distanced from their family and culture (Gilligan, 1993; Subotnik & Arnold, 1996).

Ethnic/Cultural difference and language.

In this study, two of the doctoral women were international students new to this country. Both of the women had completed a B. Eng. and a master's degree in their countries of origin. Each of these international women chose a different discipline of engineering and in a different province of Canada. These different choices added to the already complex web of 'difference' for international women and their experiences. The participants explained that acceptance into a doctoral engineering program for international students required that they be 'funded' by their doctoral advisor. Some universities had unions who helped regulate the amount of money and the hours worked for students who were 'soft-funded' by professors' research grants. Neither of the doctoral women were protected by graduate student unions at their universities, with one woman confiding that working for her advisor was slowing her own research. The other participant worked for a professor who had fewer students, and reported a more positive experience.

'Immigrant status' was thought to be important for both international women in order to apply for Canadian scholarships and to be able to work outside of the university. One participant in particular reported that she "kind of starved" herself until she could change her status. Both perceived their obligation to work for their advisors as a requirement that set them apart from Canadian engineering students. The extra burden of work also fed into stereotyping some ethnic minorities as 'hard workers'. In fact this stereotype reminds us of Dryburgh's (1999) 'work hard' culture of engineering and perhaps explains why some ethnic minorities are viewed as fitting in better with the culture of engineering (Grandy, 1997;1998; Jones, 1999). These international women can be considered as 'voluntary immigrants' in that they have moved to Canada in search of greater educational, and eventually, economic gain (Ogbu, 1987). The two participants spoke of many master's Chinese students in their departments. One participant revealed not liking engineering and knew other international women who chose engineering for practical reasons related to immigration. She thought that many international students only got student visas if they chose disciplines of engineering that Canadian students did not want. Moreover, landed immigrant status, with the possibility of citizenship, was usually obtained with a doctoral degree. For these reasons, international women who also pursued doctoral degrees in engineering can be viewed as having multiple differences and were at risk of marginalized treatment.

Language also exemplified ethnic difference in engineering. Doctoral women reported that Chinese students worked and socialized between themselves because of the language barriers. They felt understood, that it was more comfortable to talk and learn in a 'native' language. It appeared that gender was 'forgiven' when working in groups of engineering students who were ethnically/culturally diverse. The sharing of a common language and similar experiences took priority, instead of enacting sex roles, and was beneficial in order to complete and understand the difficult subject matter of engineering. One international student added that she preferred talking to nonnative English speakers because they talked slower and were more patient in answering her questions and providing help. While these engineers recalled minority students only socializing among themselves, others remembered colleagues purposely working with English speaking students because they wanted to learn the language and customs of their new environment. Thus, culture and language can be seen as barriers to be overcome in order to obtain their long-term goals for employment (Ogbu, 1992).

For our international participants, the tension of being 'different' in a culture that expects 'sameness' multiply marginalizes them. They were excluded but they were not aware of it. They felt that they were treated fairly but superficially so; they were included when their expertise was needed. Most of the 'Canadian' doctoral engineering women described experiencing sexist remarks and harassment, being invited to 'inappropriate' events or activities involving alcohol, as well as other types of negative treatment. It appeared that the international women in this study were viewed as 'very' different and were therefore treated in a 'special' way. They were neither seen as 'dating material' nor 'one of the guys'. And it was interesting that they did not even recognize this differential treatment, perhaps it was an attempt at self-preservation.

Some participants spoke of international students, both male and female as not participating in the "normal university social scene", that is, they did not participate in what Dryburgh's (1999) named the 'party hard' culture of engineering. Even when socializing with other women engineering students, differences in language and cultural background prevented full participation in the 'party hard' activities that usually included pubs, alcohol, and even the choice of foods shared. Some participants spoke of trying to negotiate the difference by hosting multicultural potlucks, thus allowing for socializing but without the usual emphasis on alcohol. In sum, religious customs and [strict] gender roles expected of women pretty much restricted their participation in the dominant culture of engineering.

Sexuality: Difference but how different?

Doctoral women who attended predominately white, higher SES universities also reported knowing GLBT engineering students and university professors. Engineering faculties in very 'traditional/conservative' regions of Canada, along with universities known for the large multicultural populations, reported "never" considering anyone but heterosexuals attending engineering programs. This notion of 'assumed heterosexuality' in engineering was noted by Henwood (1998), Hoptkins (1998), and Remlinger (1995) and reflects an ideology that is seldom questioned. Doctoral engineers who confided having friends who were GLBT also spoke of homophobia in their institutions. During her master's program, one participant worked in a research group with a colleague who "had a girlfriend". Although this lab group was mostly all-female and very close, this relationship was not discussed openly. This colleague had not 'come-out' publicly and was very private; so much so, she was harassed by the only male in the lab group who had no idea of her sexual orientation, assuming she was heterosexual. This same doctoral engineer affirmed knowing bi-sexual women as well, exemplifying the 'performed difference' at this university and adding, "women who are in engineering are not your average women anyways". Another participant recalled her roommate's 'coming-out' to the engineering society where it appeared this 'difference' was overlooked. Interestingly he was a male graduate student who, therefore, had already successfully demonstrated his affiliation with the 'work hard and party hard' culture of engineering (Dryburgh, 1999). It is not clear what response he would have received from the engineering society if he were 'multiply-marginalized', that is, belonging to another culture or being a woman.

In summary, the tensions experienced by the doctoral engineers were very intertwined and linked to complex relationships that were regulated by cultural, institutional, and historical circumstances and influences.

Tensions and the Four Research Questions

We will now address how these tensions helped solve the four research questions of the dissertation. The tensions of participating in social communities contained both 'affordances', that is positive aspects, and negative instances called 'constraints' (Wertsch, 2002). In some instances, participants chose a more neutral position in recounting their experiences. Verbal explanations or 'texts' were learned during their participation in the culture of engineering, and then appropriated. The texts or accounts that were considered personally useful for the doctoral engineers were used as a way of making sense of 'who they are' or 'who they are becoming'. Moreover, not all participants fully appropriated what they learned; in some cases it may not be relevant to 'who' they are or the identity they wish to adopt. This is referred to as 'resistance' and is thought to be the opposite of appropriation (Wertsch, 2002).

Affordances

RQ1 What sociocultural influences affect female PhD students' decisions to participate in engineering?

The family and home provided each participant with the nurturance of their abilities. All of the women engineers lived with both of their parents while growing up. The families' Socioeconomic Status [SES] cannot be ignored as most were of middle-class origins. The fathers' occupations varied: three were 'other' professionals, followed by two engineers, and two manual laborers. Interestingly, the vast majority of mothers were 'full-time moms' that is, their main occupation was looking after their families. Two of the mothers were also employed outside of the home; one in a traditionally female profession while the other was an engineer. Most participants spoke of their mothers as encouraging their interest in science and supporting their choices. In addition, many of the women engineers whose mothers did not work outside of the home, had women role models or mentors who modeled independence and persistence. Other family members were also engineers, and provided at least a basic knowledge of engineering as an occupational choice, but not always viewed in a positive light. Contrary to some previous research (Bussey & Bandura, 1999; Pajares, 2002; Zelden & Pajares, 2000), the doctoral women were encouraged to be independent and adventurous. In sum, all parents valued their daughters' education and supported their interests in science and engineering.

All of the participants excelled in school and tended to be 'well-rounded' students. Many attended special schools or programs that fostered their science and math skills. Teachers encouraged their abilities and offered public praise. None of the participants reported negative treatment by their teachers during their public schooling experience. The doctoral women's remembrance of peers was minimal, neither as a great help or as a hindrance; this finding is inconsistent with previous studies in which high ability females had to make many adjustments in the classroom (Evans, 1991; Kerr, 1994; Leroux, 1997; Tavris, 1991). Extra curricular activities at school were also mentioned as enriching their self-confidence, even if not directly related to science. Those participants' whose schools were lacking in stimulating activities received guidance or 'alternative' science instruction from teachers and/or parents; this finding is consistent with a study of Wood (1999). All doctoral engineers were successful in math and science. Similarly in another study, this academic success was described first as a career interest in science and engineering which was thought to be an issue of self-efficacy. The participants' self-efficacy was predicted by previous academic performances and subsequently related to parents' income level (O'Brien et al., 1999). In other words, these Canadian doctoral engineers were white, middle class females who were not burdened with 'multicultural issues' or other 'differences' in addition to their gender (Cassidy, Lord, & Mandell, 1998; Giroux & McLaren, 1994; Jones, 1999; Noble et al., 1999). Overall, these participants were very bright, resilient women who reported experiencing a positive home life in addition to liking and doing well in school.

In sum, the participants' sociocultural milieu, including background experiences and individual predispositions, positively influenced their perceptions and opportunities of high achievement (Astin, & Leland, 1991; Butler, 1999; Maccoby, 1999; Spargo, 1999). The next research question will examine more specifically the participation and learning experiences in universities in both Canada and abroad.

RQ2 What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering?

The participants did reflect on the procedures that promoted participation and learning. Engineering pedagogy was deemed important, especially when flexibility of the structure of the lessons/curriculum, type of projects, positive learning strategies, and interdisciplinary work groups were present. Another salient theme concerns research groups and how interdisciplinary teams added a new perspective to participation within the lab group community, along with discussing how this affects positive workspaces for women.

Pedagogical practices.

Doctoral women were able to interpret these pedagogical practices that were beneficial to their learning. Classes that had a flexible structure, that is, where graduate students had the opportunity to teach each other and relate the concepts to personal/prior experiences, were high on their list of positive learning opportunities. The positive pedagogical practices can be related to proven sociocultural strategies such as the zone of proximal development (Vygotsky, 1978), scaffolding (Bruner, 1996; Harper & Hedberg, 1997), the apprenticeship model of teaching (Lave & Wenger, 1991), and the discussion and critique of scientific concepts (Bereiter, 1999; Driver, 1995; Guzettti & Williams, 1996; Kelly & Chen, 1999). These strategies provided an opportunity for more knowledgeable others to assist the novices, where new concepts challenged old ways of knowing or folk theories of science, and where knowledge was revisited with more complexity. The doctoral women valued the respect of their learning styles and interests, as well as enhancing their critical thinking skills in course delivery. Assessing learning styles with undergraduate engineering students has become important in Canada (Woods, 2003), Australia (Armarego, 2002; Fowler et al., 2001a), and the US (Morgan & Rinehart, 1997; Reklaitis, 1999; Rinehart & Watson, 2002).

The participants emphasized the importance of well-planned and stimulating group work/assignments. Projects that were self-chosen, challenging, (Middleton et al., 1992; Wood, 1999; 2002) and based on 'real world problems' were thought to be most beneficial to learning (Armarego, 2002; Hannafin, 1997; Proulx, 2002). The doctoral women stressed the importance of choosing their own group members so that their needs were addressed, and their abilities recognized and valued (Fowler, et al., 2000; 2001b; Lee et al., 2000; Van Driel et al., 1997; Wood, 1999).

Problem based learning [PBL] was particularly held in high regard, as it allowed the engineers to practice what would be expected of them in their future workplace-solving ill-defined or 'wicked problems' (Armerego, 2002). Research related to improving instruction in professional disciplines, where problems needed to be solved in teams and where communication was emphasized (Armarego, 2002; Hannafin, 1997, Savin-Baden, 2000; Proulx, 2002; Woods, 2003) as well as ethical dilemmas (Lynch & Kline, 2000) were seen as salient. Incorporating 'real life examples' into lectures and questions was another way of keeping students interested and motivated. The 'timing of examples' and 'just in time concepts' (Proulx, 2002) are in keeping with constructivist strategies similar to scaffolding (Bruner, 1996), where information is revisited with greater complexity. The zone of proximal development (Vygotsky, 1978) was another pertinent constructivist strategy in that, the students were not overloaded with information that was not relevant to what they were currently learning or beyond their understanding/application. Participants thought the inclusions of these teaching strategies added to their depth of learning. Similar to adolescent girls enjoying guest speakers in their science classrooms (Wood, 1999: 2001), doctoral women preferred discussions with expert speakers and actual clients in industry. This added relevance to the problem and knowledge being learned.

Interdisciplinary courses, as well as working with students from different disciplines of engineering allowed the doctoral women to appreciate different ways of defining and solving problems. This alleviated, in some instances, the notion of superiority, and perhaps encouraged communication among engineers which was a 'skill set' highly prized in the actual industry setting (Duncan, 2000; King et al., 1999; Mayberry, Welling, Phillips, Radeloff, & Ress, 1999).

Research groups.

Another affordance highlighted by the doctoral women engineers was learning in interdisciplinary research groups. While not all aspects of interdisciplinary work were seen as positive, the women generally thought this method of research reflected many of the positive pedagogical practices seen in interdisciplinary engineering classrooms. It favored communication and viewing problems from different theoretical and applied aspects (Duncan, 2000). Participants focused almost exclusively on the work to be done and not on relationship building. Each woman participant had a specific role to play in the solving of problems and they viewed their contribution only on this basis. A study of Walker (2000) confirmed that male engineers did not verbally admit to the extent of women's participation and contribution to group problem solving.

Criticism and questioning by the interdisciplinary research group members was part of the problem solving procedure and was seen as ultimately beneficial, since doctoral candidates eventually have to experience a multi-perspective jury during their defense. Having the opportunity to prepare and defend answers, and improve presentation practices increased their overall confidence. The notion of women benefiting from additional preparation was similar to Fox (2003) where women thesis advisors had extra requirements for women graduate students in order to increase their 'range of inter-actional capacities', so they would be groomed for their 'competence testing' once they proceeded to faculty or industrial work environments.

In the lab research environments, participants felt that their increased presence was conducive to learning and active participation. Having more women increased the degree of 'relational activity', or at least the value of 'relational work' was seen as adding to the environment and was more equally distributed amongst members. One participant recalled working in a research group that was predominantly women, and where the only man could not deal with their interactional style and emphasis on relational activity. Fletcher (1994; 1999) and Walker (2000) found when there are few women, this relational work is viewed from an essentialist perspective, that is, it is natural and expected that the woman deal with the emotional nurturance of the group. Moreover, since this is viewed as her natural role, it is not reciprocated or valued.

To recapitulate, pedagogical practices and research groups are viewed as conducive to participation and learning in engineering when they are student-centered, practical and related to real world problems. In addition, relational activity must be valued and more equally distributed amongst the members of the group in order to address improved learning.

RQ3 What do female PhD students perceive as the 'unofficial' ways of continuing the history and traditions of the profession in faculties of engineering?

Informal practices adopted by the engineers to align themselves with the profession were seen as overwhelmingly masculine. The voiced remembrances of the participants were recounted as constraints and discussed in detail further in this chapter.

RQ4 How does the female PhD student's non/participation in engineering affect their identities?

Some of the doctoral women viewed their overall participation in engineering education as positive, while others remained more neutral in their descriptions, and yet still other women recounted many negative facets to their treatment that has left them unsure of themselves in relation to their occupational choices. The affordances that some women addressed focused on mentorship and role modeling, and how those positive experiences uncovered a desire to pursue these roles.

Many spoke of female members of their family as models of independence, perseverance, innovation and creativity. Other doctoral engineers spoke of older females who encouraged their interest in science by demonstrating its worthiness and relevance.

Later during their educational path, only one doctoral engineer had the privilege to have a woman doctoral advisor as role model and mentor, in and as provider of important networking opportunities. The pro-active modeling of what is possible for women in engineering, along with the introduction to networking channels was supported by many researchers (Duck-Sherwood, 1994; Emerson, et al. 2002; Ennett, 2002; Fox, 2003; Henwood, 1996:1998; Walker, 2000). This ideal scenario is indeed rare. Riordan, Manning, Daniel, Murray, Thompson, & Cummins (1999) suggest that establishing 'portable mentors' for women engineers because 'in house' women engineering professors are not always available.

In summary, the doctoral women recounted many affordances in their narrative descriptions. The sociocultural influences, as well as the pedagogical practices and lab research groups, were seen in mostly a positive light by the participants. We will now examine the constraints in relation to the same four research questions. I would like to remind the reader that some of the constraints have already been discussed more in-depth in relation to their tensions in the first section of this chapter.

Constraints

RQ1 What sociocultural influences affect female PhD students' decisions to participate in engineering?

The doctoral engineers recalled very few negative influences. The general complaint in their early years of schooling was the lack of individualized instruction or advanced science programs. Some teachers were unable to meet the needs of these bright students but luckily, many of the participants' parents met the challenge of providing their daughters with either additional science instruction or another type of extracurricular activity.

The women's lack of information concerning engineering as a university program and a profession was considered a constraint. The women reported choosing engineering for two main reasons; their strength at math and science, and engineering as a practical choice related to the time invested in obtaining the degree and being subsequently hired by industry. Most other aspects of engineering remained unknown. Perhaps, as some of the women suggested, this was a good thing. Had they known the challenges of participating in the culture of engineering, they may have opted for another orientation. WISE programs' emphasis on encouraging female high school students to make more informed choices has been criticized as the answer to women's low enrollment in engineering. Without structural changes being made, imparting more knowledge about engineering will not retain women, since it is the alignment of identities that can be seen as problematic; that of gendered identities and engineering identities (Henwood, 1996:1998; Walker, 2000). According to Voithofer and Foley (2002) a 're-examination' using postmodern perspectives is suggested to address the complex influences of social, cultural, political dynamics that further affect the negotiations of race, gender, class, and ethnicity in learning environments.

In sum, the sociocultural constraints were few for these doctoral women who had a supportive family and home, and positive early schooling experiences. Had these 'basic' needs not been met, they would perhaps have had a different perspective in recalling the influences of choosing and remaining in engineering.

RQ2 What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering?

The participants' stories uncovered three main areas thought to be constraints in relation to participation and learning in engineering programs. The doctoral advisors were reported to be problematic along with their poor teaching practices. In addition, incidents of negative treatment and exclusion were recounted.

The doctoral women perceived their advisors for the most part to be a barrier to their learning. The participants criticized advisors for putting their research agenda above the welfare of their graduate students, for not giving sufficient guidance to their teaching assistants in the running of a course, and for taking advantage of their services [for example, asking them to baby sit]. Engineers elaborated on these non-constructive practices that resulted, if you will, in 'detours' that prolonged the time necessary to complete their doctoral research, and in some instances exceeding the time limit for completion set by the university. Participants complained of advisors who had poor communication skills. Others complained about professors' styles of interacting with students as perhaps indicative of how they regarded their role as advisors, that is, whether they respected their students or not. Overall, engineering students relied on their advisors for advice, direction, and support- all of which are implicit expectations difficult to measure and mandate. Fox (2000) asserted that the advisor-advisee relationship has remained untouched, and faculty are free to train and supervise their own students any way they see fit. Without guidelines for what constitutes sufficient work to complete the degree, Fox surmised that the advisor is left with the power to decide who gets the degree and within what time frame.

Professors were overwhelmingly labeled as poor teachers. Participants felt they were not trained in pedagogical skills and lacked a basic understanding of principles of teaching. They were also criticized for their unavailability and inconsistent guidance or feedback as well as for their interacting styles. Some participants perceived poor teaching to be related to professors' lack of effort as well as to a dissimilarity between learning objectives and teaching strategies (Trigwell & Prosser, 1996; Trigwell, Prosser, & Taylor, 1994), and academics' beliefs (Samuelowicz & Bain, 2001; Saroyan & Snell, 1997). The perception that professors did not value teaching, and 'teach as they were taught' were noted by Ney, Ross, and Stempel (2001). Ney et al., (2001) further explicated three misguided assumptions that tended to represent the undercurrents of the women's comments concerning their professors' teaching, namely that 1) good scientists are automatically effective teachers, 2) the body of knowledge in their discipline is unchanging, so therefore curriculum and teaching methods can remain the same, and 3) students and teachers are static bodies living in an unchanged world. Because science and engineering pedagogy is based on a foundation of unexamined traditions [epistemologically], the 'lecture only pedagogy' tends to remain unchanged. All is not lost; fortunately the critical examination of science epistemologies and teaching practices can perhaps, modify positively student's negative perceptions of teaching and learning in engineering (Fox-Keller, 2001; 2002; Hall, 1982; Haraway, 1997; 2002; Herzig, 2001; Rosser, 1998; 2001; Rosser & Zieseniss, 2000).

Working with peers and small groups were considered another constraint to learning. Peer interactions had a huge impact on how doctoral women perceived their learning and their classroom environment. Participants commented quite negatively on how learning takes place in the mixed gendered classes in both their undergraduate and graduate engineering programs. On the basis of gender, 'other differences', learning styles, motivation, and level of ability, the complex interplay between similarities and difference impeded learning for the women engineering students. Moreover, how tasks were assigned within groups was often based on stereotypical sex-roles and the women's perceived level of competence. The international doctoral women experienced exclusions and differential treatment in which sexism was difficult to differentiate from racism (Jones, 1997).

The negotiation of participation in group projects, coupled with various work ethics created a difficult environment for some women. The participants' difficulty in negotiating their participation and learning in the non-traditional environment of engineering was similar to Henwood's (1996:1998) and Walker's (2001) findings, where women engineers' gendered identities and their engineering identities were in conflict. Perhaps another difference that set these women apart from their male peers was their funding. All of the women acknowledged receiving some type of scholarship for their doctoral research. Jealously of scholarships and funding affected the group dynamics within their peer groups. Male peers questioned whether the women deserved the scholarships obtained and sowed the 'seed of doubt' that still follows some of the women engineers. Successful women still carry with them this internalized gender inferiority, questioning themselves and wondering if they are imposters (Noble et al.,1999).

To recapitulate, the doctoral women's tension in their relationships with their peers can be considered a negative influence on their learning and participation. Based on gender and 'other differences' but not their ability, women reported exclusions and differential treatment.

RQ3 What do female PhD students perceive as the 'unofficial' ways of continuing the history and traditions of the profession in faculties of engineering?

Informal practices adopted by engineering students and professors in faculties of engineering continue the history and traditions of engineering as a profession. These traditions were perceived as constraints by the women engineers. The particular culture of the university, that is, the specific SES of the students, the history of the university coupled with its political climate all contributed to the overall 'ambiance'. Moreover, engineering professors were thought to be one of the main sources of the transmission of engineering beliefs and traditions reinforcing elitism, competence, and sameness. Faculties of engineering and their professors are the gatekeepers to the profession of engineering, transmitting the history and deciding who should be 'weeded' out (Dryburgh, 1999). Another source of transmission of engineering beliefs was that of more experienced engineering students, the apprenticeship model if you will, where during frosh week the neophytes were ushered into the practices and expectations of the culture of engineering. 'Older', more advanced engineering students modeled the practices and behaviors expected of successful engineering students, and administered the punishments for infractions during the course of their programs. The apprenticeship model's impact continues when the iron ring was bestowed at the end of the program, where professional engineers [P.Eng.] returned to welcome the less experienced members into the profession during the 'ringing' ceremony. All of these masculine symbols and practices set the profession of engineering apart, excluding women from the "brotherhood" (Dryburgh, 1999; Faulkner, 2000; Henwood, 1996:1998; Walker, 2001).

Participants were aware of the traditions and values of the engineering culture that included sameness, common shared experiences, perseverance, patience, self-confidence and time-management skills. Some doctoral women thought that distinct dress or appearance was important. These similarities demonstrated the new engineers' 'affiliation with the profession', an act that is especially important for women (Dryburgh, 1999). Moreover, the perception of engineers taking more difficult courses and not having time to spend on their appearance reflects Dryburgh's (1999) 'work hard and party hard' culture of engineering. Interestingly, if the women demonstrated an alignment with the 'work hard' aspects of the culture, their low level of participation in the 'party hard' aspect of the culture of engineering was excused (Dryburgh, 1999). In sum, the doctoral women detailed the ways the masculine culture of engineering is maintained through faculties of engineering, keeping 'alive' the history and practices of the brotherhood of engineering.

RQ4 How does the female PhD student's non/participation in engineering affect their identities?

Doctoral women's participation in engineering, and in some instances non-participation revealed aspects of their appropriated and resisted identities. Their recall of the descriptions and behaviors 'others' have bestowed also complicates the interplay 'becoming' a doctoral engineer. How women spoke of themselves, how they performed their multiple identities in different environments, and how they viewed their futures all contained stories and elements thought to be constraints.

The notion of being a 'true' engineer was a constraint for those women coming to the doctoral program from other disciplines of science. They were reminded through direct statements and behaviors that they had not passed the 'competence testing' of the undergraduate program and professional engineering associations, and therefore could not call themselves engineers. These participants stated with hesitation, "I am not really an engineer"—a description of how they viewed themselves in the culture of engineering. Even for those women who completed a B.Eng., not all assumed the engineering label. Not wanting to identify with the masculine label was an act of resistance, because to accept the one identity is to deny the other; the dichotomy of gender and engineering in conflict (Henwood, 1996:1998; Walker, 2001). Therefore, those engineers that came to the doctoral program with a B.Eng. had the ability to choose more freely how they spoke of themselves. Other doctoral women appropriated the labels given, which hindered their expressions of identity.

The performance of identities was an adjustment process that was enacted, on the basis of explicit and implicit sociocultural expectations. Doctoral engineers appropriated and resisted societal expectations as to their educational needs on the one hand, and relationships on the other hand. In the academic setting, negotiating the many roles of a doctoral student collided often with the expectations of advisors and male peers in research groups and classes. Unlike the women in Holland and Eisenhart's (1990) study, these women were able to 'stay the course', that is, they maintained their career goals.

The process of becoming a doctoral engineer can be qualified as a challenge. Entering engineering to contribute to society was an aspiration for some women engineers. After participating in the culture of engineering, some participants renegotiated their goals infusing them with more realistic notions, while others contemplated leaving the field of engineering, or just 'reaching for the sky'. In practice, most participants are still weighing their options; their identities are 'liquid', not yet fixed. Finally as an afterthought, many participants experienced more personal aspects of their identities, and how these complemented or conflicted with their future career goals.

Composite Sketches: Becoming

From the 'narrative life histories' of my participants, that is, the story of how they have come to be doctoral women in engineering, three composite sketches were developed to illustrate their experiences. Although there are probably other routes, these three were based on similarities and differences reported by the doctoral participants. These combinations of individual identities also help to preserve confidentiality; yet still they allow for the emergence of a 'picture' of who these women have become. The following sketches of doctoral engineering women describe in point form the Optimistic, Conflicted, and Reconciled ways of appropriation of the participants.

Optimistic

- Whatever choices made in school/career, were supported by her parents
- Somehow, her science interest was nurtured in school and at home
- Younger participants
- Completed engineering programs consecutively
- Has little or no work experience
- Have in past or are currently dating engineers
- Have had positive experiences with mentors

Conflicted

- Choice of interests and schools not supported by both or either parents
- Gender/sex differences felt
- Considered leaving engineering or not sure how to find a work environment that suits her
- Negative experiences in engineering program, academia, and/or industry
- Difficulty with dating relationships somehow related to engineering/PhD culture

Reconciled

- Supportive parents but neither are engineers (mothers were housewives, fathers were professionals)
- Special schools or programs
- Recognized or experienced negative treatment in industry

- Academia may be the only place to pursue their type of research
- 'Settled/committed' personal life
- 'Significant others' are engineers or a related occupation

Some doctoral women have convoluted experiences in their social/family and work-related lives. Other women have had more intensive co-op work placements or research site experience. For some women engineers, immigrating to Canada required the learning of new customs and adaptation to a new culture and country, definitely a challenge to overcome. In sum, the similarities of the women's stories allowed for the development of composite sketches to help portray different 'types' of experiences. The different paths of the doctoral women added to the degrees of 'tension' as they experienced the process of becoming doctoral engineers.

Equality or equity? Both are problematic. Without a critical examination of the culture of engineering's notions of 'masculinities', equal treatment tended to be seen as 'inappropriate' by the women doctoral engineers, while equitable treatment appeared to exemplify 'differences' and promote marginality. Structural changes, while most difficult and possibly most resented by those enjoying 'privilege' in the profession of engineering-are needed in order to bring about 'real' inclusion (Fox, 1998; Henwood 1996:1998; Walker, 2001). This suggestion for change reminds us of Henwood's (1998) notion of 'disidentification' in which women engineers not only reject the dominant discourse but also 'dis-identify' with it; that is, they work on and against the 'prevailing' discourse.

'Disidentification' in Walker's (2000) study found that the 'strong girls' [women engineers] failed to 'counter identify' with dominant ways of being male and female. Her notion of being able 'to do the job', similar to my notion of competence, operates within conventional boundaries of what is masculine and feminine. The males in her study, like Henwood's (1998) males, reverted to gendered statements in order to return to the 'natural order of things' when the 'girls' out-performed the men. The women engineers stated that gender was not an issue; they were just different from other women, distancing themselves from sexist treatment (Henwood, 1998; Walker, 2000). Moreover, these same women engineers admitted to struggling with the prescribed 'traditional roles' of women, that is, the nurturing roles, the organization of the team, and the emotional work-- similar to Fletcher's (1994) notion of women's 'relational work'. In order to survive, these women engineers did not challenge males or their 'masculinity'; they became a certain 'type of female', to get the job done. In any case, the presence of these visibly successful women was constructing a new kind of engineer. They 'reworked' the gendered selves available to them and in this process are producing, in Foucault's terms, 'the object of which they speak'.

Although Walker's (2000) women engineers did not challenge dominant gendered notions, there was a novel glimpse of Henwood's (1998) 'disidentification' or Castell's (1992) 'project identity' in my study. One participant thought "it is important to be as she-she, fou-fou as we want to be." Being able to express her femininity and be an engineer was the "the ultimate expression of feminism in engineering". She added that women engineers did not want to be like male engineers and elaborated, "I think it is important to define ourselves as women in engineering perhaps different than men engineers but we bring something to the table to offer, that is, a different perspective". This same participant also suggested that engineering should not be "homogenized";

throwing out the suggested notion of 'equality' that does not recognize 'difference'. She was what I had characterized in my profiles as a 'reconciled' engineer, who both resisted and appropriated [in sociocultural terms] the modes of discourse available to her. This participant's suggestion of not 'homogenizing' engineering is reinforced by Rosser (1998) who affirmed that multi-perspective approaches to increasing enrolment and retention of women in engineering were more effective and in keeping with addressing notions of 'difference' in engineering populations.

These bright women engineers are constantly reinventing themselves in agreement with Bauman (1996; 2000) where there is no single model for becoming a woman doctoral engineer. The task or path is too messy and complicated. The ability to adapt and become who they need to be to 'get the job done' is an asset, while in fact for some women this unfixed, uncharted territory, 'undifferentiated path' has caused them anxiety (Taylor, 1989). These women engineers who through 'narrativization' (Hall, 1996), cultural cohesion (Bruner, 1996) and opportunities for learning as social participation, have re-negotiated their sense of selves in relation to their engineering environments, aiding in their adaptation and proliferation.

CHAPTER NINE

IMPLICATIONS

This chapter reviews the path of this research study. A summary of the study in relation to the four research questions will first be examined, followed by a reflection on the insights of what I have learned from conducting this investigation. Contributions and limitations will constitute the third section of this chapter. Recommendations and suggestions for change for faculties of engineering, engineering pedagogy, and inclusive practices will be presented. Finally, areas for further research will be highlighted.

Summary of the Study

A summary of the findings will be discussed in relation to the four research questions:

1. What sociocultural influences affect female Ph.D. students' choices to participate in engineering?
2. What are the perceptions of doctoral women engineers related to participation and learning in faculties of engineering?
3. What do female PhD students perceive as the 'unofficial' ways of continuing the history and traditions of the profession in faculties of engineering?
4. How does the female PhD student's non/participation in engineering affect their identities?

Sociocultural influences.

Overall, the doctoral women are very bright, resilient women who experienced a positive home life and successful school life. The participants' sociocultural milieu, including background experiences and individual tendencies, positively influenced their perceptions and opportunities of achievement. Overwhelmingly, the doctoral engineers recalled very few negative influences. The general complaint in their early years was concerning schools that lacked individualized instruction or advanced science programs. Some teachers were unable to meet the needs of these bright students but luckily many of the participants' parents met the challenge of providing their daughters with either additional science instruction or another type of extracurricular activity. The women's lack of knowledge of the field of engineering as a university program and as a profession was considered a hindrance. The women chose engineering for two main reasons; their success in math and science, and the practical aspect of engineering related to the time invested in obtaining the degree and being subsequently hired by industry. Most other aspects of engineering remained unknown. Perhaps, as some of the women suggested, that was a good thing. Had they known the challenges of participating in the culture of engineering, they may have made other choices.

Participation and learning.

The practices that best promoted participation and learning were multi-faceted, that is, both affordances and constraints were intertwined in the same learning setting. Engineering pedagogy was deemed salient when it offered flexibility in the structure of lessons/curriculum, and in the type of projects. The women viewed positive learning strategies as those that were student-centered, practical, and related to real world problems. Other favorable conditions were that of research group collaboration and interdisciplinary perspectives on learning. Participating within the group community was necessary in order for the assignment or the doctoral research to be completed. Some workspaces were more conducive to participation and learning, especially those that were female-dominated. The 'relational activity' of women engineers must be valued and more encouraged amongst all the members of the group in order to improve learning.

The constraints associated with participation and learning were first centered on doctoral advisors' overall treatment of graduate students, that is, putting their research agenda above the welfare of their graduate students, not giving sufficient guidance, using their ideas, not guiding teaching assistants in the running of a course, and taking advantage of their services. Professors were also criticized for their teaching especially their pedagogical skills and understanding of principles of teaching. They were also criticized for not making themselves available to their graduate students for guidance or feedback. Some participants also perceived their poor teaching to be related to lack of effort. Because science and engineering pedagogy is based on a foundation of epistemologically unexamined traditions, the 'lecture only pedagogy' tends to remain the rule. Similarly, if pedagogical changes are implemented, the implementation seldom agrees with the epistemological intentions- perhaps making the learning situation worse. Another constraint recounted by the participants was their experiences of negative treatment and exclusions with peers. The complex interplay between similarities and difference impeded learning for the women engineering students relative to their gender and 'other differences' in the group. The learning styles, the motivation, and the level of ability of each group member intensified the group dynamic either in a positive or negative way, exemplifying sameness or difference. Moreover, how tasks were assigned within groups was often based on stereotypical sex-roles as well as the women's perceived 'level of competence'.

Continuing history and traditions.

Informal practices adopted by engineering students and professors in faculties of engineering maintained the history and traditions of the engineering profession. The voiced remembrances of the participants can be viewed overwhelmingly as constraints where the history of the university, coupled with its political climate, contributed to the particular culture of the university. Engineering professors were thought to be one of the main sources of the transmission of engineering beliefs and traditions characterized by elitism, competence, and its sameness 'quest'. Another source of dissemination of engineering beliefs was that of more experienced engineering students who modeled the practices and behaviors expected of successful engineering students, along with administering the punishments for infractions. During their final year of the B.Eng., professional engineers returned to welcome the graduates into the profession during the 'ringing' ceremony. All of these masculine symbols and practices set the profession of engineering apart, and in the process exclude women from the "brotherhood".

Participation and identities.

Some of the doctoral women viewed their overall participation in engineering education as positive, others remained more neutral in their descriptions, and yet still other women recounted many negative facets to their treatment that has left them unsure of themselves in relation to their occupational choices. The affordances that some women spoke of were related to having a mentor and role model, and the ways these positive experiences inspired them to influence other women in science and engineering fields.

The notion of being a "real" engineer was a constraint for those women coming to the doctoral program from other disciplines of science. They were reminded through direct statements and behaviors that they had not passed the 'competence testing' of the undergraduate program, and therefore could not call themselves engineers. Even for those women who completed a B.Eng., not all identified with the engineering label. Nevertheless, those engineers who came to the doctoral program with a B.Eng. had the ability to choose more freely how they defined of themselves. Other doctoral women appropriated the labels given to them which often impeded their expressions of identity. Merging expectations from the culture of engineering with other aspects of the lives and identities can be viewed as a barrier for the women. Doctoral engineers appropriated and resisted societal expectations to fulfill their educational needs on the one hand, and relationships on the other hand. In the academic setting, negotiating the many roles of a doctoral student collided often with the expectations of advisors and male peers. Finally, as an after-thought many participants experienced more personal aspects of their identities, and these complemented or conflicted with their future career goals.

In summary, the doctoral women overwhelmingly viewed the sociocultural influences of their childhoods as affordances. The stories of participation and learning in engineering programs were more ambivalent, since the learning environment was seen in both a positive and negative light. Student centered learning was enjoyed as a positive aspect of learning, while doctoral advisors were mostly viewed in a negative light. The engineers' affiliation with the profession of engineering, in both the faculties of engineering and the workplace, was definitely seen as a constraint for the women and other people of 'difference'. The women's participation, and in some cases non-participation, very much affected how they appropriated and resisted labels given to them, as well as how they spoke of themselves. The doctoral participants can be seen as a 'work under construction'; they are constantly reinventing their 'selves' as there is no single model for becoming a woman doctoral engineer. This study has provided a convincing account of the relationship between choice of engineering education, and the retention and success of women in the profession as influenced by deeply interrelated multiple factors, such as (a) the sociocultural context, namely the support of their home, school, and culture for their educational accomplishments; (b) the nature of the participant, that is, the woman's personal circumstances or psychological dispositions; (c) the nature of the participation and learning opportunities, namely the pedagogical practices and 'inclusionary' measures adopted by faculties of engineering, and (d) the identities performed, namely their ability to adapt and become who they needed to be to 'get the job done'.

Insights

This doctoral study and the long research journey helped me to understand in greater depth the affordances and constraints of qualitative inquiry and the role of the researcher. I would like to share with the reader what I have learned.

First, I have learned the importance of selecting an overall approach and research paradigm that is in keeping with a qualitative investigation. In this study, the sociocultural approach and the interpretivist paradigm have guided my decisions with regard to the research design, the research questions, the data collection, and the data analysis. These choices were based on the belief that reality is situated within specific sociocultural contexts and meaning must be understood with respect to its subjectivity, dynamics, and pluralism. The findings illustrate how the participants came to make sense of their becoming doctoral engineers. My discussion reflects how I understand their accounts as a 'non-engineer', interestingly, a characteristic I share with some of my participants. In this sense, my interpretations are value-laden constructions of how women become doctoral engineers, and the data could be interpreted differently in other research paradigms and theoretical frameworks.

Second, I recognize the importance of the preliminary study [pilot study] I conducted to help ensure a successful qualitative inquiry. The preliminary study conducted in the spring of 2001 proved the feasibility of the study and brought my research interest into focus. Employing Mishler's (1999) open-ended interview procedures, the pilot interviews with three master's in electrical engineering students produced copious amounts of thick, rich, descriptive data. This valuable first-hand experience also allowed me to immerse myself in engineering and get a feel for asking appropriate probing questions. In sum, the pilot study helped me establish a firm understanding of women engineers that assisted me in making other research decisions.

Third, I have learned the importance of establishing trust and building rapport with participants. As we can easily observe from the findings, the women's stories are fraught with inconsistencies and tension. Many told very personal stories that were often humiliating to the participants. I see their sharing and our co-constructed narratives as a sign of trust. And I have done my best to protect their identities and honor the spirit in which the narratives were told. In building rapport with my participants, many recognized the difficulty in obtaining enough participants for their own research studies and subsequently referred my study to their colleagues to help to increase my number of participants. The anonymity of the phone interview may have helped when discussing difficult remembrances but may have interfered with building rapport and co-constructing a story.

Lastly, I have learned from this study that understanding the process of becoming a doctoral engineer cannot be explained by a simple, linear model. As we can easily infer from the findings common themes and different views coexist, very much illustrating the complexity and diversity of my participants.

Educational Implications

This section examines the educational implications of this study in three main ways including (a) contributions, (b) limitations, and (c) recommendations.

Contributions

By examining the path of becoming a doctoral woman engineer, this study makes the educational experiences of women intelligible to the general public as well as policy makers. It gives voice to the women engineers whose perspectives are rarely heard in academic settings or mainstream society. The findings of the study lend insight to the importance and necessity of more inclusive engineering education; incorporating not only women's studies courses into the curriculum (Cukier, 1993; Herzig, 2001; Maberry, et al., 1999; Salmun, 2001) but anti-racism education (Lam et al., 2000) as well as including the perspective of 'other people of difference' (Picart, 2001).

The overall interpretation of this study's findings acknowledges that reality is subjective and constructed by the participants in their various social, cultural, and personal circumstances. These differences are not currently being addressed in faculties of engineering, or reflected in their curriculum or pedagogy. Although this was an exploratory study, the perspectives of doctoral women regarding engineering pedagogy should be more closely examined from a postmodern frame to address women's enrolment and retention in programs. Statistical reports are only telling one side of the story. Women in Science and Engineering programs [WISE] promote the notion of better information to increase the number of women going into the sciences, but they have not been overly successful. Coming at the problem from another angle, Rosser (1998) suggests a multi-perspective approach to more effectively address the many differences of women.

The culture of engineering is problematic for any one who is not white and male. This masculine culture traces many of its practices to the perceived need for an 'affiliation with the profession'. The practices of this 'culture of sameness' are archaic and exclusionary and warrants mandated structural change from within the profession. A task most daunting as those experiencing this 'privilege' may not want to examine ways to share it with others. A decrease in practices that encourage 'sameness' would increase the acceptance of others with 'differences' including women minority engineers.

Disciplines of engineering where the numbers of males and females are almost equal may be the site for change to first occur. These sites through dialogue, group projects, 'diversity' courses, and constructivist pedagogy can produce a new type of engineering program and a new way to 'talk' of engineers and their identities.

As a profession, engineering prides itself on its ethical responsibility to society. Engineering practice and ethics courses are requirements for most Canadian B.Eng. students, where ethical practice and its connection to the 'iron ring' and the profession are revealed. Only recently and in feminist-inspired classrooms, or innovative classrooms with 'enlightened' professors, is the exclusion of women in engineering discussed from the standpoint of public danger. Standards for calculating body size are from a masculine point of view. Similarly, with a more prevalent female presence in engineering-design courses, has female measurements been used in addition to male standards. If exclusionary practices were discussed from this same standpoint, as suggested by one of my participants, then the notion of ethical responsibility and the value of diversity would perhaps be viewed in the same logical manner. The culture of engineering must reflect on the present concepts employed to discuss 'ethics' in the classroom and question its relevance with real world problems (Lynch & Kline, 2000), gender and diversity being important facets to be considered.

Limitations

In reflecting on the research journey it is necessary to consider what I have learned from the research process and from my participants. This process of reflection allows me to examine the study's limitations and to make constructive recommendations for future research.

First, due to the small number of women doctoral electrical and mechanical engineering students in Canada, the size of my sample is small. The findings cannot be generalized beyond the scope of this study. However, the purpose of this study is not to prove or generalize the findings to other engineering women but to increase our understanding of how sociocultural influences and the culture of engineering affect women's choices to participate in engineering. This exploratory study attempted to make visible the experiences of women doctoral engineers that are shaped by the interplay of gender/sex, race, sexual orientation, and power.

Second, most participants did not recall earlier childhood experiences with the teachers and schools. It could be that their more recent engineering education took precedence when recalling educational experiences. Since the women's sociocultural influences were a main component of this study, obtaining additional information from their parents may have been beneficial. In noting the difficulty in finding potential participants, agreement to participate may have decreased with the added burden of getting their parents to agree to participate as well.

Third, although my sample included international women, Canadian minority students did not volunteer to participate in this study. Whether they do not 'exist' presently in engineering faculties or that participation in my study did not interest them, Canadian doctoral 'minority' women's perspectives need to be examined in order to sketch a more complete picture.

Fourth, the main source of data collection in this study is open-ended interviewing with the risk of participants tailoring answers to please the interviewer. Using Mishler's (1999) life history narratives, I do not believe this happened because the narrative data in this study was co-produced and co-constructed, as an ongoing dialogue between researcher and participant (Mishler, 1999). Moreover, I used two open-ended interviews with participant verification after the first interview. In this way, the transcripts of the co-constructed narrative were reflected upon to better illustrate the participants' stories. In addition, the second interview allowed the participants to further elaborate upon the co-constructed stories and perspectives discussed.

Lastly, the possibility of researcher bias, as the sole researcher, was significant. My subjective views have likely influenced many aspects of this study. To offset this limitation a reflective journal was kept that outlines the rationale for decisions and helped keep a complete record of how the data were collected, recorded, analyzed, and interpreted. Doctoral research is not completed in isolation but with the assistance of my doctoral advisor, committee members, colleagues and friends who were all vital in reducing researcher bias. My findings and interpretations are partial and can be 're-read' and altered with further reflection.

Recommendations

Since engineering education is the focus of this study, recommendations for change will begin here. Faculties should examine epistemologically how science is constructed and taught, and how a change in this 'view' can assist professors to teach in ways to encourage learning and participation especially for engineering students of 'difference'. Since professors' teaching was viewed as a hindrance, offering workshops as part of their teaching workload to pedagogically improve content, delivery, and evaluation of courses would be a starting point on the continuum of change. Appointing a committed working group of professors to investigate a holistic student-centered program, such as mechanical engineering at University of Sherbrooke, is another salient recommendation. An important consideration when designing courses and lessons for the classroom is not to use 'binary logic' or simply use a 'taxonomy of difference', that is, insert a cultural component into the current curriculum that isolates the 'essences' of various culture. This insertion could misrepresent foreign cultures and reinforce stereotypes, constructing students of 'difference' as 'Other' (Guest, 2002).

More specifically for faculties of engineering, structural barriers and policy procedures need to be examined. The doctoral women perceived their advisors as a barrier to their timely and successful progression through the PhD program. A doctoral candidate's positive relationship with their advisor is of paramount importance (Cooper & Stevens, 2002; Crude, 2001; Fox, 2000). Faculties of engineering need to develop explicit expectations as to what constitutes adequate PhD research, dissertations, and doctoral experiences. In other words, faculties need to mandate explicitly the preparation of doctoral candidates. This could minimally include listing basic criteria needed to complete the PhD, specific timelines for student-progression along the PhD continuum, and ways so encourage and assist with conference presentations and publication of articles. Moreover, advisors should receive training from the faculty/university on how to 'become' an advisor. Areas to be addressed are guidance strategies, examining and improving interactional styles, how to train RA and TAs, and examining the perceptions of the 'role of advisors', that is, challenging the new advisors' previous beliefs and assumptions. Graduate exit surveys could be employed, similar to current teaching evaluations, to help shed some insight on what the advisors are doing well and what needs improvement.

In addition, 'difference' sensitivity training could be undertaken and led by members of the engineering faculty so there would be an awareness of differential treatment, and subsequent appropriate strategies could be implemented and re-examined. Addressing the ways the masculine culture of engineering is maintained in faculties of engineering, where histories and practices of the 'brotherhood' are kept alive, needs to be made visible. These bonding practices need not be 'outlawed' but examined and modified so that 'affiliating with the profession' is more inclusive and representative of Canadian universities' diverse populations.

As part of the engineering program, elective courses should be taken outside of the faculty to provide exposure to 'difference' in relation to students and curriculum as well as various teaching methods. Moreover, ethics courses or design-engineering courses could examine sexism, racism, and homophobia, along with its many shades and subtleties, in order to question the 'androcentric' focus in engineering. A priority for faculties of engineering should be the recruitment and retention of women professors and advisors. In order to attract women professors into academia, financial support and assistance with teaching and mentoring must be made available as well as allowing this to be reflected in the tenure-process as outline by the University of Waterloo (2002). The critical mass of women engineering students, along with other types of 'difference', must be mandated through policy change in faculties of engineering in order for Canadian society to be truly represented in the profession of engineering. The notion of 'affiliating with the profession' may provide bonding and strength for its 'privileged' members but its traditions are excluding for people of 'difference' and do not reflect a multicultural Canada.

It should be mentioned that many of these recommendations were made over ten years ago by the Canadian Committee on Women in Engineering (1992). Unfortunately, the challenges of increasing the number of women in engineering, as well as keeping them there, still persists.

In sum, structural changes need to be addressed inside faculties of engineering and in conjunction with industry and the bodies that govern the profession of engineering. While WISE programs and scholarships have improved the presence of women in faculties of engineering, without structural changes this may not continue. By adding a postmodern frame to research and solutions, as suggested by Voithofer and Foley (2002), the complex social, cultural, and political influences that affect the negotiations of race, class, gender/sex, and sexuality in engineering can be examined. The value of 'difference' in diverse engineering environments can, therefore, be made visible.

Questions For Further Study

This study was exploratory in nature with the hopes of understanding the process and influences in regard to doctoral women becoming engineers. I concur with Wolcott (1990) and see no reason to force closure on an interpretive study. That is, to go beyond what was in my study and make pronouncements about what ought to have been. Instead, I have concluded my work with unanswered questions about the sociocultural influences that affect women's choices to participate in science and engineering.

-Why was parental influence in the women's careers minimal but yet with a positive outcome?

-What do parents think they did to encourage science self-efficacy; what was deliberate?

-What role did SES play in the women's science successes, to what degree?

-Why did my participants' career interests remain central not marginal [to the culture of romance] as in Holland and Eisenhart's (1990) study?

-What difference does a two-parent home make to science and school success (also stay at home moms versus working moms)? Was it just a reflection of the era or regions of the country? Does it matter?

-Are there women role models in engineering? How 'positive' are the ones who are there?

-What it means to be 'one of the guys' needs further examination for both women and men in engineering. Understanding the notion of 'masculinities' may shed light on the how males treat each other.

In closing: *Life must be lived forward, but understood backwards.*

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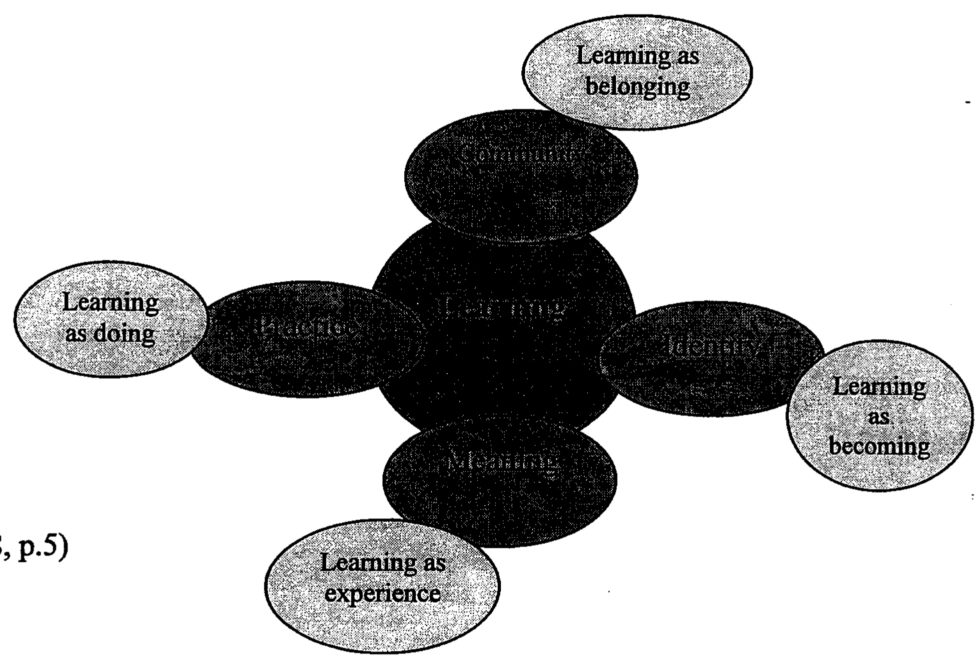
Footnotes

1) Importantly, the term 'gifted', 'achievement', and 'success' need to be clarified. Noble, Subtonik, and Arnold (1999) suggest that **giftedness** in girls is thought to be their measured potential but in women, giftedness is measured by their achievement. Often the terms success and achievement are used interchangeably. Speilhagen (1997) differentiates **success** as the recognition by others, whereas **achievement** is the setting of one's own goals and accomplishing them. Moreover, Boibeaux (1994) posits that engineering students are considered to share many of the traditional characteristics of academically gifted people who focus on their academic talents and on their diligence.

2) Critical mass has been defined as the precise point at which the presence of an adequate number of individuals effects qualitative improvement in workplace conditions and expedites reorganization in a positive direction. This threshold has been specified as a strong minority constituting a minimal level of 15% (Osborn, 1994 as cited in Pattatucci, 1998, p.11).

3) The term sex refers to an individual being considered a boy /girl or man/woman, while gender is considered as being masculine and feminine usually in relation to behavior or appearance.

4) Wenger (1998) contends that "participation here refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities" (p.4). Wenger (1998) considers this process a "social theory of learning [that] must therefore integrate the components necessary to characterize social participation as a process of learning and knowing" (p. 4-5). These components are described and illustrated below.



(Wenger, 1998, p.5)

The following components are extremely interconnected and reciprocally defining.

- Meaning: a way of talking about our changing ability -individually and collectively- to express our life and the world as meaningful.
- Practice: a way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action.
- Community: a way of talking about the social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence.
- Identity: a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities (Wenger, 1998, p. 5).

Wenger (1998) also claims that it is possible to switch any of the four peripheral components with learning (in the middle), and the diagram would still make sense. "[This] perspective is not a recipe; it does not tell you just what to do. Rather, it acts as a guide about what to pay attention to, what difficulties to expect, and how to approach problems" (Wenger, 1998, p.9).

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Appendix A

Letter to Recruit Participants
(Women Doctoral Students in Mechanical and Electrical Engineering)

My name is Shaunda Wood. I am a Ph.D. Candidate in the Faculty of Education at the University of Ottawa. I am very interested in understanding how sociocultural influences affect women's choices to participate in science. This interest has developed as a result of my own teaching experience and the findings of my M.A. study which suggest that the 'broader environment' or the sociocultural influences had greatly impacted pre-adolescent gifted girls' choices to pursue extracurricular science classes (Wood, 1999 & 2001).

I would now like to extend this research perspective to female engineering students. The field of engineering was chosen since it is still considered as having the lowest rate of female enrollment (Association of Universities and Colleges of Canada, 1995). The Canadian Council of Professional Engineers and the Canadian Engineering Resources Board (1999) report that 16.4 per cent of doctoral students enrolled in engineering to be women. Moreover, little research has been conducted with female doctoral students especially in relation to why they have continued their studies, and if they are satisfied with their career and lives (Frize, 1998).

The research will be studied in light of learning as social participation. Wenger (1998) contends that "participation here refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities" (p.4). Moreover, women doctoral students in the faculty of engineering can be seen as a community of practice with a unique identity.

The paucity of research concerning women's choices to pursue traditionally male dominated sciences is apparent. Headlines in newspapers suggest gender parity in sciences but fail to grasp the perspectives of the 'actors' and the sociocultural context in which these choices are made. It is important, therefore, to investigate how the sociocultural environment impacts on learning and the achievement of women in science. Most of all, it is time to give voice to these unique women's experiences and perspectives.

If you agree to participate, your participation will involve approximately a one-two hour interview, and approximately a one-hour informal follow-up and/or electronic verification of the summary of data from the interview. In the interview, you will be asked to discuss how you understand the process of becoming an engineer in relation to engineering as a community of practice. The interviews will be scheduled at a time

There are two copies of the consent form, one that I may keep.

____
Participant's signature

____
Date

____
Researcher's signature

____
Date

I am interested in receiving a copy of the summary report upon completion of the study.

_____Yes _____No

Contact Information:
email______________________

address____

phone_______________________

Appendix C Individual Interview Guide Doctoral Women

Life History Narrative Data

A) The researcher will ask the participants to tell their life story, **how they have come to be a Ph.D. student in electrical and mechanical engineering**. Since the stories are co-constructed, what the researcher says must be carefully noted.
-**The researcher will start by asking the participants to share** their early memories or stories about being interested in science…to present. How have they become an engineer? The interviewing process is participant led (Mishler, 1999). If thick emergent data is obtained, the following questions listed below may not need to be asked. In addition, the researcher may probe for further detail depending on what the participants reveals with the idea remaining--that this is a participant-led process.

B) **IF** the participant is silent for a 'reasonable' time, the researcher may clarify statements or ask for elaboration. This will depend on the type and amount of information, and the direction of topic (away or aligned to purpose of study).

C) If little information is given related possibly to the unfamiliar interviewing procedure, then the following semi-structured interview questions may be used based on the research questions:

1) What sociocultural influences affect female Ph.D. students' choice to participate in engineering?

- Why did you decide to study engineering?
- What got you interested in science?
- What do your friends and family think about engineering?

2) From the perspective of female Ph.D. students, how does "non/participation" in the community of practice affect their learning?

- Explain how you think science is best learned.
- If you were a science teacher, how and what would you teach to your students in elementary, secondary, post-secondary schools?
- What improvements can be made, based on your experience, to facilitate learning in the faculty of engineering?

3) How does the female Ph.D. students' participation in engineering affect their identity?

- What do you think are important characteristics needed to become an electrical engineer?
- Where do you see yourself in 10 years? What goals do you have for yourself?
- How do you define yourself, who have you become?

4) What do female Ph.D. students perceive as the "unofficial" ways of continuing the community of practice in the faculty of engineering?

- Please explain if you think there is such a thing as a 'culture of engineering' and if yes, how is this learned?
- Please describe your experiences in class, with advisors, professors, peers, co-op supervisors.

Appendix D

Time Line Estimation: Data Collection and Analysis (Miles & Huberman, 1994)

Activity	One participant	Seven
• Conducting first interview	3 hours	3 X 7 = 21 h
• Writing field notes [thoughts, meaning, questions, mental notes, reactions (p.66)]	1 day (p.46)	1 X 7 = 7 days
• Transcribing first interview [2-3hours]	4 days	4 X7 = 28days
• Summary of transcripts, 1st level coding (p.69)	2 days	2 X7= 14 days
• Revised data for participant verification	2 hours	2 X 7= 14 h
• Read transcript three times	1 day	1 X7 = 7days
• Emergent themes written in margins (codes)	1 day	1 X7=7days
• Initial emergent themes entered into NVIVO	1day	1X7 =7days
• Devised follow up questions and probes	3 hours	3 X 7 = 21 h
• Conducted second interview	1.5 hours	1.5 X7= 10.5h
• Further themes created NVIVO as nodes	1 day	1 X7 = 7days
• "Cleaned" and combined each participants' 2 transcripts to be imported into NVIVO	2days	2 X7= 14 days
• Data was analyzed using initial themes, codes (p. 115)	5 h	5 x 7=35 h
• Narratives were arranged around 4 Research Questions	1 day	1 X 7= 7 days
• Sub-themes, nodes were identified	1 day	1 X 7= 7days
• "Patchwork" of accounts were developed to tell story (p.193)	1 day	1 X7 = 7 days
• Revisions and retesting of my interpretation and organization of their narrative stories [with opinions of advisor] (p.170)	2 days	2 X7 = 14days
• Narratives analyzed for affordances and constraints	2 days	2 X7 = 14days
• Meeting with advisor once a week to discuss process and revise, etc [Oct 2002-July 2003]	2 hours	2 X 40= 80 h

* This is the overall order of data collection and analysis which could not be separated. Of course, there was overlap. Participant one's data may have been entered into NVIVO while participant three was being interviewed etc.

**NVIVO is a qualitative data software program that assists researchers in organizing data.

Table 1

RQ2 Constraints and Affordances

Constraints	Affordances
Doctoral Advisors	
Constraints:	Affordances:
-Treatment of graduate students	-Charisma of professors
-Ineffective advisors	-Good advisors
-Professors as poor teachers	-Lab experience as trade-off
Pedagogy	
Constraints:	Affordances:
-Lack of pedagogical training	-Flexibility of structure
	-Project/group work
	-Positive learning strategies
	-Traditional
Research Groups	
Constraints:	Affordances:
-Differences	-Interdisciplinary work
-Only woman	-Participating within the community
	-Positive work experiences
Peers	
Constraints:	
-Dynamics of mixed gendered classes	
-Tasks within groups	
-Funding	
Work Experiences	
Constraints:	Affordances:
-Co-op	-Industry research
-Teaching assistant	
-Work experience as P.Eng.	

Figure 1
Conceptual Framework

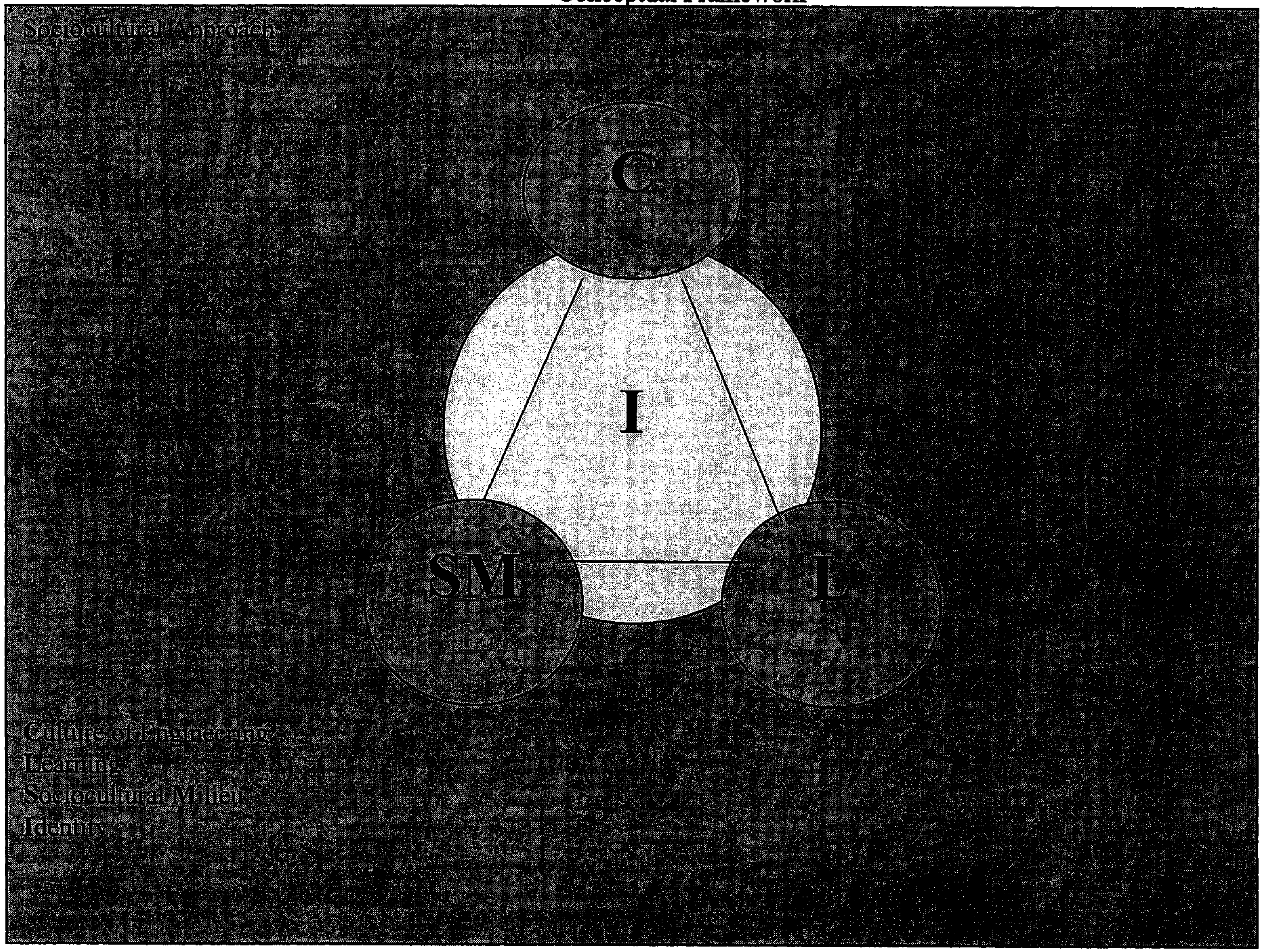

Figure 2.

Data Collection