Learning Engineering in a Problem-based and Project-oriented Learning Environment - Gendered features of learning and Identity Development

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Introduction

In many Western countries, the lack of women in the field of science and technology is seen as a problem from a feminist perspective in concern with equal opportunity. As a developed and democratic country, especially in the perspective of gender equality, Denmark witnesses an uneven gender distribution in the engineering profession – women's participation is 12%. As a joint member of an EU project about gender equality in the engineering profession, the project 'Get a life, Engineer!', managed by the Engineering Association of Denmark, aims at providing a broad picture of gender and technology, finding possibilities of reducing gender gaps and desegregation in the engineering profession and attracting both men and women to become engineers.

This paper is based on a Ph.D. study, which has its root in the Danish project 'Get a life, Engineer!'. The study seeks to understand how learning environment as well as the prevailing gender relations in the Danish society influences the learning experiences of engineering students. This research also attempts to explore barriers to and possibilities of building up a friendly learning environment to recruit students of both genders. This research argues that most projects about gender equality in engineering education are more practice-oriented and quantitative study-based. There has been a lack of overlap in perspective of researching gender, learning and engineering education. Therefore, this project serves as a contribution at both theoretical and empirical levels to the understanding of learning and gender in the context of engineering education.

This paper summarizes the theoretical discussion in this study – an integration of learning theories and gender theories. By relating the new conceptual framework to the research context, engineering education, this study argues that learning engineering involves not only the mastery of technological competences, but also a process of identity work. By locating the meaningfulness as the theme of understanding learning, this study assumes that gender plays an influential role on how individuals interpret their experiences in the learning process and appreciate the meaningfulness of learning. Based on the initial research findings from a qualitative case study in a student-centred learning environment, this paper provides a brief elaboration of how both male and female students develop an identity of being an engineer as well as a sense of belonging to the engineering profession in the process of studying engineering. The findings with respects to how learners of both genders appreciate the meaningfulness of learning engineering leads to another discussion on the changing process in engineering education at both individual and institutional levels.

Gendered Ways of Learning in Communities of Practice - A Conceptual Framework

Since the 20th century, Western countries in general have witnessed different social changes in concern with of gender equality, which has promoted the increase of women's participation into education. However, from a feminist point of view, there has been a lack of consideration of gender in the broad philosophical

standpoint in adult learning theories (Gilligan 1982; Flannery & Hayes 2000). Following the advocation of some Western feminist scholars for more contextual modes of interpretation of learning from a gender perspective, this study makes an effort of incorporating theories on learning and theories on gender. When examining learning, this study places a special focus on the meaningfulness of learning in addition to the mechanics and techniques of learning. Focusing on meaningfulness, as suggested by Wenger (2004), the understanding of learning reaches the level where learning becomes part of the experience of being human. This perspective of understanding learning is relevant to examine gendered experiences in a certain social context.

Social Theories of Learning
In perspective of examining learning, this study takes a conceptual departure from two social theories of learning developed respectively by Wenger (1998, 2004) and Jarvis (1987, 1992, 2001; Jarvis & Holford & Griffin 1998). Both writers perceive learning as social action and interaction which includes cognitive as well as affective aspects. For them, learning occurs through the processes of everyday living and communication, which involves personal growth, individual development and a process of identity work. Based on this perspective, learning transforms our ability to participate in the human world, thus learning involves a transformation of identity.

By locating meaningfulness as the core of learning, the social theories of learning are in concert with the undergoing discussions about challenges facing the competence-based education (Barnett 1994; Bowden & Marton 1998; Jarvis 2001, 2003). As suggested by some scholars (Barnett 1994; Jarvis 2001, 2003), higher education (universities) should not only expect students to fulfil the demands of standards externally present; it should also take the consideration of fulfilling internal demands of learners and provide an environment where learners appreciate the meaningfulness of the transformation process through learning.

Through examining learning from a social perspective, Wenger (1998, 2004) suggests the concept of communities of practice as a tool to understand how individuals are constantly engaged in enterprises, private and public, in which they interact with others and learn in the process. Communities of practice are defined as groups of people who share a concern or a passion for something they do and who interacts regularly to learn how to do it better. Through this concept, Wenger gives an account of learning through the exploration in a system of the intersection between social practice, meaning, community and identity. Learning takes place through experiencing our life and the world as meaningful individually or collectively. Learning occurs when individuals interpret their experience of daily life as meaningful and when they develop different identities through participating into communities of practice. This concept provides a method to understand learning as an organizational practice as well as individual experiences. It is relevant to what Jarvis (1987, 1992) highlights as the essential role of interaction between self and others as well as the prevailing beliefs and attitudes in understanding learning. Both of the writers emphasize the importance of examining learning in a social context; however, this study argues that when researching learning in an organizational context, it is necessary to take consideration of dominate beliefs, attitudes, and norms from different perspectives, for example, culture, race, class, gender, etc.

Gender
Another focus in this research is the role of prevailing gender relations on learning in organizations. Ways of looking at and interpreting gender vary. This study mainly employs the approach of 'doing gender' represented by West and Zimmerman (1991) as a basis of understanding gender. Gender is considered as being created in social, interactional praxis rather than being connected to biology or an intellectual

construction. It is not that an individual 'is' or 'has' a certain gender, but he/she 'does' a certain gender. In this sense, gender is not only created in the socialization process of childhood, but also through interactions among grown up men and women in different communities of practice. This approach provides a standpoint of seeing gender both from the perception of individual characteristics and from the perspective of institutions where gender works and is being constantly created. It also serves as a conceptual tool to link with learning in organizations.

From a similar viewpoint, feminist philosopher in science, Sandra Harding (1986), has a widely cited theoretical frame for dividing the aspects of gender into three social spheres. First, gender symbolism, that is, gender dualism – general conceptions of masculinity and femininity in different cultures; second, gender structure, which refers to gendered labour division in different organizations; third, individual gender, that is, the socially constructed individual identity and the principles of their social behaviour. These three spheres, as Harding (1986) puts, support as well as strain each other. In this light, the overall masculinity and femininity supports and is supported by the gendered division of labour and the individuals' gender identity. At the same time, some social factors that will change the division of labour in society might influence both the general and individual conception about gender. Individuals might not always stick to the image and behaviour defined by the common conception. Therefore, gender symbolism is not fixed, but consistently changing little by little in the long process of negotiation between men and women, masculinity and femininity. This perception of understanding gender can be linked with the way Wenger perceive learning – individual experience, learn and develop identities through participation into communities of practice at an organizational level, which is embedded in a big social structural context.

In her later work, Harding (1996) writes about the effects of gender, as a system of social relationships, on knowledge and learning. She uses the term 'gender cultures' to describe the broader cultures of society, for example, 'masculine' cultures of military or sports and the 'feminine' culture of the fashion world or elementary schools. Women and men can be found in both cultures, but these cultures shape women's and men's experiences in different ways, thus giving them different opportunity to acquire different sorts of knowledge and abilities. By drawing upon the notion of 'local knowledge systems', she also emphasizes the importance of looking at context. The system of gender relations at both broader and local level can give women and men different interests and concerns even when they are in similar situations, so the knowledge they have about similar situations may be different. This may also lead women and men to develop different ways of creating and sharing knowledge. She identifies how the criteria for knowledge acquisition and validation in communities of practice in Western world hinder and neglect women's contribution to knowledge.

In this light, Harding's idea is also relevant to Wenger's notion about scale, which is a term used to discuss the multiple levels in communities – from local groups to large umbrella communities. All these different levels communities are nested in a 'fractal' structure - the small and the big scale communities coexist and constitute each other. For example, the world of technology and engineering builds up a big scale community in the world (in this study, I mainly refer to western world) and smaller scales of communities locally (for example, different levels of institutions in the engineering area). Gender relations play a different influencing role on men's and women's experiences in engineering communities.

Gendered Communities of Practice in Engineering Education
Both the social theories of learning by Wenger (1998, 2004) and Jarvis (1987, 1992, 2001) and Harding's work (1986) on gender share common focuses on the individual-organizational-social structural interactions and identity development in the process. Based on these links, this study attempts to establish a conceptual platform to understand learning with gendered eyes both theoretically and empirically.

From the perspective of social theory of learning, Wenger (1998, 2004) notes that, through participating into communities of practice in organizations, people know what they know, act according to the shared practice, and learn to become who they are. From a feminist perspective, there is always a gender relation influencing the organizational behaviour (Gherardi 1995, Harding 1986, 1991). Therefore, this study argues that communities of practice for learning in an organizational context are gendered – people know whether they are men or women through collective activities. And based on both the cultural and local expectation for femininity and masculinity, they behave as a man or woman through interaction with others. Different feminist research has reviewed how gender differences and gender relations are constituted and enacted in everyday, technology-related practices (Berner & Mellstrom 1997; Edelman 1997; Nyberg 1997; Webster 1997). This leads to gendered experiences in organizations (Goldberger 1996; Tarule 1996), which generates different meanings to work in organizations for men and women. Therefore, gendered culture (Harding 1986, 1991; Gherardi 1995; Kvande 1999; Hayes 2000) in communities of practice shapes men's and women's learning and identity development differently.

Engineering education serves as an example to examine gendered communalities of practice. The male norm in broader technology and engineering culture in western countries has historically excluded and restricted women's participation. Sufficient feminist work in western countries (Cockburn 1985; Wajcman 1991, 2000; McIlwee & Robinson 1992; Mellstrom 1995; Sundin 1997) have reflected how the masculine culture and the patriarchal values of technology itself in engineering area have excluded women's involvement and marginalized women's participation.

An engineering university is an organization where future engineering professionals are cultivated with a combination of both scientific knowledge and technical skills. It can be perceived as the moderate scale of community of technology and engineering, where people learn to become engineers through negotiation of reification (technical knowledge, for example) and participation into the practices in the local context. This level of engineering community is doing gender at organizational level, where gender stereotypes can be witnessed from the sex-segregation and the male-norm. Diverse studies have been conducted on how the engineer's occupational identities are created in gendered forms through everyday practices, institutional arrangements and symbolic representations in micro settings (Hacker 1989; Berner & Mellstrom 1997; Salminen-Karlsson 1997, 1999; Tonso 1996a, 1996b).

According to communities of practice theory (Wenger 1998) and the earlier work on situated learning (Lave & Wenger 1991), learning involves travelling along a trajectory from the periphery to the centre and becoming a full member of the community. However, this study argues that people's experiences are shaped by both the social group they belong to and the individual experiences. For example, gender patterns in a community can bring about unequal distribution of power and directly shape individuals practice and learning process in the community. Therefore, men and women can have different access to participation into the community of engineering, in that the social image of engineer and the culture of engineering educational institutional are masculine. For the few women who enter a community where the prevailing norms are based on men's interest, they might have different experiences travelling from the position of

newcomer on the way to centre. Within communities of practice, there are attitudes, principles, and expectations providing messages in perspective of constructing professional identity. There are also implicit expectations as to how femininity and masculinity should be done in local scale of communities, which can shape the ways men and women take in and process knowledge in different ways. As noted by Harding (1996), men and women might have different learning opportunities and experiences, thus obtaining different knowledge when participating into a community where the culture is defined as the opposite gender.

Wenger (2004) also talks about the possible conflicts learners confront when participating into different communities and obtain multimemberships at the same time. In light of engineering education, the historical image of being an 'engineer' has been labelled as masculine in common sense. This leads to women engineers' dilemma situation – to be an engineer or to be a woman? Not surprisingly, women are either excluded from this community of practice in engineering or have to sacrifice their femininity in order to adapt to the masculine culture, even though they are very often regarded as 'guests'(Harding 1986), 'outsiders' (Harding 1991; Berner & Mellstrom 1997) or 'boundary breakers'(Salminen-Karlsson 1997, 1999).

Changing the Culture in Communities of Technology and Engineering
A common feature – change - turns to be more visible in the process of building up the conceptual framework of gender, learning and engineering education. Technology and engineering are not neutral in the social and cultural construction and their relation with society is flexible. Therefore, they are open to change. Gender relations are undergoing negotiation and renegotiation, which is a process where the weak party can consequently get advantages and power step by step to be stronger. Learning involves changes of individual behaviour and identity, as Jarvis (2001) points out, learning in a certain social context leads to changes of both individuals and organizations. Therefore, this study argues that in the process of engendering and regendering technology and engineering, cultural changes are required. The structure of the community of practice in engineering education as a whole needs a new task for transformation towards a direction to give membership and provide a sense of belonging and a meaningful learning environment to participants both genders.

Gendered Practice of Learning Engineering in a PBL Environment – Empirical Work

Previous research on gender and engineering education has identified women's marginalized and dilemma situations in traditional (lecture-based) learning environments (Hacker 1989; McIlwee & Robinson 1992; Berner & Mellstrom 1997; Dryburgh 1999). Since the last decade, various efforts have been made in Western countries such as Sweden (Brandell 1996; Salminen-Karlsson 1999, 2002), the U.K, (Phipps 2002; Williams 2002), Portugal (Williams 2002), the Netherlands (Hermanussen & Booy 2002), and the U.S. (Tonso 1996a; Shull & Weiner 2002) etc. with the aim to recruit women students to science and engineering-related studies through policy development and attempts of curriculum reforms. A number of initiatives have been put in place to improve the representation of women in this field – role-modelling, 'hands-on' interaction with science in the classroom, single-sex programs, teachers training in gender issues, etc.

The expectation that these would increase the appeal of higher technical studies for girls has partly been met. However, these educational reforms have alone not been the key to a larger intake, retention and output of girls (Hermanussen & Booy 2002). Many institutions have experienced that the measures taken until then

had been insufficient to bridge the large gap between girls and technology. Research on reformed learning curriculum in engineering education (with more team work for example) (Salminen-Karlsson 1997, 1999; Tonso 1996a, 1996b) has witnessed little changes in perspective of masculine culture. As Salminen-Karlsson concludes (1999, 2002), increasing the percentage of women in enrolment does not automatically solve the problems of the male hegemony of the education; to really make the engineering education female-friendly, a bigger social change is needed – all the elements like curriculum content, teaching methods and the prevailing culture in engineering should be changed.

Based on these previous experiences, this research examines gender and learning in a student-centred learning environment in engineering education in Denmark. Based on the theoretical assumption discussed earlier in this paper, that is, the learning experiences in communities of practice can be gendered; this study looks into the learning experiences of engineering students of both genders in a problem-based and project-organized learning environment in Aalborg University, Denmark. The PBL environment Aalborg Model is characterized by the following features, as Kolmos (2002) summarizes. 1) problem-orientation, which relates learning contents to a broader perspective and context. 2) Participant-direction, which provides learning opportunities derived from interests and experiences. 3) Interdisciplinary learning, in which students go beyond traditional subject-related boundaries and methods in order to solve real life problems. 4) Project and group work–organization, which provides a chance to practice work life in the engineering profession as well as develop the competencies of collaboration and management. By taking both cognitive and affective learning into consideration, the PBL Aalborg Model is designed to create an active learning context and to provide a chance for the development of the collaboration, communication, cooperation and management of the learners (Kolmos 1991, 1992; Kolmos & Graaff 2003). This learning environment has been assumed as specifically female friendly from the theoretical point of view (Kolmos 1991), however, without empirical identification.

A lack of qualitative research in engineering education has been witnessed in Western countries, in that most discussions have mainly come from quantitative research. Derived from both theoretical and methodological needs, a qualitative comparative case study was conducted based on the learning experiences of both genders. The empirical work looked into two different engineering branches, where differences can be witnessed in terms of image of the education, learning contents, gendered participation and institutional culture. One case is Department of Electrical and Electronics Engineering (EE), which is regarded as one of the 'hard-core' engineering branches, and where women remain invisible. The other case is Architecture & Design Engineering (A&D), which is a newly established engineering branch, and where women take up more than half of the population. Research methods used in the two departments turned out to be different from original design and different from each other due to their differences in perspective of women's participation, institutional cultures and practical issues such as access.

In EE, Data were collected in forms of ethnographic interviews (with all the nine female students at that moment, two female and 3 male teaching staff); focus groups (group interviews with male students) and non-participant observation (following a project group). Interview guides with female students and teachers were inspired by questions asked in the works of Women's Ways of Knowing (Belenky & Clinchy & Goldberger & Tarule 1986) and Women Engineers (McIlwee & Robinson 1992). The interview processes proceeded gradually at different informants pace to the ethnographic questions concerning the reasons for their choice of engineering education, impression of the engineering profession, academic experiences (especially with technology), spare time activities, hobbies, relationships with family, teachers and friends, future plans, perceptions on gender issues both in general in society and daily experiences. In addition,

specific focus was put on their learning experiences in PBL environment – problem-solving, doing projects, and team work, etc. Follow-up interviews were carried out within one and a half years (most of them were interviewed two or three times). One female student (as well as her group members) was followed up for two academic semesters (with the purpose of observing her daily practice). Three single-male groups were interviewed with the similar questions aiming at achieving an understanding of both men and women's experiences.

In A&D, focus groups (6 project groups – 2 female single-sex groups, 1 male single-sex groups, 2 mixed-sex groups), individual interviews with four male teaching staff and non-participation (following up one project group for one academic semester). Interview questions were basically similar to the questions asked to students in EE. All the interview guides were modified based on differences among informants – personality, gender, backgrounds, institutional culture and current physical contexts. Questions about gender brought about short moments with hesitance when interviewing mixed-sex groups (informant felt more comfortable talking about the other gender without their presence). Otherwise, all the other interview questions led to interesting discussions – informants showed particular interest in questions about learning experiences in PBL environment. Answering these questions turned out to be a reflective process of their learning experiences.

Interview investigation followed Kvale's (1996) seven-stage (1) principle for qualitative interview and Spradley's (1979) three key elements (2) for ethnographic interviews. Group interviews aim to understand their experiences of doing group work and to bring discussions about their attitude towards the learning environment, and the culture of their situated communities. Observation of students' daily life is employed as another method for data triangulation and the increase of the validity of data. I was mainly observing and making notes in the non-participating observation. The data production process turned out interview transcripts and field notes from observation. Currently, this study reached the stage of analysis, which is following Mishler's (1986) suggestions on treating interviews as narratives. This method contains a temporal sequence (a patterning of happenings), a social dimension (story-telling), and a meaning (a plot giving the story a point and a unity). It functions as an efficient way of constitution group identity (Kvale 1996).

Changes as Consequences of Gendered Ways of Learning Engineering – Current Research Findings

The following texts will provide some initial findings that have been worked out at this stage of the research. Firstly, the results of the study suggest that PBL environment provides a milieu where there are multi-resources for learning and students play an active role in managing their own learning. Instead of only attending lectures and doing lab work, students spend more than half of the work time practicing engineering life by solving problems through doing project in groups. They take the responsibility of their own learning – searching relevant information through diverse sources, arranging meetings with supervisors, visiting companies, getting help from experts, managing operation, writing project reports and going through exams together, etc. Working in groups is hard and troublesome at the beginning of the project work, but turns out to be the main source of learning, where students learn to collaborate and make the best of each other. More importantly, informal activities in doing group work create a motivating atmosphere where students enjoy their learning experiences. This active learning process also provides possibilities for students to appreciate the meaningfulness of studying engineering.

Secondly, this study finds out that studying is not only competences mastery, but also a process of identity development. Besides technological knowledge, studying engineering involves learning the language, established practice, attitudes, responsibilities and values, etc. in engineering culture. Therefore, it is also an identity work process, whereby learners develop an identity of being a professional engineer as well as a sense of belonging to the engineering profession.

Thirdly, this research observed that identity work in the process of learning involves managing different identities at the same time. In addition to the professional engineer-student identity, learners in this research context also experience the development of other identities, for example, gender. This research witnessed different gender identity – community interaction situations in the two cases. The empirically work in EE observed an 'adapting' process of women to the established masculine culture when they participate into the communities of practice and develop an engineer-student identity. Being one of the hard-core engineering professions, the culture in Electrical and Electronics Engineering Department (EE) has traditionally been defined as masculine. The PBL environment does not increase the participation of women, the reasons of which should be traced back to the gendered socialization and the social image of being an engineer in the Danish society. As described in the research on women's experiences in engineering curriculum discussed earlier in this paper, these women engineering students undergo a different identity management from their male counterparts and confront conflicts between professional identity and gender identity. However, PBL environment plays a more important role on appreciating the learning experiences for female students than male students. For women, a supporting environment proves to be helpful in studying technology; while for men, it is first of all technology that they are interested in. On the other hand, the research at A&D witnessed a different situation – as a new education with more social concern in the learning contents, women bring their value into the design of technology as well as participate into establishing a new culture, where being a woman is not conflicting with being a design engineer.

Lastly, this study identifies how changes take place at both individual and institutional level. First of all, learning initiates changes of individuals. Practice of studying engineering, developing an engineer-student identity as well as developing strategies to cope with barriers and conflicts involves individual changes and lead to personal growth. Next, learning practice at both institution and individual levels are gendered. The influence of gender on individuals and institutions are mutually interacted. The 'adaptation culture' in EE leads to changes for individual women students – by developing different learning strategies to handle the conflicts between being an engineer and being a woman. The 'creation of a new culture' in A&D shows how the increase of women's visibility and active participation builds up a new aspect of engineering culture; and how individuals influence and make changes in institutional culture. Consequently, the input of feminine values and contributions to technology and engineering is the engineering-student identity at the institutional level and challenging the concept and value of engineering education in general. The increase of access and active participation into technological practice of women will in turn, make changes in the general femininity and masculinity in society.

Conclusions and Suggestions

This paper discusses a theoretical contribution of a Ph.D. study to research on gendered learning experiences in studying engineering. By focusing on how individuals appreciate the meaningfulness of learning and develop different identities in the learning process, this study builds up a conceptual framework based on learning theories and gender theories, which provides an analytical tool to look at the empirical work, learning experiences in studying engineering in a student-centred learning environment. The answers

to the research questions on how learning environment as well as gender relations influences individual learning turns out be reciprocal impacts. On one hand, when studying engineering, individual learning of both genders (especially women learners) can be greatly motivated and appreciated in a supporting and friendly learning environment. On the other hand, individuals are also playing influential role in the development and changing process of learning environments in institutions. However, issues of gender stereotypes, lack of awareness and knowledge on gender, etc. in institutions have different influences on learners of different genders with respect to learning opportunities and learning outcome. For example, the conflicts women student in EE confront can bring about barriers to the appreciation of learning.

In conclusion, this study suggests that in order to make engineering education more attractive, it is essentially necessary and beneficial to build up a friendly learning environment where learners can master technological knowledge in an active way and at the same time appreciate the meaningfulness of studying engineering and learning to become an engineer. For the aim of achieving gender equality in engineering profession at a further level, it involves rethinking of the concepts of technology and engineering as well as making changes in engineering culture and values. This demands awareness of gender, learning and changes as well as initiatives at both bottom-up(for example, individual awareness, negotiations and changes of practice) and top-down (for example policy supports, organizational changes, etc.) levels.

Notes
1. The seven stages of doing qualitative interviews are respectively thematizing, designing, interviewing, transcribing, analyzing, verifying, and reporting (Kvale 1996)
2. The three key elements for ethnographic interview are explicit purpose, ethnographic explanations and ethnographic questions, which make ethnographic interviews into a unique qualitative interview (Spradley, 1979).

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