Int. J. Engng Ed. Vol. 18, No. 4, pp. 458–464, 2002
Printed in Great Britain.

0949-149X/91 $3.00+0.00

The Impact of Women on Engineering: A Study of Female Engineering Students' Thesis Topics*

MARIA UDÉN
Dept.of Human Works and Sciences, Lulea Universaity of Technology, S-97187 Luleå, Sweden. E-mail: mama.uden@telia.com

With a focus on technological practice, this paper detects and discusses changes that arose—or did not arise—as Swedish women entered engineering across a broader front. For this analysis, quantitative and qualitative data are related. A specifically new empirical source for the purpose of gender and technology studies is explored and described, namely M.Sc. theses by women engineering students. The conclusion is that the technology displayed in the women's theses does not differ from engineering science in general.

INTRODUCTION

THE PATTERN of gender participation in technology is similar in Sweden to what has been reported globally. In the early years during which the modern engineering profession and education was developed and institutionalised, women were excluded from participation. However, in Sweden today, it is seen as good for women to become engineers, even necessary. This positive attitude has dominated Swedish policies on education and labour the last three decades. The proportion of women students in engineering has grown from well below 10% in the early 1970s, to about 30% in the late 1990s to early 2000s. The proportion of women in the engineering workplace has followed this increasing trend, which shows that female students have been able to find employment after achieving their degrees.

Despite the gains in gender equality, however, it is apparent that ambivalence still surrounds 'the woman engineer' today. In a study of the British industry, Cynthia Cockburn concluded that 'women may well push the buttons but shall not meddle with the works' [1]. The proportion of women is high in some programmes and very low in others. The career paths of women and men who are engineers are not comparable either. Moreover, a cultural contradiction between being a woman and being an engineer is mirrored in every-day language, where women are depicted as 'soft' while technology is described as 'hard'.

There has been a great deal of speculation both in the public discourse about women engineers and in feminist critique of the construction of science and technology, around who the woman engineer is, and about what women in technology will bring to the field. How do the results of women engineers' work appear and, in turn, impact upon society as a whole? Although a feminine impact on the nature of technology has been speculated about for some time, very little is known about this topic.

In this paper I report on a study of M.Sc. theses submitted by female engineering students between 1971 and 1993 at the Luleå University of Technology (LTU) in Sweden. The results of the readings of these theses and interviews conducted with some of the former students were presented in my doctoral thesis [2].

THEORY AND EARLIER RESEARCH

Charles Taylor has written on intersubjective understandings of reality and how the researcher can adjust theory and method to accommodate this notion [3]. Taylor argues that it is not enough to describe human society in quantitative terms as is done for example in surveys designed to delineate the distribution of certain attitudes (my italics):

> 'We can allow, once we accept a certain set of institutions or practices as our starting point and not as objects for further questioning, that we can easily take as brute data that certain acts are judged to take place or certain states judged to hold within the semantic field of these practices . . . *But this means that we give up trying to define further just what these practices and institutions are, what the meanings are which they require and hence sustain.*'

He concludes that interpretation is a necessary step, although this step is made more or less visible in different types of investigations. With respect to women in engineering, the interpretation of gender patterns has followed two main lines. According to one interpretation, observed gender patterns in

* Accepted 15 October 2001.

engineering result from more general gender patterns of prestige, power and influence [4, 5]. This interpretation suggests that as men and masculinity are connected to power and prestige from the start, women and femininity are excluded or restricted from fully taking part by patterns of behaviour, norms and social regulations. Berner argues that chemistry and chemical engineering is regarded as suitable for women in Sweden because chemical engineering has never been seen as a path to prestigious or politically powerful positions in the Swedish context. By contrast, for example mechanical engineering has traditionally been a leading branch of industry [5]. According to the logic of this interpretation of gender patterns in engineering, the ambiguity in a female engineers' position is as a result of contradictory power positions.

Another key interpretation of gender patterns in engineering proposes that observed differences such as between the proportion of women and men in various engineering programmes result from women's values being dissimilar from men's. According to this interpretation men are more interested in 'technology as such' while women are more interested in the contextual applications, especially the human perspective. This interpretation, which has also appeared frequently in the analysis of science education and scientists' work, can be traced to Rousseau who described the woman's place as moral guardian and aesthetic enjoyment to the rational hardworking man [6]. It is also present in recent feminist writings such as that of Carolyn Merchant [7] who contrasts modern mechanistic technology and lifestyle with a holistic organic worldview, while claming the latter is both archaic and also representative of women's present reality as mothers and caretakers.

Following the latter interpretation, women are often regarded as having the potential to bring change to technology. Ewa Gunnarsson, based on her studies of qualifications in industry, has proposed that women bring a caring rationality to technology [8]. Another hypothesis says that the exclusion of women condemns those sectors in which women are engaged into secondary status in technological development. Two examples that are given are women's exclusion from technological development in household technology (9) and office work [10]. The most well known examples however, where women are presented as bringing alternatives or contrasts to a dominating practice, are not retrieved from technology studies but studies such as Evelyn Fox Keller's writings on Barbara McClintock's genealogy [11] and Vandana Shiva's account [12] of the biological knowledge among women farmers in India.

METHODS AND MATERIALS

As engineering in practice involves a great deal of teamwork and since women are in the minority, it is not easy to find contexts where work is performed separately by larger numbers of women engineers. Furthermore, regular work performed by engineers is often the property of their employers, who often have reasons not to disseminate detailed knowledge of their plans and methods.

To obtain an engineering degree at a Swedish university, a student has to complete a project of approximately three months and present a written report. National regulations prescribe that with this project the student should demonstrate the ability to apply the knowledge gained during the years of studies and to independently handle a task. The corresponding English term for the report is the M.Sc. thesis. Within the Swedish education system it is obligatory that a M.Sc. thesis be publicly available. The theses provide one of the few accessible sources of 'engineering work' and it gives special insights into the interface between engineering education and professional practice.

Being the test and evidence of professional competence, a M.Sc. thesis identifies technological competence. It also demonstrates the student's personal capacity and *individual* judgement and creativity are expected. The authors' (students') individual interpretations of technology develop through the theses.

Among the capacities to be demonstrated, the first is the ability to find a project task. In this respect, the degree project is situated in a social space between education and career. With support from the university the students are required to establish contacts and develop agreements by themselves. Through the whole process they carry out negotiations with different stakeholders to finalise the project and thesis design.

In this study three elements of the theses were chosen for analysis: the titles, the front-page illustrations (found in 40% of the theses) and the theses' contents. The analysis of the titles and front pages covered all 376 theses by exclusively women authors.

To make the reading of the contents feasible, every tenth thesis was chosen. The method does not include a comparison with men's theses. However it is most unlikely that no gender patterns would be visible. Therefore comparison would not necessarily bring new knowledge.

The decision to study only the women's theses was taken to be able to compare and test speculations and theories about what women 'will' do as engineers with what women in their own right actually have done.

For the purpose of the test, descriptive quantitative data is given to provide a discursive and historical context of the university where the theses were produced. The historical background and quantitative data enables a better understanding of the theses themselves and are presented first before moving on to results of the analysis of the theses.

LULEÅ UNIVERSITY OF TECHNOLOGY (LTU)

In 1971, at the initiative of Prime Minister Olof Palme's social democratic government, LTU was opened in Luleå, the capital of the Norrbotten region. Until then it had always been felt in Sweden that a technical university required a highly advanced industry and economy in the immediate surroundings. This change in policy declared that a technical university should serve as a facility for the development of such a context (13). It was also during LTU's first few years that an active policy of recruiting women to technical professions and engineering was adopted in Sweden. Two key ideas about the aims and methods for social change in contemporary society were thus present in the debates and policies surrounding the establishment of LTU:

- Higher education as an instrument for regional development.
- Advancing gender equality by changing gender patterns of education.

In the fall of 1971, 47 students enrolled at LTU to study mechanical engineering. One of them was a woman. In 1991 the total number of students at the university exceeded 6000, of which 300 were post-graduates, and LTU had expanded to incorporate an existing school of education, and had developed a school of business. The proportions of women among new students during the first twenty years rose from five to twenty-five per cent. During the 1980s LTU held the highest share of female engineering students at M.Sc. level in Sweden with the almost 30% being regarded as high even from an international perspective. Through the years, a number of different engineering programs have been developed at LTU (Table 1). Comparing the first two columns (share of admitted women and share of women graduates) it can be noted that the share of women among the graduated students is the same as the share of women among admitted students. Perhaps most interesting, in relation to the inquiry of this paper, is that mechanical engineering was the most popular program among women during the investigated period, as the column showing each program's share of admitted women shows.

Results

The thesis content is typically presented in the form of text, formulas, diagrams, tables and graphical representations such as sketches, figures and photographs. The traditional guidelines for reports within science and engineering were found to have been applied and a passive impersonal style of presentation dominated.

An analysis of the contents and composition revealed that the women's theses can be described as normal engineers' accomplishments. Engineering practice is to a large degree built upon non-verbal processing and communication, which the theses confirm through the frequent use of graphical and mathematical symbols. Aims and themes are also easily recognised. For example the ability to calculate optimal conditions is well known to be a significant component of engineering competence. Performance, control, moderation, efficiency etc., were found to be the usual aims implicitly as well as explicitly expressed in contents and titles.

Titles are meant to describe the content as correctly as possible. But they are also tools for producing and reproducing identities. The titles *name* the people and institutions involved in the thesis for both internal and external audiences. In essence they are both *representations* and *names*. Hence it is interesting that the titles, more than the actual content, are characterised by bureaucratic and authoritative language. This creates an authoritative impression, but the other side of the coin is a passive, anonymous and abstract quality. In detail the abstraction results from the absence of symbols otherwise important for social and cultural identification. For example, only one title mentions the year in which the study was done. Only five titles out of the 376 include terms for people, namely: *co-workers, patients, infants, children, user* (as in user-interface). Titles that include words signifying values or affection were rare to non-existent. Instead the titles are dominated by technical language describing artefacts and procedures such as *Hilbert transform-filter*, *Software for AGV* or *P/M Udimet 720*.

Names of corporations, authorities, industries and brand names were found in 85 of the 376 titles. To that figure can be added the theses where the front-page layout included a corporation or brand

Table 1. Women in the LTU engineering programs. Share of women as compared to men (first two columns), share of women as compared to the total number of women (last two columns). Periods chosen so that admitted included students according to curriculum could have graduated.

Program	% women first years until 1989	% women graduates students until 1993	Share of totally admitted women until 1989	Share of totally graduated women until 1993
Mechanical (1971)	12	14	31	38
Mining (1972)	17	15	19	17
Environmental (1977)	50	52	21	20
Civil (1981)	21	20	11	10
Computer science (1982)	10	8	6	5
Ergonomics (1984)	52	56	11	9
Industrial management (1987)	27	38	3	3

logotype. More than one quarter of the theses included organisation and brand names in their titles and/or front-page layouts.

ADDRESSING ISSUES OF GENDER, POWER AND VALUE

LTU's female engineering students were hosted by powerful organisations and dealt with complicated issues in highly developed surroundings. As emphasised by Wajcman [4] the social and symbolic levels of technology are coupled to each other: symbols loose their function if they are not mirrored by social circumstances. Referring to Taylor [3], we would talk about a relation between practice and language. Titles such as *Steering gear for nose-wheel on aeroplane JAS 39*, *Automated drilling and tunnelling: a field test* or *Selecting a truck terminal system for Volvo Lastvagnar AB*, do not express anything unusual within the scope of the engineering profession. But as names of women's work, as identifications of women, they represent reinterpretations of what a woman is. The interviews with former students, nevertheless, lead one to ask what the conditions are for this reinterpretation to take place.

For example, the interviews show that it can be problematic to practice knowledge and ways of being that are connected to engineering in non-professional social settings. This result, however, merely confirms what is already known from a large number of studies. The issue is better conceived if transferred to society level.

From the viewpoint of a gender analysis, it is worth noting that only four titles mention women's working places or organisations that are culturally understood as 'feminine', or 'for women'. These theses were published in 1979,1987, 1990 and 1991 respectively. This cannot be regarded as increasing in frequency given the increasing numbers of women engineering students at LTU and in Sweden as a whole during this period.

A closer look at the bulk of organisations that were hosts or partners for the M.Sc. tasks, shows them as men's organisations, and in no way 'mixed' or 'gender neutral'. They symbolise masculinity and furthermore: they employ men. The ratio of men to women employed in the organisations to which the degree projects were connected was often more than 10:1. According to Berner's investigations of more than a hundred years of Swedish engineering education history, women in general have not earned influence over technology through individual women's entrance into the engineering profession (5). What is manifested through the theses, is that women who go 'into' engineering come to work with men and in men's cultural domains. Men, on the other hand will not necessarily have to integrate women or women's domains into their professional networks. An example of this is given through the gender configuration of teams who co-operated around degree projects at LTU from 1971 to 1993. At most five per cent of the men were involved in co-operation with women.

As mentioned earlier one of the key ideas at the time LTU was established, was that gender equality could be advanced by changing the gender patterns of enrolments in education. The assumption that LTU could have a positive impact on the local women's labour market and living conditions other than producing individual women to become engineers has not yet been debated in public. This indicates a distinctly gendered understanding of technology that has a direct dependence on power relations. From the students' point of view, the possibility of proving oneself as being worthy of an engineering degree and subsequently to make a career as an engineer is interpreted as resting upon highly developed organisational contexts. This is without doubt a rational conclusion of theirs. But another component occurs in the data which cannot be overlooked: a task performed within such an organisation is interpreted as a sign of engineering quality in the student herself or himself. According to this evaluation, even 'staying' to do your project at one of LTU's departments is personal failure in comparison to doing the project at an industry, caused by lack of alertness and engineering skills. 'Low tech' projects are judged the same way, and of course it is unlikely that tasks performed in environments other than those judged as technology-dense from the start, will reach an advanced 'high-tech' character. The significance given to technology-dense organisations through the titles is in accordance with general portraits of today's global pattern of science and technology created by feminist philosophers such as Hilary Rose, Sandra Harding and Donna Haraway.

By addressing the symbolic value of certain types of organisations, we have approached the discussion of the female impact on technology through their values. It can be stated that some theses do contain unusual subjects and/or seeds for genuinely holistic or humane approaches to technology. The thesis *Langas* by Åsa Belander is particularly worth noting in this regard because of its title and front-page layout. Langas is not the name of a machine, brand or corporation; it is a place by a river. Nevertheless, the 'unusual' theses remain exceptions rather than indications of change.

From a methodological point of view it is perhaps more interesting that there is one significant position in the theses where exceptions are normality: the front-page illustrations. As a result of print-shop practice, the students have the opportunity to hand in personally composed front-page illustrations to their theses. In some cases, during the early years, students included short abstracts on their front pages. But this space has most often been used for illustrations. The addition of an illustration to the theses has

been in use among both male and female students. In 169 of the 376 theses included in my study, the authors have taken the space available for their own layout as an opportunity to add an illustration.

The front-page illustrations include the same things as were mentioned in the titles but show a richer array of interpretations of both engineering methods and worldviews. Apart from the traditional machines and diagrams, these illustrations include people, animals, nature, humour and outspoken standpoints.

While there are more than twice as many titles than illustrations in the data, ten times more illustrations than titles include people. This material is promising in terms of possibilities for creative changes within engineering practice: it points towards a possible technological pluralism. Nevertheless, the insignificant level at which this pluralism occurs makes it quite hypothetical as whether it could ever affect either the practice or conceptualisation of technology. Illustrations do not carry the same aspirations for prestige as do titles, calculations or conclusions.

The results show that the technology displayed in the women's theses does not deviate from engineering science in general neither from a practice nor a symbolic viewpoint. Furthermore, the technology displayed in the women's theses does not diverge from that which the participation of women in engineering is presumed to eventually eliminate. The theses display a highly specialised world consisting of technical artefacts: abstract, out of context and empty of people. Technology intensive, 'heavy', organisations have a prominent place in the theses and the contacts with these organisations also takes prominent places in the interview results. Among the theses and most frequently in the illustrations on the covers, there is what can be seen as challenges and new definitions of what technology 'is'. This might indicate (a latent) technological pluralism among engineers. But the unusualness of the unusual theses, and the institutionally insignificant position that illustrations occupy signals that the issues and matters brought up are *outside* of what is *within* normal technological practice or 'technology' itself. Qualitative changes in the theses, as well as changes in the patterns of connections to society outside the university did occur from the 1970s to 90s. However, these did not follow the growth of numbers or share of women among the engineering students. Instead, new realities occurred in the technology concept as new programs were introduced at LTU.

The word 'lake', which is a significant example in this respect, appears in the titles of some of the M.Sc. theses of students in environmental engineering. The front-page illustrations are often less predictable in their relation to the particular programs than are the titles, but in the case of lakes it is also as a result of environmental engineering that lakes appear in illustrations. As boundaries towards women's circumstances and towards cultural expressions understood as feminine also remained quite intact through these processes, the gender of the technology concept and practice appear as basically unchanged.

Results

The conclusion of my inquiry is that women's entrance into technical education at LTU has not significantly changed the nature of engineering at that university. It has neither rephrased the practice of technology, nor the technology concept. If change at some point does result from the mere quantity of women, the point at which this might happen was not revealed by the material in this study. Nevertheless it is feasible to acknowledge that the women as individuals did do something new. To use the words of Cynthia Cockburn the women at LTU *did* 'meddle with the works'. This can be considered as a step forward for gender equality. The ambiguity displayed by the LTU sources is coherent with the progress of gender equality in Sweden as a whole [14]. If this is considered together with the fact that Swedish higher education is governed from a national level, it is feasible to assume the findings of my inquiry to be typical for engineering education in Sweden in the 1970s to mid 1990s. Recent collections on the history of women engineers support the supposition that the main features that the LTU study reveals are similar on an international level: reinterpretation of femininity rather than technology [15]. More recent developments remain to be examined. It can be expected that the present shortage of qualified students and an increasing influence of feminism is likely to affect gender in Swedish engineering education today, but still there is the surprisingly traditional gender pattern emerging in the field of Information Technology (IT).

Some important studies of women's work in science and technology show quite different findings to those I have presented here. For example, Marja Vehviläinen's [10] investigation into the work of women computer professionals, and Evelyn Fox Keller's study of the scientific interrogations by Barbara McClintock [11] can be perceived as contrary to what I found. Drawing this conclusion would be based upon a misunderstanding of our respective inquiries, though. Neither Keller nor Vehviläinen intended to produce generalisable claims through their particular investigations. Instead they deliberately chose unique examples to introduce possible alternatives. It is possible to present attractive new approaches to engineering from some especially interesting theses in the LTU data, and to build upon the plurality and richness in some of the illustrations. But the picture created through such a procedure would not be representative of the LTU women's engineering practices in general. Furthermore no attempt has been made to find the most compelling alternative examples among

men's work. Therefore we cannot rule out the possibility that some men produce as interesting alternative interpretations of science and technology as some women do.

The most popular program among women at LTU was not accredited as such within the organisation itself or in the discourse on national level. Even if more women study mechanical engineering than ergonomics engineering, there are difficulties to accept mechanical engineering as women's true choice.

Despite the lack of evidence, the assumption that women are bringing about change is not uncommon among teaching staff, university administrators and politicians. In a recent study of pedagogic projects in Swedish computer engineering education, Salminen-Karlsson [16] reported that a view among university staff and policy makers that the role of women who enter engineering education is to change the values and practices of computer engineering towards a softer more humane direction. Women who do not meet those demands are ruled out as 'not real women'. The tendency to overestimate the range of 'different' values and practices among women is easily explained, as it creates an account of reality that at the same time confirms ideology compatible to ruling gender orders and strengthens the case of women in the struggle for gender equality.

DISCUSSION

As most stakeholders in the theses apart from the women students themselves are men, the majority of decisions affecting the theses result from men's opinions. On the other hand, it is not reasonable to establish conditions for authenticity that exclude all accomplishments that have been subject to influence by someone other than the originator herself. There is a call for a methodical trial to answer the question of authenticity. For this purpose, it is helpful to turn to the Intentional Explanation model developed by George Henrik von Wright [17]. According to this model, if a person has a goal and also an idea of what to do to reach that goal, then she or he will undertake the required action when the right situation is at hand. In the case of the investigation of women's theses in engineering, it could be that the results are distorted because the right situation was not at hand; the women had an idea of what to do, but could not find the space or resources to do it. If so, what is written in the paragraphs above may reveal more about the Swedish system of engineering education and LTU than about the intentions of women engineering students. It could also be that the students have goals that differ from 'usual' engineering, but lack ideas of how to act to realise these goals.

Personally though, I feel that both the objections that arise from implementing von Wright's model to the matter of women's M.Sc. theses have relevance, as the basis for action rather than conclusion. These objections highlight opportunities for feminist and gender equality action. Women in many countries, who are teachers in science and technology, have recognised this and started projects to produce alternative pedagogies. The importance of such initiatives has been shown by the results of this inquiry. When new programs are introduced, such as environmental engineering, together with their new cultural designations and new curricula, novel approaches to practice and concepts appear in the theses.

When it comes to the relevance to the actual historical process however, the two objections lack credibility. Basically this is because historical data does not arise from what could have been, but from what actually took place at a certain moment and place. Furthermore, I hold that there are empirical facts that speak in favour of the theses as authentic expressions of women's intentions. It is improbable that a situation as free of the requirements of profitability and yet so well provided by all sorts of resources will ever again occur in the professional life of an engineer after the performance of the M.Sc. task. It is possible that more mature women would act otherwise—the typical author is in her mid twenties. On the other hand, interviews with women engineers do not indicate that these women commonly use their technological competence in creative ways beyond the realms of their employers [2, 18].

REFERENCES

1. C. Cockburn, *Machinery of Dominance: Women, Men and Technical Know-How*, Pluto Press Ltd. London (1985).
2. M. Udén, Tekniskt sett av kvinnor (Women technically speaking), (diss.) Luleå University of Technology (2000).
3. C. Taylor, *Philosophy and the Human Sciences*, Cambridge University Press, Cambridge (1985) p. 29.
4. J. Wajcman, *Feminism Confronts Technology*, Polity Press, Cambridge (1991).
5. B. Berner, Explaining exclusion, *History and Technology*, special issue *Women in Engineering in a Comparative Perspective*, **7**, 30 (1997).
6. G. Qvist, *Konsten att blifva en god flicka* (The art of becoming a good girl), Liber, Stockholm (1978).
7. C. Merchant, The death of nature: Women ecology and the scientific revolution, (diss.) New York (1980).

8. E. Gunnarsson, Att våga väga jämnt (Daring to be equal), (diss.) Luleå University of Technology (1994).
9. C. Cockburn and R. D. Fürst (eds.), *Bringing Technology Home*, Open University Press, Buckingham, UK (1994).
10. M. Vehviläinen, Gender, expertise and information technology, (diss.) University of Tampere (1997).
11. E.F. Keller, *A Feeling for the Organism: The Life and Work of Barbara Mcclintock*, Freeman, New York (1983).
12. V. Shiva, *Monocultures of the Mind: Perspectives on Biodiversity and Biotechnology*, Zed Books, London (1993)
13. J-E. Lane, *Creating the University of Norrland: Goals, structures and outcomes*, Umeå University (1983).
14. L. Mósesdóttir, *Gender Mainstreaming: The Swedish Case*, European Trade Union Institute (2000)
15. A. Canel, R. Oldenziel, K. Zachman (eds.), *Crossing Boundaries, Building Bridges: Comparing the History of the Women Engineers 1870s–1990s*, Harwood Academic Publishers (2000).
16. M. Salminen-Karlsson, Bringing women into computer engineering, (diss.) Linköping University (1999).
17. G. H. von Wright, *Explanation and Understanding*, Cornell University Press (1971).
18. R. Carter and G. Kirkup, *Women in Engineering: A good place to be?* MacMillan Education Ltd., London (1990).

Maria Udén earned her M.Sc. degree in mineral processing and metallurgy at Luleå University of Technology in 1988. After a few years active in engineering, she returned to the university and its Department of Human Work Sciences where she in the year 2000 presented her doctoral thesis 'Women technically speaking'. Maria's research is profiled towards interdisciplinary studies of technology, and attempts to create feminist approaches within the engineering sciences. Presently, she is teaching at Luleå University of Technology in the departments of Mathematics and of Human Work Sciences.