Gendered Learning Experience of Engineering and Technology Students

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Abstract
UK National statistics for science, engineering and technology studies and careers confirm the under-representation of women in these disciplines. A literature review formed the basis for developing survey questionnaires exploring issues of female students' attraction to, and retention in, engineering and technology studies. Findings indicate that having family members in the engineering or technology industry plays an important part in the students' choice of degree topic and future career. In particular, we found that female students need to be encouraged to study a "male dominated" subject, such as engineering or technology but that teachers do not contribute much to such encouragement. While at university, female students were more comfortable in small practical sessions rather than in a large lecture theatre environment and, when evaluating self-confidence in their skills at graduation, the female students were less confident than their male colleagues. In addition, the study highlights that gaining work experience through an industrial placement should be one of the priorities for engineering and technology students. A high level of determination and wanting to do engineering or technology is especially necessary for women who may be discouraged by the stereotyped image of engineering and technology studies and professions.

Keywords
Engineering and technology students, education, learning environment, learning style, gender, female engineers and technologists

Introduction

The DTI[3] (the UK Department of Trade and Industry) statistics for the period 1992 - 2002 shows that only 25% of female and 40% of male science, engineering and technology (SET) degree holders were actually employed in SET occupations (DTI, 2003). This paper focuses on the situation of engineering and technology students and is part of a larger research study which investigated the problems faced by female engineering and technology students and the low percentage of women engineers and technologists in industry and academia. The study was partially funded by the European Social Fund (ESF) under Priority 5, Measure 2. This priority aims to improve women's participation in the labour market. The project consisted of a year long study into the situation of engineering and technology students and women qualified as engineers and technologists working in the North West of England. In this paper, we present the findings from questionnaires distributed to students. The questionnaires were intended to identify good practices as well as problem areas and barriers to attracting and retaining students.

[3] Please note that The Department of Trade and Industry has been renamed the Department for Business, Enterprise & Regulatory Reform (BERR) in July 2007

Women's Entry to Science, Engineering and Technology (SET) Studies

Bennett et al in their paper suggest that knowing someone in the profession helps in making career decisions (Bennett et al, 1999). This is also confirmed by another UK based study where women engineers were more likely to report having an engineer in the family (Sewell, 1995).

> Gender stereotyping of girls' abilities still represent a major barrier: "Despite the efforts of the education community to encourage girls to pursue math, science, and engineering careers, age-old prejudices like 'girls don't have the ability or interest to do technical work' persist" (Brake & Tessmer, 2004, p.142). Two Australian studies identified similar trends. The first considers the initiatives aimed at encouraging a better representation of women in undergraduate engineering courses and discusses the persisting difficulties in attaining gender balance but interestingly declares that there is still a long way to go (Coles, 1994). The second acknowledges an improvement in the late 20th century in the numbers of women entering "male dominated" technology professions but recognises the beginning of a reverse effect that has begun at the start of the 21st century. The study strongly recommends that the whole of society needs to take action to combat this state of affairs (Chiu et al, 2002).

Equally, in the UK, there are a number of initiatives that are run by different organisations that aim at encouraging girls to study SET. Amongst these initiatives is the national Insight course, which is an annual one-week residential programme. Most recently, the Royal Academy of Engineering integrated Insight into its Headstart suite of programmes that aim at encouraging young people to study SET courses for future careers in SET. Currently, participating in such initiatives is limited. We believe that these initiatives should be mainstreamed in schools' curricula in order to adopt an inclusive approach to counteract gender stereotyping of careers and abilities. It is evident that the negative views of girls' ability or interest constitute a major factor in the under-representation of women in SET studies.

Jacob Blickenstaff, in the USA, recognises the complex attributes to female under-representation in science, technology, engineering and mathematics (STEM).

> The factors that remove women from the STEM pipeline can be seen as layers in a sex-based filter; though no single issue can be called the primary cause (Blickenstaff, 2005, p. 384).

Blickenstaff suggests that an intricate problem like this requires a multifaceted solution and he puts an onerous responsibility on the shoulders of science educators,

> Over time, individual actions by sympathetic teachers will help women to break down the filter in the STEM pipeline and result in equal participation, which will be good for STEM and good for society in the long term (Blickenstaff, 2005, p.385).

Although we agree with Blickenstaff about the responsibility of science educators, we would stress that all stages of science and engineering education including university need to be taken into account. The solution is thus much more complex and would need

to include not only the educators taking responsibility but society as a whole, especially making sure that industry plays its part.

The Importance of Learning Environment and Style

"If *how* one learns – learning style - is influenced by gender, then *what* one learns is equally so" (Campbell, 1999, p.30). Katy Campbell describes the masculine values traditionally conveyed in technology based learning. She highlights that technology teaching designs are limited by relying on male-centred experiences and proposes methods for making the teaching more inclusive of women's experiences. Campbell recommends utilising the educational potential of computer technologies for the creation of an inclusive learning environment. Equally, Mbarika et al identify the need to evaluate the learning environment in engineering classrooms and question if the gender of the user should be considered (Mbarika et al, 2003). This view is further supported by the notion that gender-specific attitudes need to be considered during the design process of an information technology dependent learning environment (Proost & Elen, 1997).

According to Frize from Canada, the issue of gender differences in learning styles needs to be addressed when designing initiatives to attract and retain women engineers.

> Women tend to favour relational learning, which associates applications to theory. They enjoy group work and a collaborative approach when there is a critical mass of women in the group. To retain women who have chosen this path, it is important to provide networking and mentoring opportunities and create a climate that integrates and respects feminine values (Frize, 2001, p.34).

Other studies of SET students at varying stages in their career suggest there is a difference in male and female socialisation processes. The appreciation and accommodation of the differences play an important role in the retention of women in SET. They point out that SET subjects are taught in a way that male students are used to learning from, but which is foreign to female students (Etzkowitz, 2000; Gregg et al, 1996).

> That women and men respond to the scientific education system differently is exemplified by a female student's observation, 'Science is a wonderful example of how men just have their own little world – just men and men's ways, and men's concerns, and men's thinking' (Etzkowitz, 2000, pp. 53-54).

Likewise Danish anthropologist Cathrine Hasse noted differences in the way male and female physics students approached their tasks as well as their perception of physics (Hasse, 2000). Heather Stonyer from Auckland University of Technology, New Zealand, makes a similar point when saying that "[w]omen prefer engineering to be linked to social context and needs…and to learn in cooperative classrooms that encourage engagement to peers (Stonyer, 2002).

Additionally, Flis Henwood from the UK reflects upon the need for innovative changes to curricula:

> The prevalence of very limited, and therefore limiting, understanding of the gender-technology relationship within conventional technology curricula and the possibility for challenging the understandings that are offered by more progressive

> and innovative curricula in information technology-based education (Henwood, 1999, p. 26).

Henwood calls for not just rejection of the meanings and subject positions intrinsic in the prevailing dialogue surrounding gender and technology but for understanding the origin of those meanings. Also, Henwood ascertains the need to define alternative meanings and subject positions to establish a broader array of femininities and masculinities that is more inclusive of minority groups (Henwood, 1999).

Powell et al in another UK based study suggest that engineering and related courses have been designed for male students. Hence, the engineering education is not of equal benefit to men and women. This was based on the consideration that women in their study were not completely satisfied with certain aspects of structural and cultural areas of engineering higher education (HE). Powell et al urges HE engineering to review structures, culture, practices and curriculum in order to retain female engineering graduates and improve the appeal of the sector to women (Powell et al, 2004).

The accumulation of barriers to the entry of women in science and engineering is well documented in the literature. The process starts from the very early years of ones life and continues during school education. The old fashioned image of SET and the presumed masculinity of SET professions do not help attract women to such studies and careers. Additionally SET degrees are traditionally conceived by men for men and until recently did not account for minority differences and learning needs. Many researchers recognise gender differences in learning styles when studying to be scientists, engineers or technologists.

In the following sections, we firstly investigate the motivating and encouraging influences that contribute to the choice of study by male and female students. Secondly, we look at the learning support needs of engineering and technology students and investigate socialising patterns/practices of the two genders. We then take a closer look at the confidence level of male and female students in both a lecture and a laboratory environment. Finally, we investigate students' confidence in their own skills upon graduation and their readiness to join engineering or technology professions.

Research Approach

This study used a qualitative and a quantitative approach to data collection and analysis investigating experiences of engineering and technology students as well as qualified engineers and technologists in academia and industry. A review of relevant literature on women in the SET disciplines was also undertaken. The main purpose of the literature review was to identify relevant issues and current practices, to contextualise the research team's findings and find examples of best practice. The review formed the basis for the design of several questionnaires for engineering and technology students, and qualified engineers and technologists working in the North West of England, but who are not necessarily currently working in the relevant field. In this article we mainly report on the findings from the engineering and technology students' questionnaire responses. Our research investigated the experiences, perception and expectations of engineering and technology students with a focus on where gender differences might constitute a significant factor. The questionnaire used was divided into subsections addressing

separate areas: demographic information; study skills; evaluation of learning experience and future plans. 115 questionnaires were handed out to students at the target university of which 59 were returned. The analysis we present in this article is based on the 59 questionnaire responses (48 male students and 11 female students) completed by engineering and technology students at various levels of their undergraduate (UG) or postgraduate (PG) studies.

The questionnaires were analysed with the help of the statistical software program SPSS for Windows. Any further comments added by the participants that did not fit the SPSS variables were coded in the software package NVivo. The analysis of the questionnaires includes the statistics generated from SPSS as well as the various textual comments that the respondents made when expanding on their yes/no responses. In this paper, we focus only on a selection of the questions asked.

We are aware that it is not possible to argue for the statistical validity of the student responses in terms of percentages by gender because of the low number of female students. However, the picture presented might still give good indications about differences between male and female students in terms of background, experiences and expectations. It is worth stressing the fact that the representation of female students in this study is fairly typical of, if not higher than, female percentages in engineering and technology studies in the UK in general.

Results

Demographics

In terms of ethnicity, the student respondents are from a fairly diverse group. Whereas the questionnaire respondents have over 40% ethnic minorities, the Equality and Diversity statistics indicate that the percentage of ethnic minorities at the researched university's school of engineering and technology, is normally about 20-25%. In our study about 50% classified themselves as White-British, about 13% in the different categories of Asian background (includes Indian, Pakistani and Bangladeshi) and approximately 13% as Chinese or Other Ethnic/Asian background. It is important to recognise that this ethnic diversity is most likely connected to the large number of international students found on the engineering and technology courses. Out of all the students 18.6% classified themselves as International students, 57.6% as Home students and 8.5% as European students.

Encouraging versus hindering influences to study engineering or technology

We were interested in identifying why the students choose engineering or technology based degrees by asking an open ended question; What made you interested in engineering or technology? The majority of the students linked their interest in the field either to enjoying the relevant subjects at school or having a passion / a hobby to build objects and investigate how things work or being inspired by a family member. This is reflected in the following quotations from male and female students' responses

> *"I enjoy doing practical things. Also, I enjoyed some of the modules at college".* (Male, UG Technology student)

"General interest in math and physics. Wanting an understanding of how things work". (Female, UG Aeronautical Engineering)

"Interested since a young age – inspired by grandfather who had designed and built his house". (Male, UG Civil Engineering)

"I didn't want to do a typical female course". (Female, UG Civil Engineering)

"Family are engineers and I was always better at maths and physics at school". (Female, UG Aeronautical Engineering)

"My Dad-hobby". (Female, UG Technology Student)

A striking finding from the student questionnaire returns is the number of students who have one or more family members already in the field of engineering or technology. Of the students 61% said they had one or more relatives in the field. Interestingly, only three students reported having a female family member in engineering or technology (two Aunts and one Mother) and those three students were all female. Furthermore, family encouragement was further stressed in many of the male and the female students' comments.

"Actually I studied engineering because my family encouraged me to do that and they encouraged me to do the MSc now" (Male, PG Telecommunications)

"My parents were excited about this idea" (Female, UG Civil Engineering)

"My parents help me with funding and academic support" (Male, UG Aeronautical Engineering)

"Parents just simply want the best for me" (Female, UG Technology Students)

Our findings in essence confirm the persistent stereotype that science engineering and technology are not suitable career choices for girls. If we look at what the respondents answered to the question, Who their encouraging influences are?[4] (see Table 1), it is interesting to note that not a single female student was encouraged by a teacher only. However, a teacher was one of the encouraging people for two of the female students who had a combination of encouraging influences. A female student response to the question, Do you think young women are generally encouraged to become engineers or technologists?, reaffirms the fact that school teachers do not encourage girls to choose engineering or technology as a study and a future career.

"Don't know, I was by my family but not by school/teachers, it still is seen as a "MAN's job". (Female, UG Aeronautical Engineering)

[4] The percentages presented in this scenario and throughout the paper are out of the total numbers of male or female students who responded to this particular question, not counting the missing responses

Table 1: Encouraging influences by gender (9 responses missing, of these 1 female)

		Gender		*Total*
		Female	*Male*	
Encouraging influences	*None*	0	6	6
	Mother	1	3	4
	Father	1	9	10
	Teacher	0	8	8
	Friends	1	2	3
	Other	1	5	6
	Combination	6	7	13
Total		10	40	50

On the other hand, 20% of the male students were encouraged only by teachers to study engineering or technology. It is also notable that whereas 15% of the male students report that they had no encouraging influences, all of the female students who responded had encouragement. This scenario supports the persistence of the outdated notion that engineering and technology are "not usual choices for girls". Hence, the necessity for the extra effort and encouragement to direct women to engineering and technology studies for future careers. Another important discouraging factor that was highlighted by Jensen and Takruri-Rizk (2006) is the lack of female role models for young women interested in SET.

When the students were asked if they considered engineering or technology as an unusual choice for them, only 27% of the female students and 10% of the male students considered engineering as an unusual choice. This means that the majority of the female and male students considered engineering and technology as a usual choice for them which may be explained by : firstly, the high percentage of respondents who have a family member in the field; secondly, the extent of encouraging influences these students had. Clearly, this outcome indicates that the students in our sample had good knowledge of what engineering and technology are about as studies and careers.

Learning Environment

One of the main foci of this paper is the effect of the learning and support environment at university. We asked a number of questions to identify any gender differences in self-confidence and the view of the available support.

One question asked about making use of the skills workshops offered by the university such as Mathscope, presentation skills, revision techniques, report writing, referencing and others. Mathscope is a drop-in facility available throughout the year, aimed specifically at helping students with mathematical problems relevant to their studies. 48.8% of the students in our survey had attended Mathscope. None of the other workshops on offer were used nearly as much. It is possible that students were either not

aware of them or that they needed help in areas other than those offered by the available workshops. Investigating gender differences in the use of such learning support workshops did not reveal any significant difference: similar percentages of male and female students in this survey did use the learning support available, in particular Mathscope.

The questionnaire asked the students about how confident they felt in asking questions in class and doing exercises in the laboratory. From our sample as indicated in Table 2, 78% of the female students rated their confidence as poor or very poor with none rating themselves as having very good confidence when asking questions in class. Of the male students only 27% rated their confidence as poor or very poor, 17% having very good confidence and 56% were neutral or had good confidence. We would argue that the low confidence of female students can be influenced by the experience of being a minority in large lecture classes that are dominated by male students. In addition, in most cases (80% - 90%) the lecturer is male. It would be interesting to know how female students rate their confidence in class participation in subjects where they dominate. Of equal interest would be investigating students' confidence in a gender balanced environment of students as well as lecturers.

Our argument here is supported by the results of the second part of the question which asked about confidence when working in the laboratory where group sizes are much smaller than in the lecture and the students engage in practical exercises. It is evident that the female students tend to be more comfortable with doing exercises in the laboratory than asking questions in a lecture. This result supports Frize's comment that women tend to favour relational learning, which puts theory into practice (Frize, 2001).

Table 2: Students confidence in asking questions in class by gender (6 responses missing, of these 2 female).

		Gender		*Total*
		Female	*Male*	
Confidence in asking questions in class	*Very poor*	3	2	5
	Poor	4	10	14
	Neutral	1	16	17
	Good	1	9	10
	Very good	0	7	7
Total		9	44	53

If we look at the study environment in terms of fellow students, almost 70% of the students reported that they were not in study groups. Looking at the gender split 33% of the female students and 20% of the male students were in a study group. This was consistent with the survey results showing that not many of the students rated study groups as important or very important. We considered this result in light of some of the comments that were given in response to the open ended question asking about what they thought are the benefits of being in a study group? Many of the students, even though weren't members of study groups in some cases, recognised the value of bouncing ideas

off colleagues and that being in a study group contributes to enhancing their own learning.

"Being able to share knowledge and experience" (Female, UG Civil Engineering)

"When helping and teaching each other it reaffirms what you already know" (Female, Mechanical (Aerospace) Engineering)

"You can get help when it's needed" (Male, UG Technology students)

"Get to share ideas and help from colleagues" (Male, UG Aeronautical Engineering)

"Sharing knowledge. Consolidating what I have learned though teaching others" (Male, UG Aeronautical Engineering)

On the other hand when we asked the students about the importance of exchanging ideas with fellow students, 56% of female students and 66% of male students classified this of high importance. The latter result may indicate some degree of contradiction between students' attitude to study groups and the exchange of ideas with fellow students. Here we need to understand the students' perception of a study group as a formal arrangement dictated by the university, in many cases to undertake group work. On the other hand the exchange of ideas with peers is done informally on the students' own initiative.

Career Plans and Expectations

In this section we explore students' plans and ambitions upon graduation. We asked a number of questions attempting to find out: firstly, if engineering and technology students plan to work in a relevant career; secondly, evaluating students' appreciation of taking a year out in industry to gain work experience to help translate theory into practice; thirdly, assessing students' confidence in the skills they obtain at university and how they see this equipping them for their relevant career.

Overall, 83.1% of the students said they would like to work in a relevant field to their study. Of the female students, 36% did not know if they wanted to work in an appropriate industry although none did not want to work in the field. This percentage of undecided female students indicates a higher degree of uncertainty than the male students where only 8.3% did not know if they would like to work in the industry and 4.2% actually did not want to work in the industry. In one way we may consider these results in a positive light as these percentages may not translate to career reality once the students graduate: the statistics from the UK Department of Trade and Industry for the period 1992 - 2002 shows that only 25% of female and 40% of male SET degree holders were actually employed in SET occupations over that period (DTI, 2003). The reasons for the low conversion rate are varied and are outside the scope of this paper.

As highlighted in the above paragraph, the percentages of the students who wanted to work in the relevant industry were encouraging in comparison to national statistics. The responses to the question asking if the students were intending to do or had done a work placement within their degree were not as encouraging. Half of the students did not intend to do an industrial placement as part of their degree. You could argue that this trend is due to the number of international students who usually wish to graduate and return to their home countries as early as possible. However, our data reveals that the international students showed a similar split to home students in planning to do or having

done a work placement. Considering the gender based attitude to work placement, while only 9% of the female students intended to or have done a work placement and 18% were undecided, 44% of the male students intended to or have done a work placement and 12% were undecided. The attitude of students, in particular female students, toward industrial placement requires further investigation.

We suggest a number of questions that would be interesting for universities to consider: Does a university need to emphasise further the benefits of work placements to both female and male students? Are female students in more of a hurry to graduate, get a job and earn a full salary than their male colleagues? How does the attitude of female students to work placements explicate the DTI statistics where only 25% of female SET graduates are actually following SET careers?

Another aspect that we thought was important was whether the students could see a relationship between what they were being taught and working in industry. It would seem that the female students are less convinced of the relationship between what is taught and what is needed in industry. Only 33% of the female students realised how their learning at university may translate into a career in the industry. In contrast, 62.5% of the male students recognised the relationship between what they learn and their future careers.

Table 3 shows that female students were also less confident than their fellow male students when they were asked how confident they were to work as an engineer or a technologist. Only 2% of the male students described themselves as having 'low confidence' compared to 18% of the female students whereas 34% male students described themselves as 'very confident' compared to 9% of the female students.

Table 3: Confidence to work as an engineer or technologist by gender

		Gender		*Total*
		Femal	*Male*	
Confidence to work as an engineer	*Low*	*2*	*1*	*3*
	Neutral	*4*	*9*	*13*
	Confident	*4*	*21*	*25*
	Very confident	*1*	*16*	*17*
Total		*11*	*47*	*58*

The questions in this section investigated the expectation and perception of male and female students towards career related issues. The results highlight the uncertainty of female engineering and technology students regarding their future career in a SET field and have a clear correlation to the female responses to the previous question asking about the relationship between skills taught and industry needs. We argue that the female students' uncertainty and lack of confidence in the skills they learn at university contributes to the low conversion rate of female graduates into females working in the industry as shown by the DTI statistics. Our results confirm Bennett's research finding where professional women were more committed to remaining in the construction industry than female students who have not yet entered the industry, (Bennett et al, 1999). Although the female students are unsure about their skills at graduation, in many cases if they do have practical experiences of the industry, they are able to identify with

their career and consequently, this contributes to their persistence and retention in those careers.

Based on the points of concern raised in this section, we recommend that universities should accentuate the importance of work placements. This is to encourage more students, in particular female students, to complete a work placement. A number of the students' responses to the open ended question concerning what had been the most interesting part of their studies so far, highlight the desire of the students for the integration of further industrial involvement in their studies to be done through visits to relevant industries or by actually spending a year in industry.

"Site visits to bridge and construction sites" (Male, UG Civil Engineering)

"Industrial Placement" (Male, UG Aeronautical Engineering)

"Designing a football stadium" (Male, UG Civil Engineering)

We make the case here that undertaking a work placement would give students better confidence in their skills. Consequently, having reliance on their own skills would result in better translation of SET graduates into SET employees; female and male.

Conclusion

In this paper we presented some of the results of a study focusing on gender differences in students' motivating influences to study engineering or technology. Moreover, some aspects of the learning environment at university as well as students' views of the immediate future upon graduation were investigated. The results show that female students need to be encouraged to study engineering or technology but that teachers did not contribute much to such encouragement. Considering the learning environment, female students were more comfortable in practical sessions rather than in a large lecture theatre environment. When evaluating self-confidence in their skills at graduation, the female students were less confident than their male colleagues.

Based on the above we recognise the necessity of counteracting the gender imbalance in SET studies by making SET a more inclusive area for study and work. There is a need to mainstream initiatives aimed at encouraging girls to study SET within school curricula. At university level there is a need to address and accommodate the issue of students having different, gender-related, types of learning and support needs. In addition, putting the theory of the subjects taught into practice by engaging the students in exercises not only enhances their skills and improves their confidence in what they are learning , it prepares them for a career in the real world. We believe following these recommendations would improve the percentage of graduates actually entering SET careers, in particular female graduates. The research suggests that universities would do well in not only making sure the skills they teach are relevant to a career in industry but also in providing graduates with assistance in making the transition from being a student to becoming a professional. Making sure industrial placements and contacts with industry are part of studying SET could be a way to ensure a definite entry to the relevant industry. Furthermore, the question of identifying with the profession and coping with its culture can be just as difficult for other minorities, whether it is an ethnic minority or people with disabilities, who also have a lack of role models and can be affected by the same issues of isolation and stereotyping. Here we also confirm Jensen's and Takruri-

Rizk's (2006) conclusion that it is useful to focus research projects on engineering and technology learning practices in higher education and in industry and to look at the types of men and women that study engineering or technology in order to gain a proper perspective on the diversity of identity practices and the role gender plays in this process . Understanding gender identities and gender practices should inform the design, the contents and the education style of engineering and technology degrees.

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