
On Gender-Related Stumbling Blocks and Factors of Success in Engineering Education

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Abstract

European society puts strong emphasis on scientific and technological knowledge, and higher education plays a key role in this knowledge based society. Many young women have the capability and the talent to become engineers. Many stumbling blocks, however, lie along the higher education path to a female engineering career. Various studies have found that women do not leave engineering education because of poor academic performance. On the contrary, women who leave engineering degree courses have higher grades than male drop-outs. They evidence, however, a higher degree of academic dissatisfaction. The aim of this paper is to research into those circumstances of academic dissatisfaction. The questioning of engineering students from Austria, Finland, France, Germany, Greece, Slovakia and the United Kingdom in particular have led to more detailed insights: not all dependent factors are generally influenced by gender, the major of the degree course and cultural differences have interfering effects.

Introduction

European research has shown a combination of factors that influence women's persistence, such as feelings of isolation, lack of familiarity with laboratory equipment, lack of practical experience, poor advice and a lack of faculty support (Engler 1999; Heublein 2000; HIS 1995; Lewin 1995; Lewin et al. 1995; Minks 2000; Robst, Keil & Russo 1998). One of the most powerful influences is the lack of self-confidence in intellectual abilities based on low self-esteem due to women's minority status. This result comes especially from North American research (Adelman 1998; Crawford & MacLeod 1990; Rayman & Brett 1995; Sandler & Hall 1984; Seymour & Hewitt 1997).

Another central study, most appropriate to issues discussed in this paper is the American WEPAN study. More than 8,000 male and female undergraduate engineering students from 29 institutions in the USA have been surveyed in the WEPAN Policy Climate Survey: 'Exploring the Environment for Undergraduate Engineering Students.' The survey is modelled after the 'Quality of Engineering Education Survey', which since 1993 has been administered yearly to engineering students at the University of Washington (Brainard, Laurich-McIntyre & Carlin 1996; Brainard & Carlin 1998; Brainard & Carlin 2001). The investigation of engineering students' perceptions of the educational climate at colleges and universities serves to identify the factors that deter women from completing engineering degrees, to explain the higher drop out rates of women engineering students, and to develop measures to increase their persistence rate. The participating 29 institutions have submitted WEPAN study reports to their presidents, deans, faculty, and faculty committees. Task forces have been established to review curricular and programmatic changes, including strengthening of programs aimed at improving the academic and social environment for female students as a means of implementing the recommendations.

Adelman (1998) has found in the USA that women do not leave engineering courses because of poor academic performance. On the contrary, women who leave engineering have higher grades than male drop-outs. They evidence, however, a higher degree of academic dissatisfaction.

The WEPAN study suggests that feelings of isolation due to minority status may contribute to low self-esteem. It has furthermore shown, firstly, that women never catch up with their male colleagues as far as academic self-confidence is concerned throughout their academic careers. And secondly, that men are less affected by poor teaching, poor organisation of course material and by dull course content. The authors suggest further research to draw causal statements regarding confidence level and persistence, especially to explain the apparently lower level of satisfaction of women with the undergraduate engineering experience.

This lower level of satisfaction with the undergraduate experience has also been reported in a study of female science students undertaken by Wolffensperger at the Agricultural University of Wageningen in the

Netherlands (Wolffensperger 1993). In a three-year ethnographic study of factors influencing attrition of male and female students from science, maths and engineering courses, Seymour (1997) reported a misfit between the learned expectations of women students entering science and maths courses and those of faculty and male peers, about the purpose and nature of the undergraduate experience, which led to female dissatisfaction with the courses and subsequently to switching to other degrees.

The climate of engineering departments, courses, and schools plays an important role in women's persistence. In a three-year study, the Women's Experiences in College Engineering (WECE) Project covered over 20,000 undergraduate women and faculty and administrators from 53 post-secondary institutions in the USA. According to Goodman et al. (2002) the reason for women dropping out of engineering majors lies not in a lack of academic ability, but in a discouraging academic climate. It is vital for women to feel part of a larger engineering community. This feeling of belonging is strongly linked to the students' self-confidence in the way that it 'increases when she feels that someone believes in her engineering abilities, cares about her, and wants her to be a part of the community' (IEEE WIE Newsletter Nov. 2002, 3, <http://services3.ieee.org/organizations/committee/women/nov02news.pdf> [10.12.2002]).

Social enrichment activities like guest lectures, field trips, social events can contribute to that. In addition to these social opportunities further support measures (i.e. mentoring, tutoring, skills workshops, career explorations) are particularly crucial during the early undergraduate years. 'Students who held positive views of the climate in their department and their classrooms were most likely to stay in engineering. Those who left often cited factors such as workload, competition, and discouraging faculty and peers' (ibid., 1). Among the recommendations are the providing of academic advisors, fewer required 'grunt' courses in the first two years and more opportunity to pursue interests outside of engineering. 'Networking can counteract the isolation that women experience—providing them with information, support, and the knowledge that they're not alone in the challenges they face' (ibid., 3).

To bring these results into a European context, the research project WomEng has been carried out in Austria, Finland, France, Germany,

Greece, Slovakia and the United Kingdom with the aim of creating 'Cultures of Success for Women Engineers'. One purpose of this cross-national comparison study is to get away from nationally limited points of view. Do the stumbling blocks in engineering education differ from one European country to another?

Methodological framework

On the assumption that certain internal and external factors may lead to gendered differences in expectations, experiences, needs and demands associated with developing engineering careers, one work package of this project was designed to identify factors of success and non-persistence for women in engineering education. Qualitative and quantitative data from all seven European countries involved gave an impression of country-specific differences in engineering education.

The study contributed to comparative education research and used qualitative as well as quantitative methods. The survey involved 1,336 female and male students and included two questionnaires. One questionnaire, comprising 114 questions, was handed to a sample of 699 engineering students, and another with 102 questions to a sample of 637 students with other majors, namely economics, philosophy, natural sciences and sociology. The major part of both samples was between 20 and 23 years old (74.5% of the engineering students and 69.1% of the non-engineering students). The majority of the engineering students questioned were in the middle of their studies, only 4.3% were first year students. The following table shows the proportion of female and male engineering students in the different countries.

Although over 1,300 students participated in the survey, the table below shows that the number of persons in the single cells—combining the two variables country and gender—is only about 50 (sometimes even lower, sometimes a little higher). In some cases (with many items) this led to problems in statistical treatment of the data, while on the other hand the low number called the validity of the results into question. That is the reason why this paper presents only frequencies and percentages, but no statistically significant results.

Table 1. Details of the sample

Country	Engineering students			Non-engineering students		
	Male	Female	Total	Male	Female	Total
Austria	45	34	79	55	58	133
Finland	71	59	130	28	86	114
France	53	53	106	33	40	73
Germany	50	50	100	51	49	100
Greece	40	40	80	32	32	64
Slovakia	49	49	98	51	49	100
United Kingdom	56	50	106	32	41	73
Total	364	335	699	282	355	637

Nevertheless the paper discusses eight interesting hypotheses and the corresponding results of the sample. Those results which confirm the state of the art in the field of ‘women and technology’ can be interpreted as verification of the particular hypothesis. Results which bring new findings should be the starting point of further studies.

Hypotheses

This paper refers mainly to the work package called ‘Success and Non-Persistence’, which aimed at identifying internal and external factors that may lead to gendered differences in expectations, experiences, needs and demands associated with developing engineering careers and factors that influence success or non-persistence in completing the engineering degree. Based on findings in other studies, eight core hypotheses can be defined according to the general assumptions of the work package:

- Hypothesis No. 1: More female than male engineering students would like more non-technical subjects in the engineering degree course.

- Hypothesis No. 2: For women, encouraging fathers are more important for the pursuit of an engineering career than mothers.
- Hypothesis No. 3: Salary potential and employment opportunities are more important for male students. For women, the interest in the subject is more important.
- Hypothesis No. 4: Female engineering students are at a disadvantage concerning interaction with faculty.
- Hypothesis No. 5: Male students see knockout exams more as a challenge, whereas for female students knockout exams can be an impulse to drop out.
- Hypothesis No. 6: All engineering students have thought of dropping out at least once during their studies.
- Hypothesis No. 7: The reasons for thinking about dropping out differ between the sexes.
- Hypothesis No. 8: As to the general reasons for dropping out of their engineering degree course, students more often consider reasons relating to the student body than within the faculty.

Results

The hypotheses, which make gender-related supporting or hindering factors a subject of discussion about success and non-persistence in engineering education, are compared to the results of the questionnaire in the following. All generally discussed results for the ‘total sample’ refer to the sample of all seven countries.

Hypothesis No. 1

More female than male engineering students would like more non-technical subjects in the engineering degree course.

This hypothesis could not be verified in the total sample because more than one third of the males want more non-technical subjects as well, as

does a good third of the females. A closer look at country-specific data shows interesting differences.

In Greece for instance there were no gender differences in the data of this question: 75.0% of male Greek students and 76.7% of female Greek students would like to have more non-technical subjects.

In France, Germany and the UK the data are not simply against the hypothesis; they show the opposite tendency, with more males who would like additional non-technical subjects in their engineering degree course than females. In France, 13.4% female engineering students and 23.5% males would like more non-technical subjects in the degree course. In Germany, 42.0% of the male and 38.8% of the female engineering students want more interdisciplinarity in their degree courses. In the UK, 35.7% of males and 30.0% female students want more interdisciplinarity in their degree course.

In Austria, Finland and the UK the hypothesis could be verified. More Austrian female students (64.7%) than male students (53.3%) would like to have more non-technical subjects included in the curriculum. But interestingly, Austrian students (58.2%) generally want more non-technical subjects than other European engineering students (average number for seven countries = 36.3%). Only 16.7% of the male Finnish students would like to have more non-technical subjects as compared to 35.0% of the female students. 36.7% of the Slovak females want more interdisciplinarity in their degree courses as compared to 22.5% of their male colleagues.

Hypothesis No. 2

For women, encouraging fathers are more important for the pursuit of an engineering career than mothers.

The support of family and peer group is vital for the pursuit of an engineering career. But contrary to the hypothesis, females think that both parents (the answers 'mother' and 'father' also include female and male guardians, respectively) influence them in equal measure and males think that the influence of their fathers is greater. That means females judge the influence from mother or father to be much the same (60.3% and 59.3%), but 53.1% of the males agree with the influence of their mothers and 58.6% confirm the influence of their fathers.

While the results in Finland, Germany and the UK are contrary to the hypothesis, Austrian, French and Greek data confirmed it. In Finland 74.0% of female engineering students were encouraged by their mothers to pursue a career in engineering, whereas only 67.9% received support from their fathers. In the case of male Finnish students the results are the opposite. They consider their fathers to have had more influence on their decision. In Germany, too, the mother was most important for 82.0% of the female engineering students and 73.5% males confirmed the influence of their fathers. In the UK too, the person who is the main source of encouragement for females is the mother (and the father for males).

In accordance with the hypothesis, Austrian females see their father as more encouraging than their mother. Interestingly, Austrian male students say the opposite and consider their mother as having been more important for their decision than their father. In France, the hypothesis that fathers have more influence on females (69.8%) than on males (55.6%) was also confirmed.

The same applies to Greece (69.5% females confirmed that their father played a major role in their decision), but fathers are also and even more important for Greek male engineering students (80.6%).

In Slovakia, the situation is totally different from that in other countries. The engineering profession does not seem to be appreciated by parents. Mothers are thus the most discouraging persons for students of both sexes (77.5% of the female and 79.2% of the male students stated that), or put the other way round, the fathers are slightly more encouraging for both females (61.3%) and males (66.7%).

Hypothesis No. 3

Salary potential and employment opportunities are more important for male students. For women, the interest in the subject is more important.

The hypothesis could be partly verified. Salary potential (72.0%) and employment opportunities (70.3%) are really more important for male students than for females (63.4% and 63.1%). For women, interest in the subject (71.1%) is more important than those two factors, but interest in the subject is also important to men (70.5%).

And the results from the different countries show an even more complex situation.

In Austria the situation partly contradicts the hypothesis: Austrian females see employment opportunities (84.9%) more as an encouraging factor than Austrian males (71.2%), and males agree slightly more with the importance of interest in the subject matter of engineering (77.3 vs. 72.7%) than females. In France, too, one part of the hypothesis only is valid. More females confirm their interest in the subject (73.6%) than their male colleagues (64.2%). But both sexes are nearly equally interested in employment opportunities (47.1% females, 50.9% males) and in the salary potential (67.9% females, 67.9% males). But the interest in the subject is more relevant to females than salary or employment opportunities. The hypothesis could not be totally confirmed in the German sample: while females see 'employment opportunities' and the importance of 'interest in the subject matter of engineering' quite similar to males, they differ slightly in agreeing with the influence of 'salary potential'. A few more males agree with this statement than females (60.0% vs. 54.0%).

In Greece, females—in line with the hypothesis—consider interest in the subject matter of engineering (67.5%) as being more encouraging for the pursuit of an engineering career than salary potential (59.4%), while for males the salary potential is more important (79.4%). But for Greek males—in contradiction to the hypothesis—interest in the subject matter of engineering (69.3%) is nearly as important as are the employment opportunities (69.2%). The Slovak data partly confirm the hypothesis. For Slovak male students employment opportunities (83.3%) and salary potential (77.1%) are more important for their pursuit of an engineering career than for Slovak females (55.3% and 55.1%). But females see interest in the subject matter of engineering as being equally important as their male colleagues do (59.2% vs. 58.7% of male students). In line with the hypothesis, UK females see interest in the subject matter of engineering as the most important factor while for males it is the employment opportunities. Counter to the hypothesis, however, is the salary potential which is more important in tendency for females than for males.

Hypothesis No. 4

Female engineering students are at a disadvantage concerning interaction with faculty.

In contradiction to the hypothesis, more women have advantages in interacting with faculty members than males. Like in this main result from the total sample, the detailed results from Austria, France, Germany, Greece, Slovakia and the UK contradict the hypothesis. In Austria, advantages in interacting with female vs. male faculty members were relatively the same for male students (15.9 vs. 20.0%); females say more often that they had more advantages in interacting with male (31.2%) than with female (14.3%) faculty members than other engineering students. The French results also contradict the hypothesis: it is true that more male engineering students (15.1%) than females (7.8%) state they have advantages in interacting with female faculty members, but on the other hand, more females (32.1%) consider interaction with male faculty members easier than their male colleagues (18.9%). The German results show that 25.0% of the women think they have advantages in ‘interacting with male faculty members’ (16.7% of the men do). In Greece both sexes have advantages in interacting with male faculty members, the females (45.7%) even more so than the males (39.5%). In contrast to the hypothesis, more Slovak females (35.4%) than males (22.4%) say that interaction with male faculty members is easier and both sexes think that they have the same advantages with female faculty members. In the UK—also contrary to the hypothesis—more females than males think they have advantages in interacting with faculty members.

The hypothesis could only be confirmed in Finland, where fewer female students (18.1%) than male students (25.0%) report advantages in interacting with male faculty members.

Hypothesis No. 5

Male students see knockout exams more as a challenge, whereas for female students knockout exams can be an impulse to drop out.

About one quarter of the engineering students of the total sample report so-called knockout exams. Examinations of this kind are intended to sort out students at the beginning of degree courses. One reason for this procedure is the overcrowding of the courses; another reason is the fulfilment of the expectations and images of some studies as being very difficult and elitist.

In Finland and the UK there are fewer (under 10%) and in Germany more students (about two thirds) who report knockout exams.

The hypothesis about the male perspective of knockout exams could be partly verified. But while there are no big gender differences in increasing the self-confidence, more females are apprehensive of these exams and more males (15.6% females and 26.3% males) feel comfortable with them. Fewer Austrian students (13.6%) feel comfortable with these exams, and the proportion of females is smaller than in the total sample (6.4%). The situation in France is more complex. While more males (22.2%) than females (9.7%) think knockout exams lead to drop out, more females (83.9%) are apprehensive of these exams compared to their male colleagues (58.4%). Contrary to the hypothesis, more French females (22.6%) than males (15.0%) say that knockout exams increase their self-confidence. But on the other hand, males feel more comfortable with these exams than females (3.2% females, 22.2% males). In accordance with the hypothesis, German females are much more apprehensive of these exams than their male colleagues are (49.0% vs. 27.1%). And German female engineering students feel less comfortable with knockout exams than males (28.0% vs. 39.6%). In Greece males and females concur that they are both apprehensive of these exams (total: 70.6%, males: 80.0%, females: 66.7%) and they strongly disagree that they do not feel comfortable with these exams (total: 76.5%, males: 100.0%, females: 66.7%). While Greek males (60.0%) agree that this kind of exam leads to dropping out of the course, females (91.7%) strongly disagree with this statement.

In contradiction to the hypothesis, a few more Slovakian male students think that knockout exams lead to drop out (73.5% of the males and 64.1% of the females). 73.0% of all students agree with the statement 'I am apprehensive of these exams'. In the UK—contrary to the hypothesis—more males think that knockout exams lead to drop out (female 37.5%, male 53.9%), but they also more often agree to feel comfortable with

these exams (female 12.5%, male 38.5%) than females. On the other hand more females think these exams are necessary for efficient students (female 50.0%, male 23.1%).

Hypothesis No. 6

All engineering students have thought of dropping out at least once during their studies.

No specific drop out data is generally available for the seven countries covered in this study. Some experts from engineering education state in the interviews that they think data is collected but they do not know where and what the exact figures are. Their guesses vary in a range between 10 to 60 percent. Two thirds of all engineering students know at least one colleague who dropped out of an engineering degree course ('at least one' means that they know 1, 2, 3 or more or they do not know a precise number). In Austria, Slovakia and the UK the percentage is higher—more than three quarters know colleagues who dropped out.

Interviews with students show that the drop out rates are highest during the first year. This can be explained by different expectations about engineering subjects, the heavy workload, and of course the new situation at a university. But in the sample of this study more than two thirds were in the middle of their studies (between third and seventh semester) and 95.7% had already completed their first year. So it was no surprise that the hypothesis that all students have thought of dropping out at least once during their studies could not be verified. One third of the engineering students said that they had thought at least once about dropping out of the engineering degree course.

But there is an interesting gender-specific result. Only about a quarter of the male but nearly a third of the female engineering students thought of dropping out of their engineering degree course. And once again a detailed look at the country-specific results shows a more complex picture: the Austrian situation of males who thought of dropping out is quite similar to the average result, but the results for Austrian females are significantly higher: 28.9% of the male and 47.1% of the female students thought of dropping out. In Germany more students thought of drop-

ping out of an engineering degree course: 36.0% of the male and 42.0% of the female students thought at least once about dropping out. In Finland more males (38.8%) than females (27.3%) thought of dropping out of engineering education. France shows no relevant gender difference in this question: 28.2% of the male and 30.0% of the female engineering students thought of dropping out. While in Greece, only 12.5% males and 17.5% females had these thoughts, the percentage in Slovakia is much higher (46.9% of female and 38.8% of male students). And in the UK, 30.4% of the male and 42.0% of the female students thought of dropping out of their engineering degree course.

Hypothesis No. 7

The reasons for thinking about dropping out differ between the sexes.

Those 33.4% engineering students who thought about dropping out gave the following main reasons:

- Because of the heavy workload (12.6%)
- The course wasn't what I had expected (11.8%)
- When I failed my exams (11.8%)
- I thought of changing to another course (10.1%)
- I didn't know how to learn effectively (8.0%)
- I disliked the subjects (8.0%)
- I didn't feel comfortable (7.9%)
- Because of my future career prospects (7.0%)
- For financial reasons (6.5%).

This overall result must be rounded off with a glimpse through the 'gender glasses', and from this perspective it can be shown that the hypothesis of the reasons differing between the sexes is verifiable:

Female and male engineering students generally explain their reasons for thinking of dropping out in very different terms. Females say they think of dropping out of the engineering degree course when they do not

feel comfortable, because of the atmosphere at the department and because of different expectations from the course. Males see the main reason for their drop out thoughts in their lack of learning strategies, dislike of the subject or financial reasons. These results corroborate the results of Adelman (1998) and Goodman et al. (2002) for European countries. Both studies showed that female engineering students do not leave their degree course primarily because of poor academic performance but because of a discouraging academic climate.

Hypothesis No. 8

About the general reasons for dropping out of their engineering degree course: Students more often consider reasons relating to the student body than those having to do with the faculty.

The hypothesis could be verified. More than three quarters of the students of both sexes think that poor exam performance is the main reason for dropping out of an engineering degree course. More than two thirds of the engineering students also say that different expectations about the course and the heavy workload are also reasons for dropping out. Somewhat less than two thirds of the students think that a dislike of the subject could be a reason and more than one half agrees that students who dropped out from engineering changed to another course. The main difference to the female perspective is that males agree a little more with the heavy workload argument but not so much with the different expectations as main reasons for dropping out of an engineering degree course than females do.

Conclusions

First, a detailed country-specific analysis of European data is very important: the results of some questions show a different picture in the total sample compared to country-specific analyses. For example, in three of the eight hypotheses mentioned the data from the total sample contradicted the hypotheses, while in some countries the hypotheses were confirmed.

And in two others the total sample partly confirmed the hypotheses, whereas the situation in the different countries is even more complex.

Second, European engineering education has a high potential (and need) for improvement: Female and male engineering students think of dropping out because of the heavy workload, the department atmosphere and for other reasons relating to specific universities and institutes (external factors). Students of both sexes wanted to have more non-technical subjects and interdisciplinarity in engineering education, which corroborates results from other studies by Wächter (2004) and Thaler (2006).

Third, stumbling blocks and factors of success differ in the various European countries (see also Thaler 2005), but they also differ for female and male engineering students: For instance, if we want to reinforce the positive influence from parents for the pursuit of engineering careers we must keep some differences in mind. In countries such as France and Greece the father is an important encouraging factor for both females and males. In Austria females also get support from their fathers, but males from their mothers. And in Finland, Germany and the UK encouragement by the father is a key factor for males, while the mother has a decisive role for female engineering students.

We must examine the hindering and supportive factors in the different European countries very carefully in order to recommend the appropriate actions relating to culture and gender.

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