Investigation of the causes for the low attraction of female students in engineering careers

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Abstract

This work presents the comparative results of a research conducted among male and female students of 26 technical universities of European countries. The questionnaires investigate the influence of family, school and social environment in the choice of studies, the correspondence of university programs with the expectations of the students etc. The research was extended, interviewing men and women in the working sphere, where women engineers present slower professional development compared to men. The conclusions of this research are particular important for the configuration of studies at Technical Universities and for the incorporation of women engineers in the technical sector of each country.

Key words: female students, technical studies, engineering careers.

1. Introduction

Throughout the European countries the number of young people undertaking engineering studies is falling, for this reason the European Union focus in intiatives attracting more young people and especially girls, provided that their presence is lower than boys, in the engineering profession. In Greece there is high number of female students in the Schools of Architecture and Civil Engineering but the number of female students to study Mechanical, Electrical or Naval Engineering remains low and the number of female engineers who establish their own company or have a high position in their company's rank remains also low. The under-representation of females in the engineering profession has become a preoccupying factor in Europe, in particular with regard to the fact that up to half the potential talent for the European engineering workforce is missing. However, many studies have shown that women engineers can bring different views, diversity the mono-cultural engineering workforce and broaden the impact that engineering has on society. Women are particularly attracted to and interested in the societal aspects of technology and science. By becoming engineers, women will be able to reach a high level of responsibility and finally to play a significant role influencing company policy, in relation to social and environmental responsibility and improved quality of life. Attracting more women into engineering studies and careers can also contribute to the fight against gender gap in the European society.

The main objective of the research project 'Creating cultures for women in engineers WOMENG', which was conducted from 2002 through 2005 by seven partners[1] was to understand the reasons why women are not attracted by technology in general and engineering in particular and to propose efficient tools that could be used to correct this situation. The number of women engineers can be augmented by increasing the number of female students who study engineering and finish their studies and by reducing the number of female engineers who do not follow an engineering career after their studies. In order to achieve this on a European level it is necessary to understand the procedure someone has to follow to become engineer in each country and which are the factors and social stereotypes influencing the decision of young girls in each stage of their path.

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2. Methodology

The research has been organized into three interlinked items:

I. Reasons for choices: aims to understand the internal and external influences on women's choices towards engineering. Why, when and how do young women decide to choose or not to choose engineering careers. Who influences their choices parents, friends, teachers? In some countries the first key stage for choice can be when the girl is only 13 or 14. If at this stage she chooses not to study physics it is not possible to become engineer. The next important time is to choose a course at university. Then, she must decide to pursue an engineering career so we also look at the first job. How easy was to get this job? How much training does the company give its engineers? How easy is it to become promoted?

II. Success – Non persistence: Not all women who choose to study engineering are successful. So the second theme of the research aims to identify internal factors (like self-confidence) and external factors (such as family support) that may influence success in completing the degree and developing an engineering career or that may cause a woman to drop out of her studies or her career.

III. Organisational culture and social change: This theme aims to identify gendered institutional cultures and structures in higher education and in the professional sphere and to analyse their influence on women's studies and careers.

For the monitoring of the three interlinked themes of the project, comparison was chosen as a research strategy assuming that a comparative approach would provide more than national results and would represent an opportunity to reveal new hypotheses [1]. Tools that were used combine qualitative and quantitative methodology are thoroughly presented in a specific previous publication [2]. The design of the research methodology for large-scale international cross-comparisons implies dealing with:

1. The specific issues of cross-comparisons, either a variable-oriented approach, or a case-oriented approach;
2. The standard problems of research design in human and social sciences, first of all the choice of qualitative, quantitative or mixed methodology, according to the needs of the research topic;
3. The large-scale issue, generating a huge amount of data.

Specifically, a cross-comparative research project has to ensure comparability through the definition of common research objects, common classification, and common scales of evaluation. This is particularly obvious when dealing with a notion as vague as that referred to by the term "engineer", which corresponds to various levels of qualifications and various areas of expertise across Europe. The WOMENG project decided to concentrate on the common characteristics of engineering in all countries. "Engineer" is defined here as an academic degree confirmed by an accreditation board, at master's level, in all scientific and technical areas, excluding agronomy, business and architecture, which are not considered as engineering disciplines in all European countries. As far as possible, existing ISCED and ISCO[2] international classifications were used to enable the use of existing data and facilitate further comparisons. In the quantitative questionnaires, approval and disapproval were measured on a scale of 5, "1" meaning "strongly disagree" and "5" meaning "strongly agree". Even if the participating countries differ by the size of their population or the percentage of students in engineering (Fig. 1), the same number of questionnaires was handed out in all countries.

[2] ISCED = "International Standard Classification of Education" (1997 – UNESCO); ISCO = "International Standard Classification of Occupations"(1988, used by EUROSTAT).

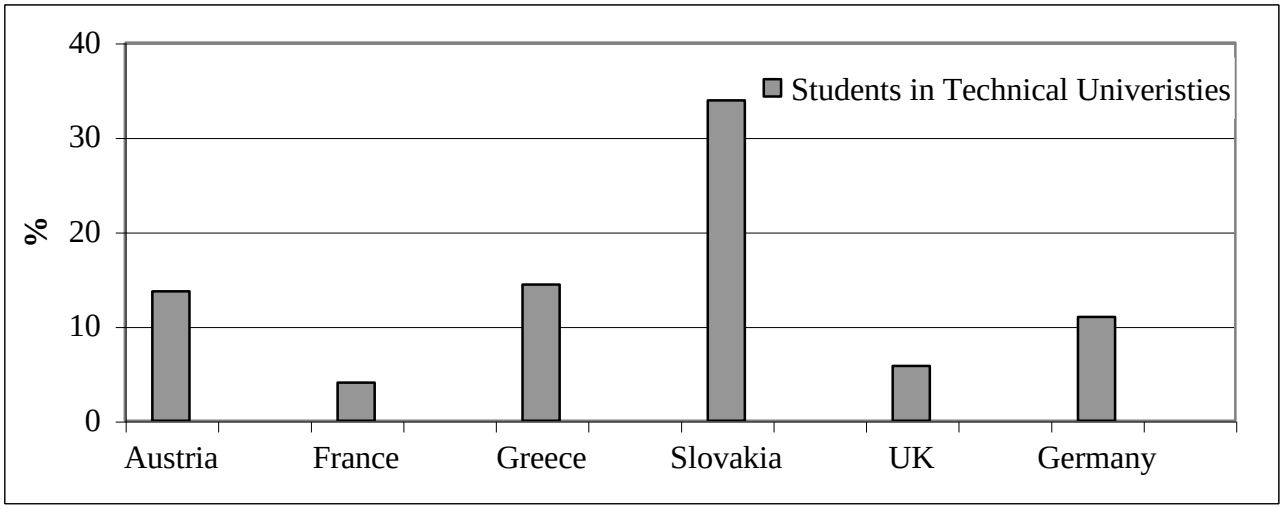

Figure 1: Percentage of engineering students per country

The sampling philosophy was based on three assumptions:

1. The same methodology and sampling method have to be used to compare the situation of women and men.
2. The sampling has to be larger where women are a minority, because their situation is supposed to be more diverse.
3. To understand why people choose engineering or not, it is important to study also the reasons for not having chosen engineering.

Based on these, 200 questionnaires were handed out in each country the following way: 50 male and 50 female engineering students and 50 male and female students who could have chosen studying engineering but chose another faculty. According to the mean percentage of female engineering students in each country, 50% of the questionnaires were handed out in settings where the percentage of women students is low, 20% where it is the average, 30% where it is high. Sampling of non-engineering students is composed of 40% of students in Natural Sciences, 20% in Human and Social Sciences, 40% in Economics. The universities involved in the research are presented in the Table 1. In the professional sphere, three criteria were selected for an exploratory study of two companies in each country: the sampling includes at least one company in the energy sector, one with "good practices" in hiring and employing female engineers, and, if possible, one in the construction sector.

In Greece, the National Technical University of Athens (NTUA) and the Technical University of Patras were chosen for the distribution of questionnaires among students of enginnering. NTUA is the first Polytechnic School founded in Greece with a long tradition whereas the Technical university of Patras was established in 1967 but soon became one of the best known Universities in Greece. NTUA is situated in the capital of Greece, Athens, and the Technical University of Patras in Patras, the third city in population in Greece. The NTUA buildings are settled in a special campus, whereas the building of the Technical University of Patras are settled in the same campus with other University Schools, where the meeting of students from various disciplines is facilitated.

The female students percentages during 1999-2000 especially in Greece were:

- Chemical engineers (42% female students, the highest relating to the other enginnering studies)
- Civil engineers (30% female students)
- Mechanical, electrical and computer engineers (8% female students of 8% which was the lowest)

Accordingly with the above persentages the NTUA questionnaires were selected from:
- 5 female and 5 male students of chemical engineering
- 7 female and 7 male students of civil engineering
- 13 female and 13 male students of mechanical, electrical and computer engineering

and the Technical university of Patras'questionnaires were selected from:
- 3 female and 3 male students of chemical engineering
- 4 female and 4 male students of civil engineering
- 8 female and 8 male students of mechanical, electrical and computer engineering

The number of the completed questionnares per country are presented in Table 2.

Table 1: Universities involved in the research by questionnaires

Country	Q1: 100 questionnaires to engineering students (goal 50 men/50women)	Q2: 100 questionnaires to students who could have chosen engineering, but did not (goal 50 men/50women)
Austria	Graz University of Technology Vienna University of Technology University of Linz	University of Graz University of Vienna University of Linz
Finland	University of Oulu University of Helsinki University of Tampere, University of Jyväskylä	University of Oulu University of Tampere University of Jyväskylä
France	ENSAM in Paris Centrale-Lyon INSA-Lyon Université de Technologie de Troyes ENSCP in Paris	students in social sciences (prep. class. Lycée du Parc, Lyon) students in business and management (prep. class. Lycée du Parc, Lyon) University of medicine (Lyon 1)
Germany	Technical university of Berlin Technical University of Aachen University of Wuppertal Technical Univ. of Applied Sciences, Berlin University of Applied Sciences, Stralsund	Technical university of Berlin Technical University of Aachen University of Wuppertal Technical university of Applied Sciences, Berlin
Greece	National Technical University of Athens Technical University of Patras	Pantheion University Athens University of Economics and Business, University of Piraeus National and Kapodistrian University of Athenss
Slovakia	Technical university of Kosice Slovak University of Technology,Bratislava Technical university of Zilina	Technical university of Kosice Matej Bel University, Banska Bystrica Safarik University, Kosice University of Presov
United Kingdom	Glasgow University Strathclyde University Napier University Edinburgh Heriot-Watt University	Glasgow University Strathclyde University Napier University Edinburgh Heriot-Watt University

Table 2: Completed questionnaires Q1 and Q2 per country

Country	Q1 in engineering students			Q2 in non-enginnering studies		
	males	females	Total	males	females	Total
Austria	45	34	79	55	58	113
Filand	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
Slovak Rep.	49	49	98	51	49	100
Un. Kingdom	56	50	106	32	41	73
Total	364	335	699	282	355	637

When using cross-comparisons in social studies, two main categories are identified [3]:

- A vague and abstract variable-oriented approach, based on quantitative data from many countries. That methodology misses the connections to actual empirical process, social bases and specific phenomena, but enables comparisons between many different countries.
- A case-oriented approach, on the other hand, treats each case as a whole. The drawback of such a method is the difficulty of extending it to a large number of cases because an attention to complexity across large numbers of cases is very difficult. Another sensitive issue is the possibility of generalizing conclusions from a few cases.

Ragin proposes "to formalize qualitative comparative methods without departing from the general logic of case-oriented approach" [3] and recommends "examination of constellations, configurations and conjunctures" that will describe the causal complexity of the phenomenon. From Ragin's conclusions we tried to go beyond a quantitative approach and to develop mixed methodologies. Mixed methodologies, which are still emerging, have been thoroughly described in [4]. In our field, a mixed methodology offered the opportunity to use all the available data, both qualitative and quantitative, with heterogeneity due to the different countries. The WOMENG methodology is iterative and uses three levels of data collection:

I: An overall statistical framework, built from existing gendered national data, expressed in international classifications and when it was possible, collected from EUROSTAT.

II: Specific quantitative data collected by the project on specific questions. The aim was to check hypotheses in a comparative context and to identify significant factors related to choosing engineering. These data were provided by WOMENG-designed questionnaires applied to specific samples in higher education, and by information about selected companies.

III: Qualitative data from interviews, focus groups, participant observation and document analysis. The aim was to understand why and how specific situations may be explained and to find reasons and explanations for results observed in data I and II.

Quantitative and qualitative methodologies were designed to allow mixed and iterative methodologies: some questions are common to questionnaires and interviews or focus groups. The sets of data in seven different countries form a rich database offering possibilities of testing a number of associations, correlations, etc. This means that direct access to the data, which is the usual research situation, is no longer achievable. Our process in reporting and classifying results insisted on the linear process of the interview, which is useful for getting at the inner logic of each interview, but is not very convenient for addressing the same question in different settings.

During the project, we also encountered practical problems. In WOMENG, a crucial issue was the timing for handing out the questionnaire or doing interviews, which can be different from one country to another. The same problem exists with companies; they are not available for questioning at any time of the year. Another problem was to find equivalent settings for handing out questionnaires or carrying out interviews. The questionnaires tended to be too long, so some students or colleagues were afraid of filling them in or answering them because a whole hour was required. This may be the price to pay for the collegial design of common instruments. This collegiality limited the number of different research instruments. The number of interviews and fieldwork about professional sphere per country are presented in Table 3. The design process could be improved in order to be less cumulative and more integrated. The technical process of collecting and reporting must be defined very carefully to avoid missing or mixing up data and the huge amount of data to be analysed must be considered from the beginning. Statistical treatment of the data was long and not so easy due to the large number of questions. After basic processing of the data, all the items were tested from the country and gender points of view according to the nature of the variables: Kendall's tau-b, Somers' D, Spearman's rho, Mann-Whitney test, Analysis of Variance, etc. However, it is essential to combine those quantitative results with qualitative results in order to work on an interpretation.

Table 3: Interviews and fieldwork about professional sphere per country

Research in	Austria	Filand	France	Germany	Greece	Slovakia	UK
Women engineers	2	3	1	2	-	2	1
Hunan Resource Managers	2	2	2	2	2	1	-
Managers	5	6	6	7	4	4	6
Representatives	2	1	1	2	2	3	-
Men engineers	-	-	1	1	-	-	-
Retired women engineers	4	4	3	4	3	4	3
Internet	2	2	2	2	2	-	2

3. Conclusions

Most of girls choose engineering studies because they are interested in mathematics or in sciences at school or because becoming an engineer offers good professional perspectives and social recognition. Despite the differences in the educational system of each country, children are also influenced by the professional status and educational level of their parents and from examples in their social environment as well. In the following figures 2-5, the educational level of parents (mothers and fathers) for male and female engineering students is presented. It is obvious from the greek data that the university education of parents – not necessarily in engineering- is a positive factor for the girls to choose engineering studies whereas the boys choose the engineering studies even if their parents are not university graduates.

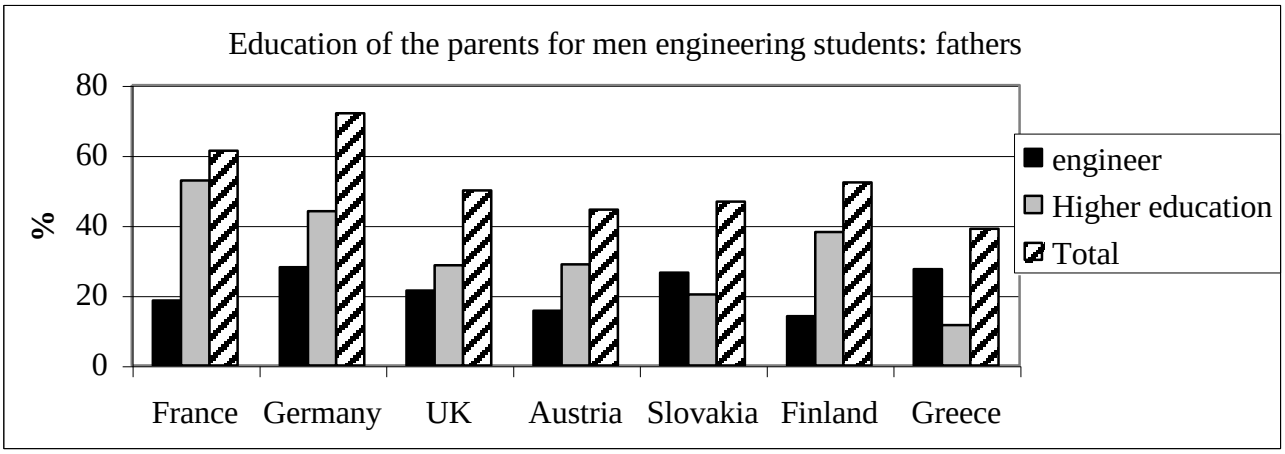

Figure 2: Education of the parents for men engineering students: fathers

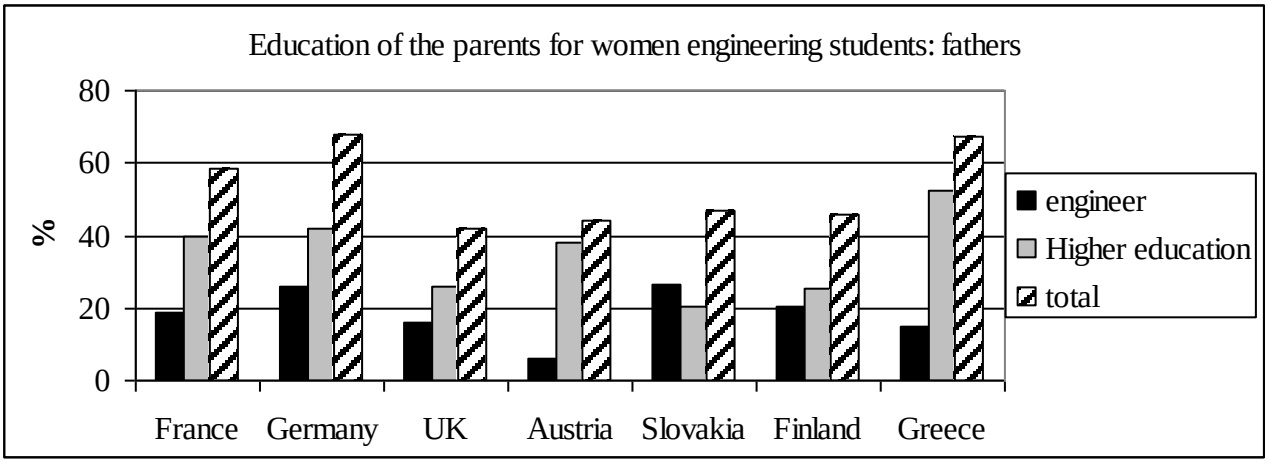

Figure 3: Education of the parents for women engineering students: fathers

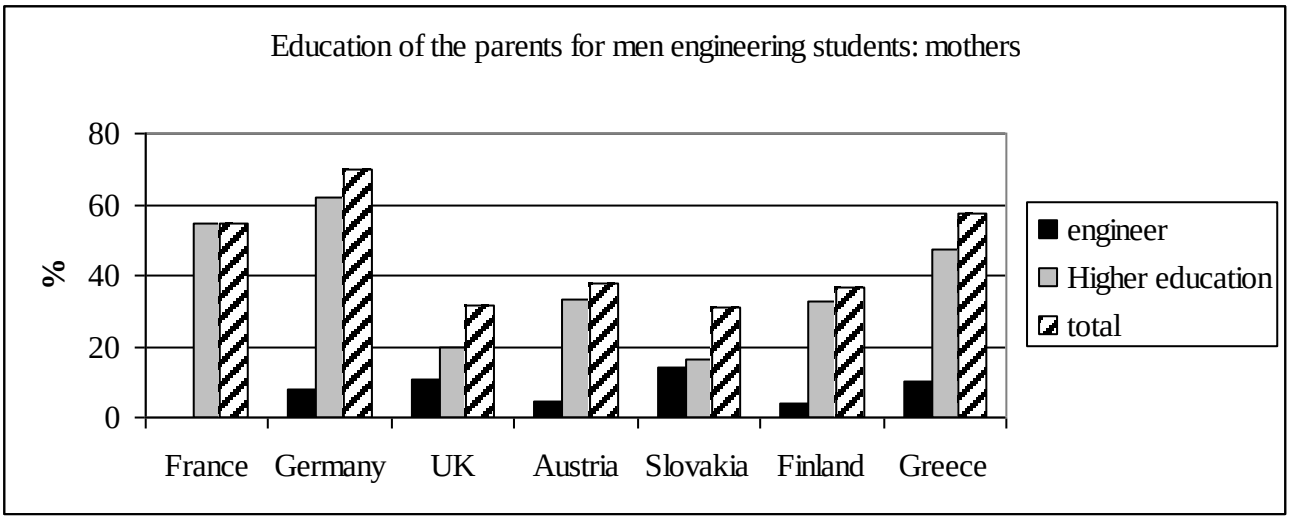

Figure 4: Education of the parents for men engineering students: mothers

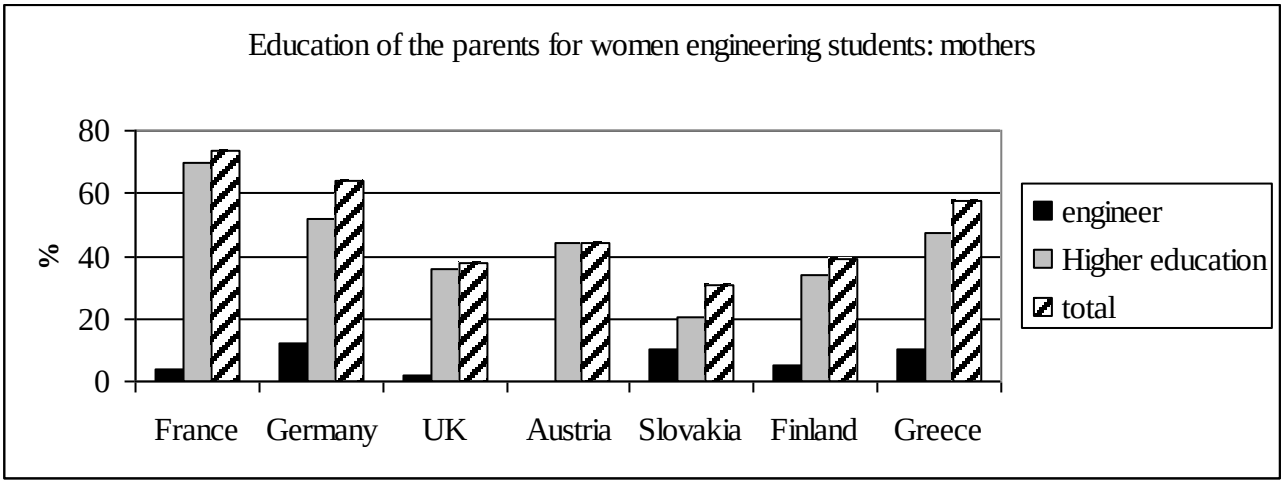

Figure 5: Education of the parents for women engineering students: mothers

In the question if femminity fits with the image of a female engineer, the Greek male engineering students were negative (fig. 6) influenced by the professional stereotypes of Greek society.

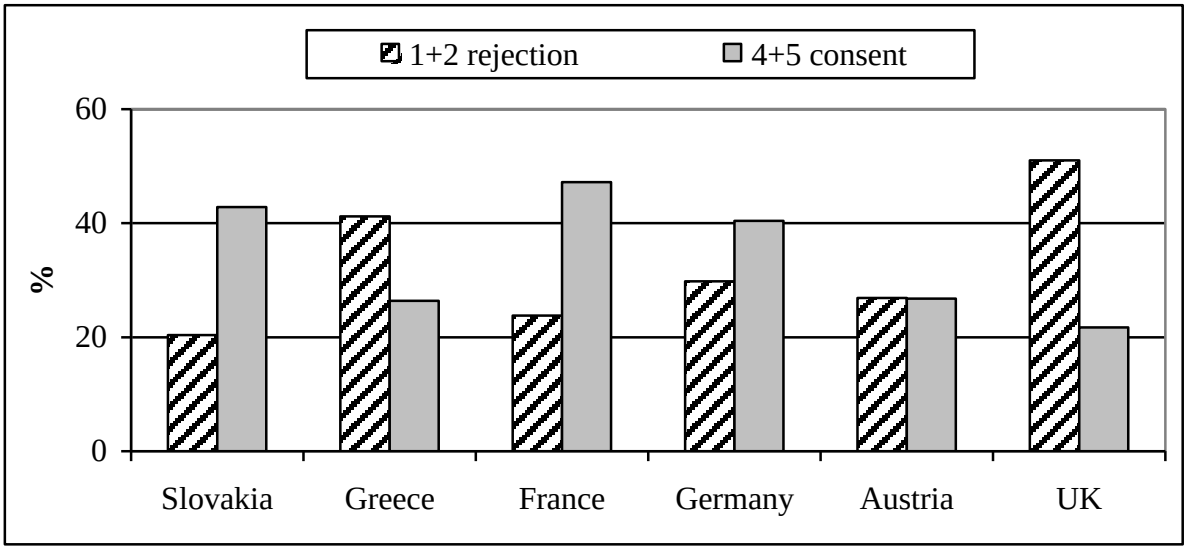

Figure 6: Femininity fitting (%) with the image of a woman engineer (answers of male engineering students).

Two main strands of activity are needed at the level of Higher Education to increase the number of women engineers. The first is to attract more girls (and boys) into engineering by changing the image of the profession of engineers. It is important to emphasise that engineering is a caring subject, responsive to the needs of society by providing more information about careers and courses through web pages, through Open Days for pupils and increased contact between women engineers in industry and university to act as role models and mentors for young girls. The second strand of activity is to reduce drop out once students have chosen to study engineering. This could involve relatively simple measures like providing top up classes for students whose maths or physics is weak, or who lack technical experience, perhaps by providing classes before the main course starts. Welcome events at the start of semester, team work, institutional and peer support will help to integrate female students into the family of engineers. It was clear from our study that introduction of inter-disciplinary courses such as languages and soft skills would make engineering studies more attractive to students, in particular we found, to students who could have chosen engineering studies but did not.

In terms of the labour market, things are much more difficult for women and especially for female working in the technical sector. It was reported that people graduating from engineering schools search for the personal, social and mental satisfaction and that the salary is not the most vital factor. In our samples, both male and female students have similar ambitions and motives. All students, male and female start with the same expectations but female engineers do not get as easily promoted as male ones. From the interviews collected, it was obvious that the stereotypes and the discrimination towards women are present even in the first job. A great difference was apparent between what the companies promise for equal opportunities at work and what is really happening.

Dual carreers, the conciliation of personal and professional life, the pressure and the sense of feeling guilty for not conforming to the expectations of the company and the society are the most frequent problems of female engineers. Companies must take on an active role and make a clear statement that they are not only willing but that they actually will hire technically qualified women. They should include women engineers in their presentation staff at congresses, recruitment fairs, etc., so that young women (and their teachers and parents) can get in contact with them. Companies should get inspired by good practice examples in their field. Good practice companies have a code of conduct that does not allow harassment or discriminative behaviour and they favour the inclusion, or at least minimise the exclusion of women and other minorities.

The WomEng project has confirmed that there is still a long way to go until gender equality in science and engineering is achieved. Special emphasis should be put on close co-operation between institutions of education and companies, integrating both female and male key actors and decision makers. Activities within the organisations should aim at strengthening the positions and increasing the number of women at all levels. Networking and mentoring programs are important ways of bringing women in technical fields into contact with interested young women. Contrary to young men, young women seldom know engineers of the same sex in their environment so role models, are an important source of information, motivation, affirmation, and support. Consciousness-raising programs could appear to increase young women's interest and motivation to pursue careers in science or engineering. To ensure qualitative, vertical feminisation, it is necessary to foster the promotion of competent women in bigger numbers on all levels of hierarchy in companies and universities likewise [5]. In order to implement gender-sensitive recruitment policies, a standard evaluation procedure about empoloyemnt percentages should be established. This would contribute to more comprehensive, gender-specific company data, which up to now are not available.

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