

A Gendered Look at Interdisciplinary Engineering Education

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Abstract

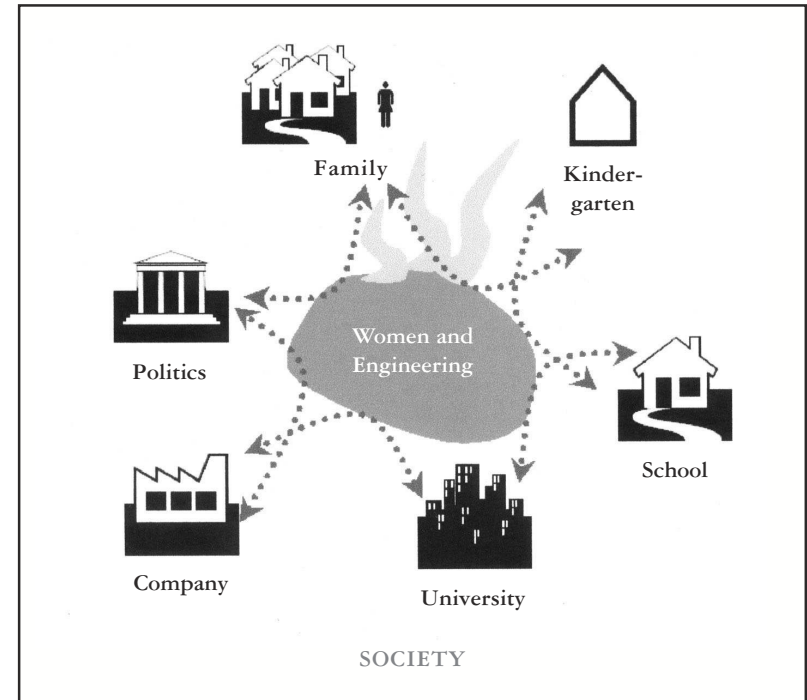
It is widely acknowledged that education institutions and companies that mainly recruit male employees leave out an enormous pool of gifted women. This is especially relevant for the area of science and engineering. In recent years, various studies have shown that what drives women away from technology are not women's deficits in, for example, abstract thinking but the content and the climate of teaching and working prevalent in technical institutions,—institutions that are still formatively influenced by a culture of 'dominant masculinity'. Universities and other training institutions are therefore called upon to improve their curricula, thus making both the climate and the content of teaching appropriate to attract and satisfy both men and women. A one-year exploratory research project was carried out as an Accompanying Measure for the IHP Programme of the European Union, to put the hypothesis to the test of whether a higher proportion of non-technical subjects in engineering degree courses (at least 25 percent) would make these more attractive for women. This paper will draw on the specific situation in Austria.¹

Introduction

General background

The under-representation of women in Science, Engineering and Technology (SET) has been of concern for more than 40 years. Changes have come so slowly that it will take several hundred years and many generations to overcome this unsatisfactory situation if the pace of improvements does not increase dramatically. The slowness of this process is partly due to a phenomenon that we attempt to describe as the 'hot potato model', the hot potato being the issue of women in engineering. What are the reasons for the low participation rate of women in SET? What measures have to be taken to improve the situation? Who are the main agents and actors? Questions like these are passed around like a hot potato fresh out of the oven.

Figure 1. The Hot Potato Model



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A common reaction of interview partners has been to allocate the roots of the 'problem' not within their own sphere of influence but either in areas that come before or after their environment. E.g. in companies you will often hear, 'We would employ women but they don't apply for vacancies' (Wächter 2002, 16). So they throw the hot potato to the institutions of higher education. Higher education representatives often throw the hot potato towards the school system, the step below, or to the next step, the companies, arguing that there are not enough role models around and companies do not offer enough projects for women students. Many interview partners seem to act according to the NIMBY principle,—not in my

own back yard. Obviously the situation cannot be changed with singular activities in any one field, even if one could be agreed upon, but that is not the question. The question is how can we work together to achieve sustainable changes. Steps have to be taken in all areas. And most often, the agents are actors in more than one field. As we are not only managers or teachers, we are also fathers or mothers, brothers, sisters, neighbours, grandparents, friends, and many more. In the following, the focus will lie on the University and Company levels.

It is widely acknowledged that education institutions and companies that mainly recruit male employees leave out an enormous pool of gifted women. This is especially relevant for the area of science and engineering. Various studies have shown that what drives women away from technology are not women's deficits in, for example, abstract thinking but the content and climate of teaching and working prevalent in technical institutions,—institutions that are still formatively influenced by a culture of 'dominant masculinity' (Brainard et. al 1996; Brainard & Carlin 1998; 2001; Copeland 1995; Godfrey 1995; Goodman et al. 2002; McLean et al. 1996). Therefore, universities and other training institutions are called upon to improve their curricula, thus making both the climate and content of teaching appropriate to attract and satisfy the needs and interests of both men and women.

Over the past 20 to 30 years, much research has been conducted, innumerable reports written and huge quantities of statistics gathered in order to analyse and explain the phenomenon, and several theories have been adopted to help in attracting more women to engineering. Some of them have been verified in practice in various model programmes and experiments in several universities (ETAN Report 2000; Lewis & Copeland 1999; Möller 1999; Möller & Ziebel 1998; Möller et al. 1995; Schaare et al. 1993; Schneider & Schmelter 1995; Thom 2000; Wächter 1999a; 1999b). Some of the most interesting theories (Bennett 1996; Kuark 1994; Helling 1994; Hering & Nöller 1996; Ihsen 1996; Kahlert & Mischau 2000; Metz-Göckel & Steck 1997; Metz-Göckel et al. 2000; Roloff 1989; 1996; 1999; Schwarze & Webler 1998; Schwarze et al. 1998) argue that:

- Interdisciplinary degrees appear to be more attractive to female students than single, traditional, classical engineering degrees.
- Single-sex training instead of co-educational training is a central point for women to be more successful in and attracted to engineering studies.
- Project-based learning, small teaching groups, and teaching of non-traditional topics by specialists have been recommended, among others, as factors creating more effective learning environments for female students.

A stronger emphasis should be placed on the social and environmental aspects of technologies throughout technical education. This could be done, for example, by providing interdisciplinary courses which examine the use and impact of technology on societies, including gender and culture, and differences in experience. This analysis should furthermore be implemented in core engineering subjects, thus offering students interdisciplinary subjects that discuss, for example, issues of gender and technology. Engineering departments can work with humanities, social sciences and women studies, encouraging students to cross their disciplines' borders and work co-operatively. The courses offered by the Inter-University Research Centre for Technology, Work and Culture – IFZ for students of Graz Technical University are a first step in this direction. New courses need not necessarily be installed, but existing courses and materials could be scrutinised and evaluated to make supplements that integrate these topics into regular courses. These curricular changes may lead to an overall improvement in engineering education so that not only women but students in general, and so-called 'non-typical males' in particular, would profit from this development.

The project

As far as interdisciplinary degrees are concerned, it would appear that including at least 25% of socio-economic content (i.e. management, business, economics, languages, cultural studies, sociology, politics, psychology, philosophy, ethics, arts, STS – science, technology and society, communications,

law, history, design, gender studies) make them more attractive to women. An in-depth analysis of this hypothesis was the main issue of 'INDECS – Potentials of Interdisciplinary Degree Courses in Engineering, Information Technology, Natural and Socio-Economic Sciences in a Changing Society'. This one-year exploratory project was carried out under the Women and Science theme as an Accompanying Measure for the 'Improving the Human Potential and the Socio-Economic Base (IHP)' priority within the European Union's Fifth Framework Programme (www.indecs.uni-wuppertal.de). Under the co-ordination of the University of Wuppertal (Germany), partners from Austria (IFF/IFZ), Greece (EDEM – Greek Women's Engineering Association), Great Britain (University of Stirling), Finland (Tulossilta Ltd, Tampere), France (CDEFI – Conference of Directors of Engineering Schools of France), Slovakia (University of Technology of Kosice), and Switzerland (University of Berne) were involved from August 2001 until July 2002.

This paper focuses on the specific situation in Austria and concludes with general recommendations gained from the INDECS project. Case studies of degree courses in Mechanical Engineering at Graz Technical University and of Information Management at the University of Applied Sciences in Graz have been elaborated. Based on quantitative data analysis and qualitative interviews with University staff and human resources managers and a representative of the Engineering Association, both the attractiveness and the acceptability of interdisciplinary degree courses in the Austrian university and economic landscape were analysed and recommendations developed.

The case studies

The project team decided to analyse representative degree courses with at least 25% of non-technical, socio-economic content, labelled 'X'. Three examples from participating countries were selected for the following case studies:

- Civil Engineering + X
- Mechanical Engineering + X

- Production – Industrial Engineering + X
- Information Technology (IT) Engineering + X,

where X is the interdisciplinary component, incorporated into the traditional curriculum.

The following remarks draw on the Austrian case studies in 'Mechanical Engineering + X' and 'Information Technology + X'.

Mechanical engineering + X

The first Austrian case study focused on the degree course 'Industrial Economics & Management – Mechanical Engineering (WIW-MB)' at Graz Technical University (TUG).

Concept and philosophy of the degree course

The philosophy of the course is to provide a broad, practically oriented education in science and engineering as well as in social sciences and economics. Outcomes of the course include knowledge of engineering and economics; the ability to think in an interdisciplinary way to solve technical, social and economic problems; holistic competencies, i.e. in addition to disciplinary competence, knowledge of methods to implement and use social skills, such as communicative and conflict solving skills; and an ability to use the acquired knowledge creatively and innovatively on practical problems, taking into account options and limits of theoretical models.

Description of structure and curriculum type

Credit Hours	Fields	%
154	Science & Engineering	74,0
54	Economics	26,0
208	Total credit hours	100,0

Mechanical Engineering is a 10 semester degree course with 3 periods of study: the first period having 2 semesters, the second period 5 semesters and the final period 3 semesters. The first period of study is identical for the

traditional course 'Mechanical Engineering' and for the interdisciplinary course 'Industrial Economics & Management – Mechanical Engineering (WIW-MB)'. Time abroad is recommended and the course also includes 8 weeks of practical training either in industrial placement or with research projects based at the university. There is little flexibility overall, with around 10% of optional subjects chosen individually by the students. The courses are sequential in nature.

Adoption process at institution

The 'FIT – Females in Technology' girls' information programme, which was established on an annual basis in 1992, seems to have been well-accepted and female first year student numbers are increasing (see section 'Attractiveness'). Beyond the scope of this project, however, there appear to be problems of retaining women students once they have entered the system, which suggests there may still be institutional resistance to the changes.

Implementation

The staff at the Faculty, as well as at TUG, is predominantly male. 'Project Management' is taught in English. The subject of the Diploma Thesis is of business relevance, is written in close relationship to the business world and is thus practically oriented.

The new Bachelor of Engineering (B.Eng. SE) course introduced in 2001/02, which comprises the seven semesters of the first two periods of study, has been accredited by the Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers (CCPE). This has led to another 4 credit hours of 'humanities, ethics and social sciences'. These 2 courses must be taken at the University so that the students learn, for example, to communicate with other disciplines, learn about their different cultures, ways of thinking, and approaches to problem solving.

Evaluation methods

Teaching methods include both project work and teachers from industry. A full range of evaluation methods are employed.

Attractiveness

Comparison of numbers of female students in the interdisciplinary degree course WIW-MB with those in the traditional Mechanical Engineering degree course shows many differences in the years covered. WIW-MB has more female first year students from 1997/98 onwards. The numbers of female students in WIW-MB are 25–50% higher than in the traditional degree course. The higher total number of students compared to the traditional Mechanical Engineering studies indicates that interdisciplinarity is also a relevant factor for male students.

In the years covered, the number of total students has constantly and dramatically decreased. The number of first year students, however, has continuously increased. The special information programme for girls aged from 16 to 18, which has been offered every year since 1992, may be one of the reasons for both the stability and the increase in the numbers of female students.

The number of male students in Mechanical Engineering has decreased (-37.3%) to 62.7%, in WIB-MB even more strongly (-43.8%) to 56.2%. The numbers of female students in both degree courses remain stable, thus the percentage increases.

The number of male first year students in Mechanical Engineering has increased (+20.8%), in WIB-MB to a lesser extent (+8.9%). The numbers of female students in both degree courses have doubled or even tripled: from 4 to 9 (+225%) in Mechanical Engineering and from 5 to 17 (+340%) in WIW-MB.

If one compares the numbers of female students in the interdisciplinary degree course WIW-MB with those in the traditional Mechanical Engineering degree course, some variations can be observed over the years covered. The most obvious fact is that WIW-MB has almost twice as many female first year students in 1997/98, 1998/99 and 2001/2002 and four times more in 1999/2000. The numbers of female students in WIW-MB are 25–50% higher than in the traditional degree course.

One explanation for the low number of female students is that 50% of the students are graduates from Technical Colleges (HTL). The number of female graduates from these Technical Colleges is extremely low. Another reason may be found in the culture at the Faculty of Mechanical Engineering,

Table 1. Comparison of numbers and proportions of first year students in 'Mechanical Engineering' and 'Industrial Economics & Management – Mechanical Engineering (WIW-MB)' at Graz Technical University, Austria

First Year	Mechanical Engineering				Industrial Economics & Management – Mechanical Engineering (WIW-MB)			
Year	Total	Male	Female	Female %	Total	Male	Female	Female %
1996/1997	81	77	4	4.9	106	101	5	4.7
1997/1998	69	65	4	5.8	95	86	9	9.5
1998/1999	70	66	4	5.7	76	69	7	9.2
1999/2000	94	92	2	2.1	105	97	8	7.6
2000/2001	91	83	8	9.6	106	96	10	9.4
2001/2002	102	93	9	8.8	127	110	17	13.4

Table 2. Comparison of numbers and proportions of overall students in 'Mechanical Engineering' and 'Industrial Economics & Management – Mechanical Engineering (WIW-MB)' at Graz Technical University, Austria

Students	Mechanical Engineering				Industrial Economics & Management – Mechanical Engineering (WIW-MB)			
Year	Total	Male	Female	Female %	Total	Male	Female	Female %
1996/1997	1,604	1,562	42	2.6	1,838	1,784	54	2.9
1997/1998	1,562	1,521	41	2.6	1,728	1,672	56	3.2
1998/1999	1,504	1,468	36	2.4	1,577	1,521	56	3.6
1999/2000	1,496	1,456	40	2.7	1,527	1,471	56	3.7
2000/2001	1,393	1,352	41	2.9	1,365	1,310	55	3.6
2001/2002	1,020	979	41	4.0	1,056	1,003	53	5.0

which still strongly correlates with a masculine culture of engineering. Students and graduates from the interdisciplinary degree WIW-MB must prove that they are 'veritable engineers'. This might be a reason why the percentage of female students is not very much higher than in traditional Mechanical Engineering.

Acceptability

Feedback from interviews with staff at TUG suggests that both the staff and the students in the interdisciplinary course WIW-MB are more open minded and more open to reforms and changes than those from the traditional Mechanical Engineering degree. However, the culture in the Faculty of Mechanical Engineering is still viewed as primarily a 'masculine culture' with students and graduates from the interdisciplinary degree course WIW-MB having to prove that they are 'true engineers'.

Recommendations

- Improve information about the wide range of careers available with mechanical engineering degrees in particular and engineering degrees in general.
- Improve information to teachers, guidance counsellors and students at key stages for making choices.
- Work to change the masculine culture of engineering.

Information technology + X

The second Austrian case study analysed the degree course 'Information Management' at the University of Applied Sciences in Graz.

Concept and philosophy of the degree course

The study objective of the Information Management degree programme is not only to impart specialised knowledge but also an interdisciplinary methodological approach based on thematically organised training. According to the philosophy of the University of Applied Sciences, Information Management studies are at the crossroads of engineering and

business studies. The graduates are holistically thinking experts with a broad and methodologically well-founded knowledge for the functions of the new information society.

Description of structure and curriculum type

Credit Hours	Fields	%
132	Science & Engineering	75,0
44	Economics	25,0
176	Total credit hours	100,0

The course has a fixed curriculum with 25% Economics and offers no choice for the students. The curriculum includes an interdisciplinary project in the 6th semester, a compulsory practical semester abroad, and a compulsory seminar on 'Societal Aspects of the Information Society' in the 8th semester.

Adoption process at institution

According to the co-ordinator, the number of women decreases during the process from expressing first interest, requesting information material and application forms, to enrolling and participating in the entrance exam to actually taking up studies. No particular efforts are made, however, to create a new organisational culture. Only if the percentage of female students were to drop dramatically below 20% would the co-ordinator think about measures to be taken. The University of Applied Sciences participates in the 'FIT – Females in Technology' information programme for girls aged from 16 to 18, but the co-ordinator feels this comes too late. In his opinion, increased information for girls should be offered from the age of 14 at the latest. Furthermore, he pointed out in the interview that information for girls should consider appropriate language, images, contexts, and examples.

Implementation

The degree course was installed in 1998 and is part of the regular programme. The first graduates entered the job market in summer 2002.

Evaluation methods

Evaluation is carried out in traditional ways through exams, course work, presentations, papers, and project work.

Attractiveness

Statistics show that the number of first year women students at Austrian Universities of Applied Sciences is slowly but gradually increasing (1996/97: 8.10%, 2000/01: 14.12%). The same is true for the Graz case study (1998/99: 17.6%, 2000/01: 20.9%).

Table 3. Numbers and proportions of first year students in 'Information Management' at the University of Applied Sciences in Graz, Austria

Course	Total	Male	Female	Female %
1998/1999	34	28	6	17.6
1999/2000	45	40	5	9.1
2000/2001	75	58	17	22.7
2001/2002	110	87	23	20.9

Table 4. Numbers and proportions of overall students in 'Information Management' at the University of Applied Sciences in Graz, Austria

Course	Total	Male	Female	Female %
1998/1999	28	23	5	17.9
1999/2000	42	37	5	11.9
2000/2001	60	47	13	21.7
2001/2002	97	78	19	19.6

Acceptability

The Austrian interviews have shown that employers would welcome more broadly trained engineers, regardless of their sex. The Graz case could be more successful in attracting women. As the co-ordinator pointed out, 35-40% of women would be welcome but, as already mentioned, he will only take additional action if the female proportion were to drop dramatically below 20%.

Recommendations

- Rhetoric and Communication should come earlier in the curriculum.
- Target group specific information should be offered to girls aged 14.

Questionnaires and interviews

Sample

The questionnaires and interview guidelines were designed for different target groups:

- representatives of higher education institutions,
- representatives of industry and of professional organisations.

The Austrian team carried out six qualitative, semi-structured interviews with the following experts:

- the co-ordinator of the Degree Course 'Industrial Economics and Management – Mechanical Engineering' at Graz Technical University,
- the head of the Industrial Liaison Department at Graz Technical University,
- the co-ordinator of the Degree Course 'Information Management' at the University of Applied Sciences in Graz,
- two representatives from the human resources departments of two international companies in the Styrian Automobile Cluster,
- the president of the Styrian branch of the Austrian Engineering Association.

Main results

Even though the small numbers must be read with caution and do not allow the establishing of absolute values, some conclusions may be drawn.

In all participating countries, employers consider the same factors when hiring new male or female engineers. Only some of them stress family planning, family situation and expectation of mobility as more important factors for women than for men (see Chart 1).

When selecting new applicants the same skills and competencies are preferred for men and women. All employers claim there is no difference between men and women and that both have equal opportunities. That practical engineering abilities seem to be less expected from women engineering graduates could be interpreted as a gender bias (see Chart 2).

Chart 3 explores ways of recruiting more women engineers through interdisciplinary degree courses. Results are difficult to interpret because of different academic traditions in the participating countries. It can, however, be assumed that according to employers and academics:

- Interdisciplinarity appears to be interesting for all students and could help them in their professional lives. Only very few academics and employers think interdisciplinarity would be a waste of time, blur an engineer's identity, and would not help in professional life.
- Interdisciplinarity could help to recruit more women into engineering.
- Even if the interview partners do not agree on the best combinations of subjects, languages (especially English) are considered essential. Business administration, economics, management skills are always proposed as very good combinations. Personnel management, psychology, leadership are interesting even if some experts believe they are difficult to teach. One has to learn those competencies by doing, through experience. Opinions are divergent as far as law, STS – science, technology and society, human and social sciences are concerned. Some consider them to be absolutely necessary, while others see them as optional and not of great interest. Interdisciplinary subjects, such as environmental studies, were also mentioned, especially in Finland and Austria.

Chart 1. Most/least important factors when employers consider new employees

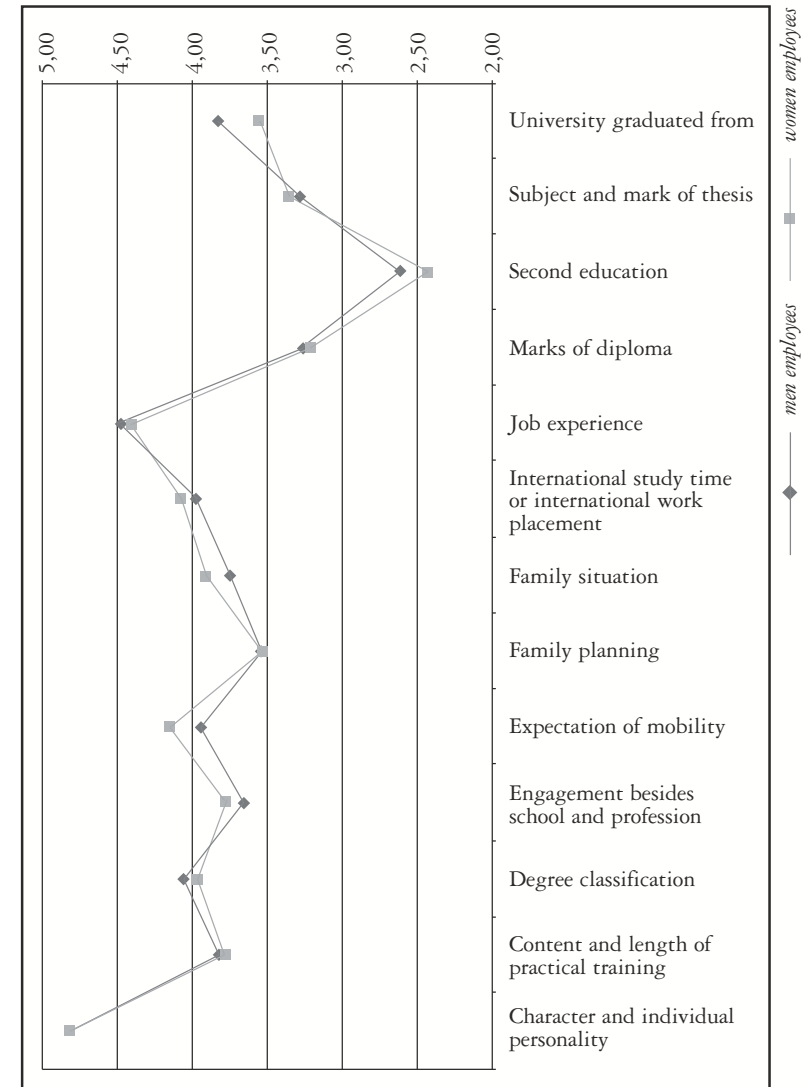


Chart 2. Skills or competencies preferred when selecting engineer applicants for employment

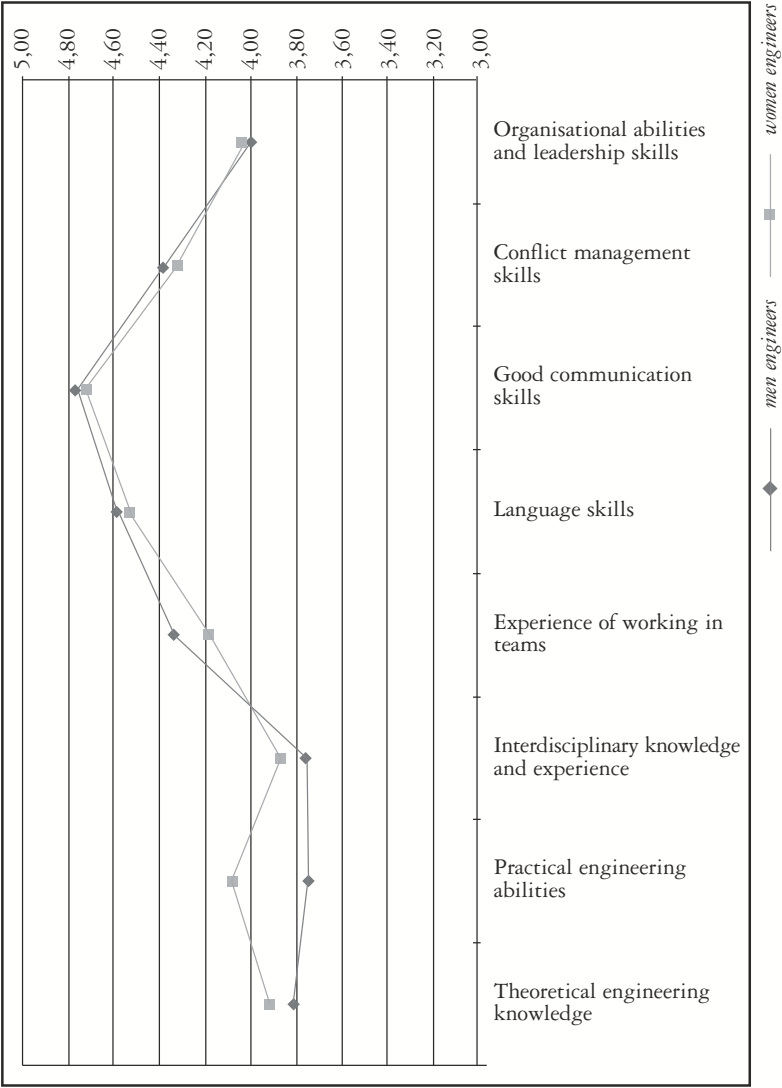
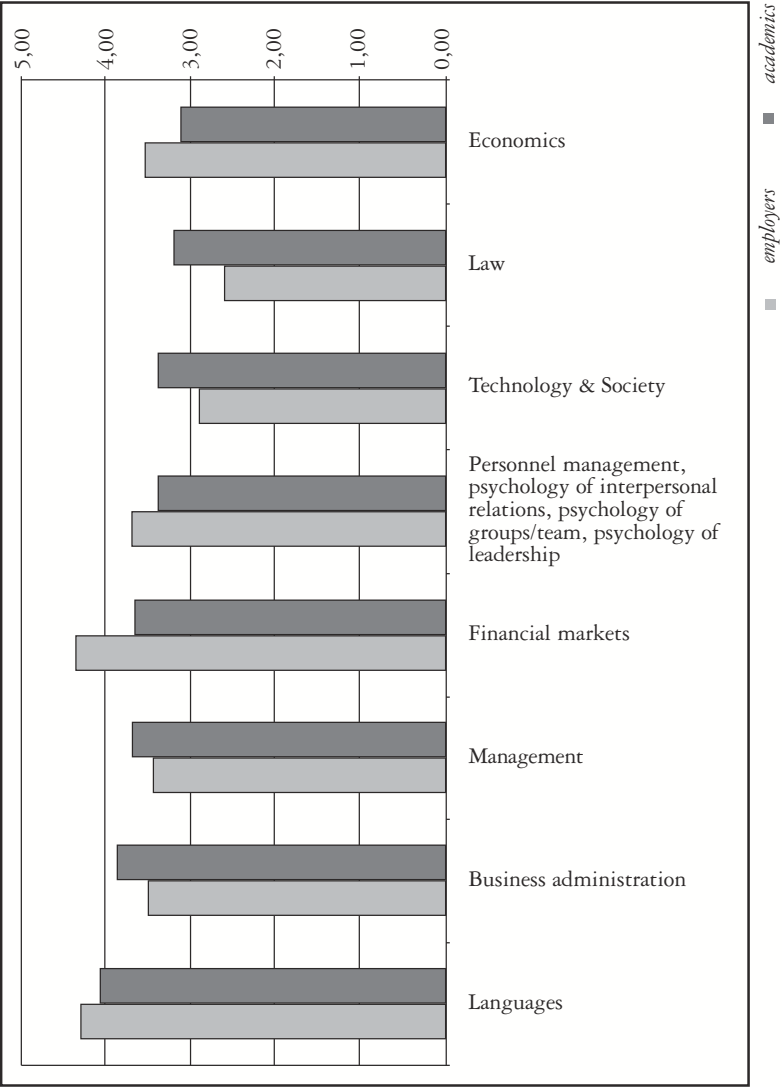


Chart 3. Which do you think would specifically help to recruit more women into engineering?



All three academic Austrian interview partners emphasised that interdisciplinary contents should be taught right from the beginning and come as early as possible in the curriculum. That way students can extend their antennae. Another aim would be to catch the girls' attention and to get them set a foot in the Technical University.

Asked about what measures would be of use to increase the proportion of women in engineering, the Austrian academic interview partners answered as follows:

- B: – *Women-oriented learning environment helps to develop an interest, an approach.*
- *Women (mother, aunt) who are accepted as role models may help as well.*
- *Financial aspects: As long as it doesn't matter for the university how many students study there is no incentive to change the system, the curriculum, etc. Therefore there should be fiscal incentives, e.g. the budget should be connected with the number of women graduates.*
- C: – *Information programmes should start earlier, at the age of 14.*
- *Innovative teaching methods, project work, teamwork are important to keep the drop out rate low.*

Recommendations from INDECS

General degree course recommendations

Interdisciplinary degrees appear to be more attractive to female students than single, traditional, classical degrees. It is therefore recommended to:

- Set up interdisciplinary degrees to increase the proportion of women in engineering.
- Include at least 25% of socio-economic content (management, business, economics, languages, [inter]cultural studies, sociology, politics, psychology, philosophy, ethics, arts, STS – science, technology and society, communications, law, history, design, gender studies).

- Introduce interdisciplinary subjects in the curriculum as early as possible.
- Ensure that information of interdisciplinary degrees and career opportunities reaches students at key stages in order to make an informed career choice.
- Use professional services to prepare this information so that girls can relate to it, using appropriate language, images, role models, context and examples.
- Take measures to improve the image of science, engineering and technology (SET) among girls.
- Install multidisciplinary learning as a step to life-long learning.

Teaching recommendations

It appears that female students can, among other points, perform better in mono-educational programmes, project-based learning, small teaching groups. It is therefore recommended to:

- Create more effective learning environments.
- Introduce gendered mentoring and other support programmes to retain female students.
- Enhance the degree of efficiency ensuring that the socio-economic component is taught by specialists.

Recommendations on institutional monitoring

To evaluate the effectiveness of interdisciplinary degree programmes in increasing the number of female students, it is essential to:

- Gather statistics and set up mechanisms to monitor the effectiveness in attracting and retaining women students.
- Keep gendered statistics on all degree courses in institutions of higher education, including drop out cases, destinations of graduates, internal transfer.

Recommendations on interactions with stakeholders

To promote the acceptance of interdisciplinary degrees, it is recommended to:

- Identify job market demands for engineering graduates from interdisciplinary degrees.
- Seek the involvement of representatives from industry in setting up interdisciplinary degrees.
- Inform institutions of higher education of this avenue to increase the pool of suitable engineering students.
- Governments should make it compulsory for all employers' sectors to publish an annual social report, which should include gendered statistics on career progression.

Comment on results and future research

All of the interviewees confirm that women engineers are needed and welcome. The extent as to what they or their institutions as main actors could contribute to make careers in engineering for women more common and less difficult, however, varied greatly. It is easier to discuss issues on a meta-level and in theory. When it comes to practical work, it would appear that there is still a long way to go.

Affirmative gender equality policy is not likely to be perceived as a bonus for the institutions' image—this is the impression that remains as one result of the interviews. In that context it seems interesting that it is the human resources department of the company with an outspoken and practised gender equality policy that is run by a woman. Is this a coincidence? What implications does the sex of human resources staff have? Are women more likely to hire women or do they have to be even more strict and severe than their male colleagues because every gender-relevant decision they make will be looked at even more critically? What significance lies in their disciplinary background? Are humanities graduates more open to innovatively, interdisciplinarily trained graduates? In what way does age influence hiring policies?

Another aspect that still needs further investigation and discussion is the quality and the varieties of interdisciplinarity. General agreement was found as far as traditional subjects in economics, law and language are concerned. Meanwhile, all degree courses have such classes in their curricula. It is not only the amount of credit hours that matters, i.e. the assumption of >25 percent in INDECS, but also what subjects should or could be included. How far away from mainstream can they be? How immediately obvious must a potential economic benefit for the future employer be? Must all skills have direct economic utility? How can this usefulness be measured?

The INDECS team started to work on the three year research project 'WOMENG – Creating Careers of Success for Women Engineers' in November 2002 (<http://womeng.net>). Three work packages focus on internal and external influences at key moments of choice for women towards engineering, internal and external factors leading to success or non-persistence, and the gendered culture of engineering in institutions of higher education and the professional spheres and how that affects the career development of women engineers. A set of executive policy recommendations will be elaborated to enhance the success and persistence of women engineers.

Note

- ¹ This paper is based on the work for an article published in Werner Lenz and Annette Sprung (Eds.) (2004), *Kritische Bildung. Zugänge und Vorgänge*, Münster (see Wächter 2004).

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