

Gender and diversity as integral part of engineering education - Review of SEFI conference papers and articles of the European Journal of Engineering Education between 2005 and 2011 for future conclusions

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INTRODUCTION

The question of women's participation plays a significant role in engineering and science education by the demographic change, the lack of specialists in research and engineering and the strong claim of equal rights for women and men [1, 6]. Accordingly, high technology industry accepts the diversity argument in case of mixed teams expecting positive results in innovation cycles. This means better results by more creativity and faster innovation processes.

Actually, a considerable amount of papers, presentations and articles had been produced over the last decade. Those articles discuss questions like career choices of women and men (including the influence of social classes, former school subjects and grade), university drop-out rates and their reasons as well as career choices and leadership. The results of all research run in the last 25 years may be focused on the central question: Which strategies can help successfully integrating women and other minorities in engineering education and labour market.

This paper³ will attempt to give a better understanding of gender and diversity in technical studies by a systematically review of 60 SEFI conference papers and project descriptions and 33 articles of the European Journal of Engineering Education (EJEE) published between 2005 and 2011 including three special issues. Therefore we have updated our previous literature review presented at the IGIP-SEFI Annual Conference 2010 [3, 5]. Improving the effectiveness and sustainability of gender and diversity strategies at universities in engineering education by quality management will help to enforce gender equality, family-friendliness and diversity in engineering.

1 LITERATURE REVIEW

The number of scientific publications in the field of gender and diversity in engineering and science education had greatly increased in recent years. While the search for relevant articles in the science database "WEB of SCIENCE" showed 40 hits in the year 2005, there were already 138 hits six years later⁴. This development reflects the great challenges for scientists, decision-makers and politicians, when they are faced with the challenges to quickly get an overview of the current state of art. This

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⁴ We search for „Gender“ AND „Engineering“ and take into account all offered document types. For details see <http://apps.webofknowledge.com>.

article will systematically reflect the discussion and critically evaluate the quality and sustainability of activities it in the light of the gender and diversity research.

It seems to be necessary looking beyond these individual contributions given the importance gender and diversity making sure that enough technical specialists are available and equal opportunities are enforced for women in near future. Therefore we accomplish a literature review: Subject of this are 60 papers and projects that were presented at annual conferences of the European Society for Engineering Education (SEFI) and 33 articles that were published in the European Journal of Engineering Education (EJEE). The latter include three special issues: Volume 30, Issue 4 2005: Theme issue on gender studies in engineering and engineering education; Volume 31, Issue 1, 2006: Special Issue: Gender Studies in Engineering and Engineering Education; Volume 34 Issue 5, 2009: Special Issue: Diversity concepts and experiences in engineering education. The period under review is 2005 – 2011. SEFI and EJEE have been selected with a view to their importance and specialization in engineering education in Europe.

Our analysis is based on the classification of the publication, based on 24 presentations held at the VDI⁵-run 1st European Conference on Gender and Diversity in Engineering and Science in 2009. The abovementioned EJEE special issues fit also into this scheme. The research topics identified prior were [3, 5]:

- (1) Women Leadership: The review shows gender similarities between female engineers and other professional groups.
- (2) Models of Work-Life Balance in Engineering and Sciences: Analyses concentrates mostly on cultural aspects in technical oriented industry and engineering profession.
- (3) Changing the Engineering profession – Changed Professional Image: The results show a wide research area including topics like female role models, occupational images, comparison and interpretation of European or international statistics.
- (4) Gender Relevance in Engineering Education: This category includes all activities on the wide field of engineering education and didactics, mostly on the project level.

First, we evaluate the content of each individual contribution; then we compare the results with one another and with our prior classification [7]. The four main categories which were supplemented and specified on the empirical material are:

- (1) Topic,
- (2) Research Orientation,
- (3) Authorship,
- (4) Diversity perspective.

2 RESULTS OF THE EVALUATION

2.1 Topic

The categories of main research topics are modified according to the findings of the extended analysis in this review. Accordingly, the first category “Women Career and Leadership” is extended to include new aspects of unequal career prospects and information about careers in science. The third category “Changing the Engineering Profession” includes now also aspects of faculty climate. The fourth category “Gender Relevance on Engineering Education” is enlarged in order to take into account university selection processes. Additionally, the sequence of topics has been changed in order to their relevance.

Summarizing the total number of 60 papers and 33 articles the topics that are covered can be clustered into four different categories:

⁵ VDI: Association of German Engineers (Verein Deutscher Ingenieure)

- (1) Gender and Diversity Relevance in Engineering Education,
- (2) Cultural Change in Engineering Education and Professional Practice,
- (3) Women Career and Leadership, and finally
- (4) Models of Work-Life-Balance.

Table 1: Main research topics

Topic	SEFI	EJEE	Total	Total %
Gender Relevance in Engineering Education	33	21	54	55,1
Cultural Change in Engineering Profession	21	7	28	28,6
Women Career and Leadership	10	5	15	15,3
Models of Work-Life-Balance	1	-	1	1,0

With a total of 54 papers and articles (33 SEFI papers and 21 EJEE articles) most contributions fall under the first category (1) gender and diversity relevance in engineering education (see Table 1). The subject of interest ranges from high school education to early university education and finally higher university education. This includes projects that are searching for solutions in order to raise the interest and motivation of high school students in dealing with technical systems from a very early stage in the educational system and probe the influence of secondary school experience on students' choices to pursue an engineering course of study at the university. Further on new strategies that attract a gender-balanced ratio of students and different approaches on how to recruit and retain more female students in science and engineering are being examined. Therefore authors analyze factors that influence diverse students in their decision of joining engineering education programs and identify impacts that indicate an institute of higher engineering education is woman friendly. Others describe and evaluate projects at a single university or in inter-university cooperation that promote gender equity in the engineering curriculum, including investigations of attitudes of the teaching staff towards aspects of gender and diversity and the measurement of the effects of teaching methodologies. Finally, not only gender but also national diversity in terms of foreign students is being considered in this category. Technically speaking diversity is mainly understood as the inclusion of foreign students and foreign language as well as intercultural competencies in this context.

The second category (2) cultural change in engineering education and professional practice includes 28 papers and articles (21 SEFI papers and 7 EJEE articles). Roughly two different approaches – institutional and individual – can be recognized.

- From an institutional approach authors and presenters discuss the importance of gender awareness in the spheres of education and professional practice and demonstrate the gender typing of different engineering branches. Central is the necessity of changing the organizational cultures at engineering departments and degree courses as well as in industry. Furthermore they identify educational strategies in order to better prepare engineers for an inclusive and participatory professional life and describe university-wide strategies (departments, study programs, gender & diversity management) for the inclusion of gender and diversity aspects. Finally they show connections of changes on the societal level and changes in the field of engineering (education and professional practice).
- Individual approaches suggest how to empower students to analytically reflect images of people and technology, and analyse male and female self-perceptions. Furthermore they identify the prevalence of male dominated language in the engineering education and profession. Overall, the contributions show a good integration of female students in engineering education on a social level, but not on a professional level.

A total of ten papers and articles (5 SEFI papers and 5 EJEE articles) range in the third category (3) Women Career and Leadership. Authors and presenters in this group put their focus on identifying areas where women are underrepresented and in this regard they examine women's career prospects and problems experienced by women in the field. Therefore they analyse working conditions of women engineers and researchers and investigate the leadership experience and the leadership competency of male and female students. In several cases authors describe and evaluate projects that aim for a higher degree of inclusion of female scientists.

Surprisingly the fourth category (4) Models of Work-Life-Balance contains only one paper that was presented at a SEFI conference. While the compatibility of family and work is often seen as the major obstacle for women who want to pursue a career it did not draw a lot of attention from researchers in the field engineering education. This might be due to the fact that only a few female students already have children. The single paper describes an example on how engineering education can react to students' work-life-balance needs. Accordingly the challenges for professionals in engineering and science were not subjects of the underlying analyses.

2.2 Research Orientation

Looking deeper three different research methods can be observed in the papers and presentations taken into account (see Figure 1):

- (1) Description of the Current Status,
- (2) Qualitative, Quantitative or Mixed Methods Design Analysis, and finally
- (3) Evaluations or Descriptions of Projects.

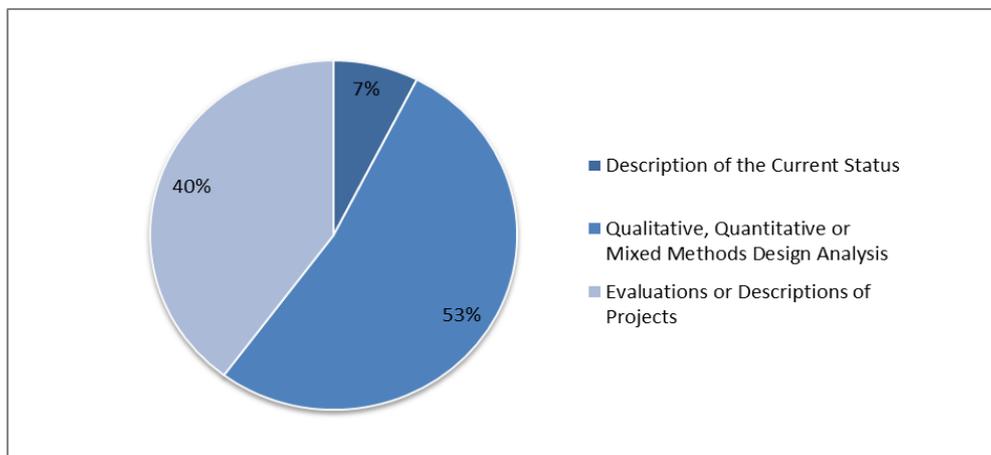


Fig. 1: Distribution of the research orientation

A small number of papers and presentations (7) give mainly an overview, a summary or a description of the status quo or existing knowledge in different regions. In this group authors mainly draw overall pictures of the existing knowledge on female scientists or students and identify gaps in gender research, for example by secondary research on existing statistical data of female undergraduate engineering students.

The method used most frequently (49 papers and presentations) is empirical research consisting of either qualitative and quantitative approaches or a mixed method approach.

- The qualitative projects include interviews, case studies, gender analysis, focus groups, ethnographic research, homepage analysis, participant observation, and diary methods. Interviews for instance were conducted with female and male as well as with international students, mentors, representatives of Higher Education Institutions and professionals. Gender analyses were conducted e. g. on faculty culture and milieu. Participant observation in

selected courses and focus groups with students (of both genders) and teachers were used to evaluate teaching and coaching methods; also focus groups with women engineers were used for drawing consequences for engineering education. In one case diaries of international students were analysed, in another case those of female research scientists.

- Quantitative research projects include questionnaires, quasi experiments, as well as secondary research from statistical data and gender analysis. Questionnaires were applied for investigation among graduates to identify the individual aspects of job satisfaction, to explore perceptions in main skills areas and to identify the various qualifications building the profile of a prospective mentor. Questionnaires were used for drawing conclusions on study conditions and gendered or culture-related preferences among students of both genders as well as from engineering and non-engineering backgrounds. In the quasi-experiments a series of tests were applied in order to measure the effects of teaching methodology and social factors in academic performance. An in-depth gender analysis was conducted on university faculties.
- One example among others for a mixed methods approach is the EU-funded projects WomEng⁶ (2002-2005) and PROMETEA⁷ (2005-2008). A total of six SEFI-papers in the period from 2005 to 2007 is based on data out of WOMENG, one additionally on PROMETEA data.

Finally the third empirical method consisted of evaluations or descriptions of single and multiple projects (26) as well as university and educational strategies (11). Projects described in this category range from networks and network opportunities, initiatives that support an institutional change for a greater inclusiveness of female scientists. In addition this category include activities to improve cultural intelligence and understanding, the creation of knowledge communities, international as well as interdisciplinary student co-operations, courses preparing graduates for the various requirements of professional practice (e. g. distributed, transnational project management), preparatory courses for international students, student exchange programs, evaluations of learning methods applied in multi-/international contexts to projects attracting school girls to science, engineering and technology.

Strategies described here address general questions regarding curriculum development (e. g. developments to include more co-operative learning practices in the curricula), efforts to integrate gender and diversity aspects into the engineering education as well as in the universities' marketing and motivation programs, university-wide strategies in gender and diversity management, descriptions of university admission structures and conceptions and descriptions of new study programs or university departments.

2.3 Authors

The 93 papers we are taking into account for this summary were published by 225 Authors. 146 prepared and presented conference papers at SEFI Conferences and 79 authors contributed articles to the EJEE. While the majority of 152 authors was female, there was also a significant number of 73 male contributors.

The authors have diverse geographical backgrounds and come from as much as 30 different countries. While the majority is originated in European countries (17) they are also of Middle-Eastern (4), Asian (3), South American (3) and North American origin (2). If we take a closer look at the single countries the vast majority of contributions stems from German (59) and US American (30) scholars.

⁶ Creating Cultures of Success for Women Engineers - WomEng, see: <http://www.erziehungswissenschaft.uni-wuppertal.de/de/personen/weitere-personen/felizitas-sagebiel/forschung-projekte/eu-projekte/womeng.html>

⁷ Empowering Women Engineers Careers in Industrial and Academic Research – PROMETEA, see <http://www.erziehungswissenschaft.uni-wuppertal.de/de/personen/weitere-personen/felizitas-sagebiel/forschung-projekte/eu-projekte/prometea.html>

The specific research view of the authors can be clustered by the professional background of the main author: While there are a few practitioners among the authors (12 authors have a professional practice background, predominantly in consulting) the great majority of authors have a research institute affiliation. These academics come quite equally from technical and social science faculties. However multitude of perspectives is worth noting when it comes to the gender distribution of the contributors (see Figure 2). While among the academics from technical backgrounds male (50) and female (53) authors are equally represented, social scientists who contribute papers and articles in the field of gender and diversity in engineering and science are, with 83, predominantly female (and 18 male).

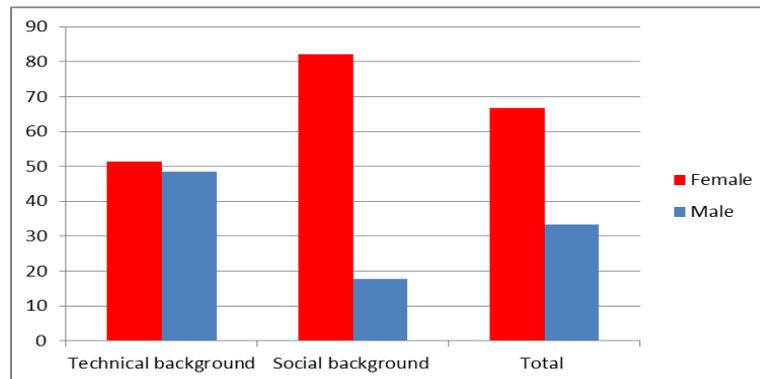


Fig. 2: Researchers' sex of the main author by faculty

2.4 Sections

Diversity Management in Higher Education aims a productive overall atmosphere, to prevent social discrimination against minorities and to improve equality of opportunity. The focus is set on the totality of members and their differences and similarities, not only on minorities (e. g. female engineers, people with specific needs). In this sense, Diversity Management in Higher Education aims a positive perception and constructive use of social diversity. Individual differences of organizational members are valued in terms of gender, ethnicity, age, disability, sexual orientation, religion, lifestyle etc., in terms of a positive appreciation.

The examined papers and articles spread quite unequally across the different diversity dimensions. The great majority (60) can be categorized under the dimension Gender Equality on all Levels of Qualification. Nationality and Internationality is the second most common dimension with 16 papers and articles. Although Models of Work-Life-Balance are only discussed in one paper, the Promotion of Family-friendly study and working conditions for both genders was addressed in seven papers. The categories Adaptation to the Needs of the Disabled and Chronically Ill, Age and Intergenerational Learning, Religion and Conviction, and Sexual Identity are missing.

3 CONCLUSION AND FURTHER WORK

All in all, the analysis showed that gender and diversity issues continue to play a significant role in engineering education. The professional culture of engineering has to deal with new requirements: An increasingly lack of skilled personnel in technical jobs, exacerbated by the demographic change, leads to several strategies of integrating new groups into the engineering profession, especially women.

This trend towards more diversity in high technology and engineering services is reinforced by the great need to come closer to further issues and today's market. It means a multitude of perspectives and a change of business culture by working interdisciplinary. The development is being accompanied by the political demand for equal rights of all humans.

This review showed a high consistency in theoretical approach, methodological background and scientific outcomes. Almost all examined papers and presentations are more or less strongly related to

gender and diversity studies, using methods of social sciences (e. g. interviews, questionnaires and statistics) and focusing on engineering. Also all papers and presentations show a unique scientific outline, scribing a specific problem and their theoretical and methodological perspectives; then describing the changing process and the results, followed by measures of quality assessment and evaluation. However, it is regrettable, that some papers accept sex as a social category without any further discussion of current gender theory.

The unequal distribution of topics shows that the research is still very much focused on culture and environmental studies, whereas the problem areas "Women Career and Leadership" and "Models of Work-Life Balance" play a rather subordinate role (see Section 2). Making engineering for other groups more attractive, it must be succeed to integrate all groups into the study program and the labour market. These require target group oriented curricula's, equal opportunities for women and men and improvements in work-life balance. Currently it seems that some strategies of integrating new groups into the engineering education lead without knowledge to blind activism.

The analysis of authorship shows a strong European orientation. On the one hand this might be due to the selection of EJEE articles and SEFI presentations; on the other hand the under-representation of women in engineering is a particular problem of Western European Countries and the USA [6].

More or less equally authors have a social sciences and engineering background. Only a minority are practitioners. About all papers and presentations it is possible to categories three different research perspectives. Research view from:

- Outside science and engineering
- Inside science and engineering
- Project level.

Over all publications discussed in this paper, we have also found a high consistency of outcomes:

- Growth in engineering depends on the high rate of foreign students in Germany and Western Europe [2]⁸.
- Integration in the university on a social level is very good, but not on a professional level.
- Drop out of female students and engineers out of their professions do not depend to the family balance but to their social and professional integration into the engineering culture⁹ [4].

A point that still attracts criticism is the lack of sustainable quality management of projects and programs in engineering education. Although we have found a lot of named "best practice" in gender orientation, there is little systematical analysis on effectiveness of these practices. It is hardly surprising, that effectiveness analysis of gender and diversity activities are often missing.

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⁸ Please refer to the project homepage of Spurensuche! for more details: <http://www.gender.edu.tum.de/spurensuche.html>

⁹ Please refer to Potenziale nutzen, Ingenieurinnen zurückgewinnen - Drop Out von Frauen im Ingenieurwesen: Analyse der Ursachen und Strategien zu deren Vermeidung sowie Handlungsempfehlungen für eine erfolgreiche Rückgewinnung. 2009 for more details: <https://www.gender.edu.tum.de/abgeschlossene-forschungsprojekte.html>

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