Natural Sciences in the Information Society

First Experiences

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Abstract— **The goal of the GALILEA project is to design and implement innovative programs and curricula, providing solutions to the changed job specifications for engineers and natural scientists and are capable of attracting more female students to these programs. In this article we outline the design, implementation and the first evaluation results of our pilot program, the bachelor course of "Natural Sciences in the Information Society" that started in the winter term of 2007/08.**

Keywords- engineering education; natural sciences education, gender studies; e-education;

I. INTRODUCTION

For years experts have warned that the number of graduates in engineering and natural sciences fails to meet the growing demands in a high-tech society [1, 2] (c.f. Figure 1). Unresolved, this situation will have a strong negative impact on the future development of society and economy. Despite a growing presence of high-tech devices in everyday life, the portion of high-school graduates choosing to study engineering or natural science programs is declining. A negative image of technological studies has been identified as one of the major reasons behind this trend. They are perceived as focusing too much on theoretical issues, while ignoring experimental, hands-on aspects of technological disciplines. At the same time, potential students are alienated by the perceived lack of social relevance and the failure to teach important core skills in school education. In particular, the lack of young women in these fields has been the topic of an intense debate for some time.

When designing gender-balanced courses and curricula, it is necessary to emphasize that technological-oriented programs are not less attractive for women but that women's interests, educational preferences, and requirements differ from those of "standard" male students [3]. In addition, not only women would benefit from such an alteration of curricula also supporting non-technological skills and expertise (e.g. soft skills, analytical competencies, or information literacy). The demands of the economy of the 21st century such as lifelong learning and the effects globalization has on today's employees require engineers and natural scientists to be autonomous, and disciplined. Employees must have sophisticated communication skills such as speaking different languages and working in teams with different cultural backgrounds. In order to accept the challenges, universities have to reconsider their structural and educational concepts.

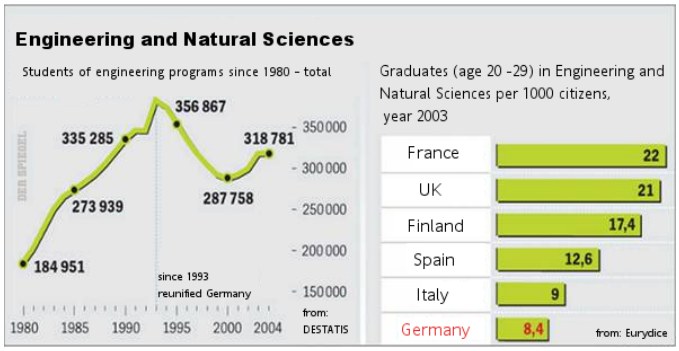

FIGURE 1. Left: Number of students in engineering and natural sciences programs from 1980-2004 in Germany (pre- and post unification), Right: Graduates in engineering and natural sciecnes per 1000 citizens in selected European countries as of 2003. Graph published in Spiegel Online [4], translation added by authors

Due to the Bologna process, European universities have the opportunity to reform their curricula. Within the GALILEA project [5] our goal is to design and implement such innovative curricula, which answer to the changed job specifications of engineers and are capable of attracting more female students. Our first new Bachelor of Science program "Natural Sciences in the Information Society" started in the winter term of 2007/08. If offers a *studium generale* of natural sciences at Technische Universität Berlin (TU Berlin) and can be continued either by a corresponding Master of Science course "Natural Sciences in the Information Society" or Physics, Mathematics, Computer Science or Chemistry.

This article reports on our first experiences, and evaluation results.

II. THE GALILEA PROJECT

Originally, GALILEA was established at the Department of Mathematics and Natural Sciences; however, it is operating as a supporter for many courses at the entire university. The aim

of the GALILEA project is to design and implement new gender-sensitive courses within technical and scientific disciplines. Therefore new curricula have to be proposed, combined with modern educational styles overcoming the above described challenges. In this manner, practical aspects as freedom of scope, comprehensive projects, teamwork, and an internship play an important role. The program has been designed with educational preferences of women in mind. It allocates educational key qualifications and interdisciplinary skills as well as leadership and management qualities. Since language requirements have become important, especially in technical and scientific fields, we decided to offer at least some of the courses in English (Figure 2).

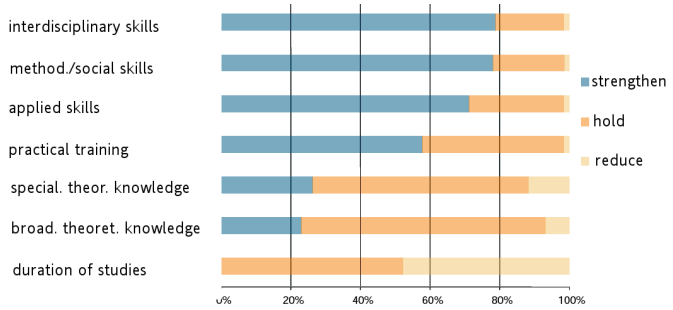

Figure 2. Wishes of the industry regarding programs. Source [6], translation added by the authors

One of the main deficiencies in academic education in Germany is the low attendance of young students in large universities. GALILEA has an integrated mentoring program, especially for freshmen but also for older students.

A. *Natural Sciences in the Information Society*

The "Natural Sciences in the Information Society" (NidI) program as the first GALILEA course started in the winter term of 2007/08 with 15 students (9 female and 6 male) and 37 students (17 female and 20 male) in the winter term of 2008/09. It offers a wide repertory of natural sciences, engineering and non-technological courses at TU Berlin. The core attributes of all natural sciences are the close correlation between theory and experiments and the high standards in mathematical and computer sciences education. These connections are the guidelines of the two-tier program:

1) *Bachelor program*

The NidI Bachelor program provides a great range of access to the basics of natural sciences. The curriculum of this three year program is built on a theoretical basis (59% of the credit points) and supported by a compulsory elective (21%) part, a freely chosen part (10%), an internship (3%) and a bachelor thesis (7%). In fact, students have about 110 compulsory elective subjects to enrich their individual study plan. The technological broadness of the curriculum accommodates the multidisciplinary interests of women. Therefore, emphasis is put on integrating natural and life science aspects. During the concentrated study, the mandatory internship (of at least 12 weeks in duration) has to be concluded. It ought to give an insight into professional life. The theoretical basis of the curriculum is formed by mathematical and physical courses supplemented by several courses in computer science. Additionally, in the first year there are two mandatory modules in scientific information management chosen selected by at least one the following criteria:

- Content-related course of study,
- Teamwork in co-ed teams,
- Teaching core skills,
- Project-oriented work.

Students are taught general scientific methods they will need for managing projects (i.e. experiments), regardless of the explicit fields they will specialize in. Therefore we provide two new project-oriented Bachelor program lectures "Scientific Information Management" and "New Media in Teaching and Research". The students are taught basics of knowledge management, presentation techniques, multimedia education, and research. The first course is carried out by the staff of the university library, the second by the Center of Multimedia in Education and Research of TU Berlin.

2) *Master program*

After graduating with a bachelor of "Natural Sciences in the Information Society", students have the opportunity to join a master program that will result in the "Master in the Natural Sciences in Information Society". Since the bachelor program offers a wide basis in the natural sciences it is also possible to join other master programs from the natural sciences (i.e. astrophysics or nanotechnology).

3) *Mentoring program*

Students can participate in an internal mentoring program providing organizational, social, and technical aspects. This program aims at improving the educational and organizational atmosphere in large universities by a close mutual relationship between freshmen, older students and academic staff. Our goal is to increase the motivation and performance especially of freshmen and women. Beside individual meetings, we provide a wide offering of social events, and additional non-technological and technological advanced training (i.e. exam stress, programming, or mathematical workshops). The mentoring program also allows us to react quickly if structural or technical problems of the program become apparent.

B. *Aim of the program*

The industry and economy still have a high demand for interdisciplinarily educated graduates with great scientific knowledge (cf. fig. 2). Multi-disciplinary, application and research-oriented programs impart methods and fundamentals of computer science, mathematics and natural sciences. In the bachelor program students acquire the necessary knowledge and familiarize with general and specific methods for treatment and solution of problems in natural sciences. This enables them to transfer their knowledge to practice and create the basis for continuing their academic studies, e.g. in the master program.

The following cross-technical competencies and social skills are mediated beyond the purely technical aspects:

- responsible life-long learning,

- problem-analysis and development of problem solving concepts,
- social, scientific, gender-specific and ethic points of view in action and decision strategies,
- multi-disciplinary communication and ability to work in a team,
- presentation skills including the presentation of scientific results for different target audiences,
- modern methods of scientific information management.

After graduation the students are able to find jobs that require great scientific and methodological knowledge whereas the specific skills are acquired on the job. Some examples are: technology writers and other activities with scientific publishers, scientific librarians, advisory activities in politics/ministries/authorities, project-management in scientific-technical areas, science management at universities and research institutes, activities in financial and insurance companies.

Most of the structure of this multi-disciplinary program is tailored to suit women's preferences, yet the large amount of experimental modules might be a problem. Due to their socialization women frequently underestimate their abilities and do not possess the same degree of experience as men [7]. Experiments and theory are closely connected in natural sciences. Consequently it is neither possible nor desirable to design programs in these areas without experimental components. On the contrary: strict emphasis has to be put on the connection between theory and experiment and on offering additional possibilities for experimenting, e.g. virtual laboratories [8].

The bachelor and master programs "Natural Sciences in the Information Society" are the basis to modernize programs, e.g in physics where in general the ratio of female students is one of the lowest of all programs. The development of a program in astrophysics as the field of physics that is traditionally very attractive for female students could be an example. This is reflected in the numbers of students graduation in physics at TU Berlin: Only about 10% of all physics students are women, yet approximately 30% of all female graduates and scientific assistants choose astrophysics as their specialization.

For a detailed summary of the "Bachelor of Natural Sciences in the Information Society" programs please see [9].

III. Evaluation of the New Courses

Overview

So far students' feedback indicates that we are on the right track. We learned that the high relevance of practical courses and projects in these modules, the extensive access to laboratories and independent experimenting, the possibility of a wide choice and the internship are of special interest for our female students.

The mentoring program of the course also allows evaluating the success of the program itself. This feedback from students is crucial, especially in the first year, in order to make adjustments to the program. This hopefully leads to more support from graduates in the future, e.g. by becoming mentors or providing internships for students.

We evaluated both courses and found out that the concept was generally well accepted. Male students appreciated the courses focusing on gender aspects even more than female ones. The courses were offered a second time, but an evaluation has not been conducted so far To find out if and how the students' point of view changes during the term, each course was evaluated twice. There was a weekly poll for "Scientific Information Management" and a final questionnaire evaluation, whereas "New Media in Teaching and Research" has been assessed monthly and ended with a final questionnaire session. The results will be presented in brief.

A. Integrated Lecture: Scientific Information Management

22 students took part in the weekly evaluation over a total of nine weeks. Every time five male and five female randomly-sampled students were interviewed. The male students followed the lessons a bit more concentrated and took part more actively than female students did. They also expressed to have learned a lot for use in the future.

In the final evaluation, the students evaluated the course with average grades. They expressed that they had learned a lot and were able to transfer it into practice. The students were able to handle the level and scope of this course very well. Different kind of media used in the lessons motivated the students. They preferred to work in mixed teams. The students even appreciated the mandatory attendance of this course because they understood that it was adequate due to the teaching methods applied [9].

B. Integrated Lecture New Media in Teaching and Research

Each of the 20 students (12 male and 8 female) and the three lecturers were interviewed to compare their impressions of the students' participation during the lessons (monthly evaluation). While the assessment of their own contributions to the lessons was balanced around a good average, the lecturers were more pleased than the students thought they would be. However, this changed in the second half of the term.

For the final evaluation, only students were interviewed. They considered this course to be useful for their future and that they would use the learnt methods (e.g. presentation skills) in their everyday life. They really liked this course and graded it with an average of 1.75 on a scale from 1 (best) to 4 (worst). The level and scope of this course were adjusted to the students' previous knowledge. There was no mandatory course attendance, yet 45% of the students visited almost every lesson, 70% attended more than half of all lessons. Four of them would have even preferred a compulsory attendance. The students enjoyed the different kind of examinations ("prüfungsäquivalente Studienleistungen"): There were four different types of exams: an oral exam, several assignments, delivering a scientific paper and a presentation. The students appreciated the oral exam the most (average: 1.42 on a scale from 1 to 4) and the assignments the least (average: 1.95). Referring to these types they claimed to be able to present the

topic and their knowledge more easily. Altogether, we found that the concept was well accepted both by male and female students.

Besides the acquired knowledge students developed useful soft skills and applied them immediately in other courses. Although there are some aspects that still need to be improved, the concept seems to be successful. During the present term similar evaluations are carried out to validate these results and to find out what has improved and what else needs to be done.

C. *Mentoring*

The evaluation of the mentoring program was included all participants – mentors and mentees. All mentors were evaluated through means of a short questionnaire, and all mentees completed four guided interviews with some additional questions included in a short questionnaire. Two female mentees and two male mentees filled out the questionnaires. Respectively, one of each mentees was actively participating in the mentoring program. At the time of the questioning, all mentees were at the end of the second term.

Generally, the acceptance of the mentoring program by active mentees was positive, whereas the temporal effort strongly varied (2 to 9 hours per term). But only one non-active mentee positively reviewed the program. According to the asked mentees the aim of the program is to assist students through a contact person during their studies and especially at the beginning. However, the interviewees seem to have no specific conception of the program. Therefore, the mentoring program was used mostly at the beginning of the studies, in order to clarify organizational questions. If no concrete questions arose, the mentees did not make use of the program. It was criticized that there were difficulties to make appointments and that clear guidelines were missing. Both mentors and mentees should have had a clear conception of the meaning of mentoring. However, if there was a personal relationship between the mentor and the mentee, the conceptions and expectations of the mentees were satisfied. This relationship was characterized as amicable. The general aspects of the mentoring program were of interest to the mentees. This part of the program was also used in parts if the student did not have a mentor.

An obstacle of active participation in the mentoring program is represented by the first appointment with the mentor. If this took place, then generally a good relationship between the two formed. However, different challenges appeared due to the status group of the mentor (student, scientific staff, professor). Thus, appointments with the status group "professor" hardly took place. In contrast, friendly relationships arose out of the status group "students" in which the mentoring becomes less important.

IV. SUMMARY AND FUTURE WORK

Especially the German industry needs more qualified engineers and natural scientists at this point in time. The number of students currently enrolled in the corresponding programs is too small to fill this gap. While more female students could stand in, the majority of these programs are rather unattractive to women. In particular, many students in these fields are not well prepared for their future professional life. Thus, important soft skills or communications skills are needed.

Numerous evaluations [3, 10, 11] prove that the quota of women in the programs mentioned is considerably increased by special adaption to their needs (e.g. multidisciplinary). However, this can only be achieved if the curricula are readjusted. Moreover this can also motivate numerous male students. The awareness in Germany to readjust courses of studies is developing very slowly, yet constantly growing. In addition, there are many efforts to encourage female students. Thus, female students will be supported from kindergarten onward all the way to studies at the university level through scholarship programs. However, the criticism grows that many male students are now facing disadvantages due to the changing gender stereotype settings and activities [12]. Therefore a lot of male school graduates would not continue to university any longer and would also not come into consideration for a qualified profession.

At TU Berlin the mentioned challenges are well-known, and different solutions are being sought out. TU Berlin strives to be a forerunner for new challenges in research, economics, and society, in order to achieve a new image of engineering and natural sciences. One of these approaches is the GALILEA project financed by the European Social Fund (ESF). GALILEA is designing programs in order to increase the quota of women in engineering and natural sciences by integrating specific female requirements and new educational paradigms. Through the Bologna declaration [13, 14] the incentives for completely new programs are provided since the two-tier bachelor and master system is a completely new structure in the academic education in Germany. Therefore, the GALILEA project designed the new program "Natural Sciences in the Information Society" aiming at a quota of about 50% female students. This new approach is integrated not only into the concept of the entire program but also through the individual lectures "Scientific Information Management" and "New Media in Teaching and Research".

These two lectures for the Bachelor program were evaluated. Generally, the lectures were positively assessed. During the first run of these lectures students identified some technical procedures such as high expenditure of work or too many examined topics to be disadvantageous. The multidisciplinary approach was assessed as good, and the students had the feeling that the lectures impart soft skills that can be useful in further studies or future jobs.

In addition to the changed curriculum a mentoring program is integrated into the GALILEA program, accompanying students throughout their studies. An evaluation of the mentoring program took place as well. Here, the biggest issue found was that the meaning of the notion "mentoring" is not universally understood, in spite of efforts of explanations in training courses. Students are already aware

of the existence of a contact person, but this offer is accepted mainly in the first term. Nevertheless, the program was evaluated positively. A good approach was to enlist sophomore students as mentors for their freshmen fellow students. The developing relationships are considered amicable and lasting.

In further evaluations, we would like to examine specific problems within the lectures and the mentoring program to improve our courses.

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