Breaking the habit – new approaches in engineering education

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INTRODUCTION

The research project buildING│bridges@teaching aims at the integration of gender and diversity aspects in different teaching formats in engineering and is associated with the research group “gender and diversity in engineering” at RWTH Aachen University.

Within the framework of the project a gender- and diversity-oriented teaching evaluation and modern, media-supported blended learning approaches were used in order to achieve the intended goals. First research results of the literature and status quo analysis were already implemented and tested in newly designed teaching approaches, for example in a multidisciplinary introductory lecture of civil engineering at RWTH Aachen University.

1 BACKGROUND, FACULTY CULTURE AND ENGINEERING HABITUS

The underrepresentation of women in engineering education and later in employment is still very evident. Although there have been numerous initiatives over the past 25 years to attract and retain more women in engineering fields, the progress is slow. In 2013, the percentage of women among first year students in engineering was 23,7% at German universities. Compared to 1975, when only 7,8% women were among first

year engineering students, this is a positive development. But last year's numbers show that the percentage of women in engineering fields are stagnating roughly at one quarter [1]. These numbers do also mirror the international development, although in the year 2011 in the United States (17,3%) and in Japan (11,7%) the percentage of women in engineering at universities were considerably lower than in most European countries [2].

Furthermore, the drop-out rates in engineering education at German universities (of men and women) are the highest among all subject fields and amount to approximately 30 - 50%, depending on the specific subject. Besides performance problems study motivation plays an important role for the abandonment of engineering [3]. Studies indicate that further reasons for the low participation of women as well as the high degree of drop-outs lie in the very structure of engineering education [4].

In the historical context engineering was considered a male domain [5]. The stereotypical connection of technology and masculinity ramifies in the process of socialisation, particularly in western industrial societies, where 42% of boys compared to only 5% girls are interested in technology [6]. As a predominantly male domain, engineering has developed a specific habitus that shapes engineering education [7], [8]. This habitus prevents many women from studying engineering in the first place, but also causes problems that could lead into the drop-out from studies.

According to social scientist Pierre Bourdieu, the habitus (the system of dispositions consisting of lasting, acquired schemes of perception, thought and action) has a great influence on the perception and cultural attributions of a subject. The respective habitus is built through the access, the possession and participation in economic, cultural and social capitals [9]. Generally speaking, these capitals are more often entitled to males. Therefore, Bourdieu also discusses a "masculine domination" [10].

Through their own integration into an existing habitus of a social group, people are continuously recreating the habitus and thus perpetuating the existing structures and processes. The male domination functions as a common way of looking at things in this scenario, as a domination that is self-evidently enclosed into our schemes of the habitus as a gendered view of the world. The scheme of classification, in which the male and the female are reconstructed as binary oppositions is integrated into the habitus and is used to create our way of looking at things [11].

The dominant habitus in natural sciences and engineering prevents many women, as well as some men from studying a corresponding subject because he [the habitus] underlines dominance, distance and hierarchy, it sequences subject contents, instead of referring to connections, he practices a rather traditional didactic style and seldom promotes social skills, discrete, scientific and holistic thinking [9].

The habitus thus manifests on many levels of a subject. For example, the didactic planning, design of lectures and curricula and is mirrored in the homogenous and hierarchically structured composition of chairs. The described faculty culture and the inherent habitus of teachers and students thus more or less subtly suggests that women (as well as various types of men) who do not identify with the habitus of the field do not fit in. They are thus more likely to face gate-keeping-scenarios and loss

of motivation [9]. Due to the same reasons STEM-subjects are also unattractive for young man with potential in this field [12].

In order to integrate more women into engineering subjects as well as diverse men and to lower drop-out rates, it is therefore not enough to increase women's interest in technology but also to enhance the feasibility of study itself, without lowering the quality of study. Following this argumentation, gender- and diversity- sensitive teaching is a criterion for the quality of teaching. In this regard not only the attitude of the lecturers is important, but also a reformation of the courses themselves [13], [14], [15]. Such a new design could contribute to a didactic that would benefit both genders [12], [16], [17].

Research in this field has provided different measures in order to generate a learner-friendly course of study. Examples are the avoidance of 'sort out exams' [18], the application of a type of didactic that favours a higher participation of students as well as the inclusion of a high level of application- and professional orientation [16], [19], [20], [21].

Based on these findings, it is to be assumed that new, interdisciplinary and gender- and diversity-sensitive teaching formats in engineering are beneficial for all engineering students regardless of their gender. Furthermore, these measures should result in a decrease of drop-out rates and the increase of study motivation.

2 PARTICIPANT OBSERVATION – TEACHING IN ENGINEERING

Within the framework of buildIng|bridges a participant observation was carried out in selected courses of the Faculty of Civil Engineering at RWTH Aachen University in the summer term of 2013 as well as in the winter term of 2014/2015. Almost every lecture was held by a different lecturer. This characteristic enables the observation of the human factor and the influence of teaching types on the implementation and the consideration of gender and diversity aspects.

Methodologically, the participant observation is based on the approach of Münst (2002) [22] and supplemented by the findings and experiences within the framework of the research project IGaDtools4MINT[1]. The concept of this project was based on the analysis and combination of existing nationwide best practice measures in the field of teaching, which led to a comprehensive package of measures that aims at gender equal teaching (didactics and content of computer science) as well as an opening of the faculty culture for diverse women and men. To record the data systematically, a survey sheet was designed in order to document relevant communication in the lecture. Furthermore, aspects like the use of gender-neutral language, teaching methods and ideas for a transfer to future professional activity as well as references to the lifeworld of the target group were analysed. The lectures were held in German, which increased the opportunity for a linguistic analysis, since the German language allows feminine, masculine as well as gender-neutral variations of specific terms.

[1] The overall goal of IGaDtools4MINT was the development of a concept which contributes to the increase of the percentage of women as well as to a reduction of the drop-out rate in STEM-subjects. IGaDtools4MINT was a joint project of the research group "Gender and Diversity in Engineering" and the Computer Science Department i9 at RWTH Aachen University as well as the research group Models and Theory of Distributed Systems at TU Berlin and funded by Federal Ministry of Education and Research.

In the following paragraph selected impressions and results of the participant observation will be presented.

2.1 Effects of teaching performance

The observation showed that there is a general knowledge of different teaching tools. Different types of participative elements were visible in every lecture. As different researchers have already shown, participative elements led to an activation of students, who would otherwise not participate in the reflection of learning contents [23], [24]. In addition, the mixture of diverse teaching methods seems to cause a sustained attention of the students which also corresponds to previous research [25]. Therefore, one finding is, that the willingness to actively participate in lecture corresponds to the way teaching methods are implemented. The more the lecturer addresses different students as well as diverse groups of students and promotes active participation, the higher is the voluntary participants of the whole audience and results in an exchange of opinions and perspectives and as a consequence an improved learning success [26], [27], [28], [29].

The addressing of diverse student groups (for example male, female, disabled, foreign etc.) is particularly important, because the focus on one homogeneous group leads to the exclusion and inactivity of students who do not identify with this group. One of the results of the participant observation indicates an existing interrelation between the professor's individual awareness of diversity and the students' learning success. The analysis indicated that the use of modern didactical elements by itself is no guarantee for successful learning. In this context it is more important to fully understand how and why a concept should be implemented in a specific learning/ teaching situation and also to fully grasp the effect of the implementation [30].

2.2 Diversity perspectives in engineering education

With regard to diversity dimensions in teaching we can derive that in the analysed lectures diversity dimensions were only very roughly addressed, if at all. This observation leads to the assumption that the connection between individual teaching contents, diverse perspectives as well as the various requirements of students seems difficult to implement in teaching formats.

Linguistical, psychological and sociological research has shown that the impact of using male dominated language leads to a certain degree of exclusion among female students and solidifies the existing male habitus [31], [32], [33], [34], [35]. In the observations a lack of the use of gender-neutral language was clearly noticeable. Almost all lecturers used masculine forms of occupational titles like builder, manager, researcher, employer and director, although German allows the use of feminine and in some cases even gender-neutral forms. Most of the chosen examples used in the lectures entail typical male connotations and reflect male experiences. These findings show that the advantages of the use of gender-neutral language as well as a balanced choice of examples during lectures is not fully understood or in some cases completely unknown to lecturers. A sensitisation in this regard seems to be necessary in order to change teaching as well as the faculty culture [36]. The target must be to develop lectures and lecture concepts which regard human beings in their diversity and are characterised by an inclusive teaching style.

2.3 Lessons learned

Following the aim of the research project buildIng|bridges, there was a distinctive reflection process which allowed discussions about the different perspectives and habits of the lecturers. The constant interdisciplinary exchange between researchers

and the analysed lecture made it possible to implement the essential framework conditions of the respective subject as well as the core issues in a diversity-oriented teaching concept. The exchange process also demonstrated that the active confrontation with diversity-aspects in a conversational setting is the best way to guarantee a sustainable implementation into teaching concepts.

3 IMPLEMENTATION OF FIRST RESULTS – INTRODUCTORY COURSE CIVIL ENGINEERING

Based on the first results of the participant observation, the findings were implemented into an interdisciplinary lecture-concept. A team of eleven research associates from nine different research groups[2] at RWTH Aachen University developed a lecture-concept which illustrates the different disciplines of civil engineering to first semester students.

3.1 Cycle of reflection – Sensitisation of lecturers

As the findings of the participant observation as well as the results of the literature analysis have already shown the continuous sensitisation of lecturers and the permanent reflection of teaching concepts are core elements during the development of teaching formats. Therefore, the actual process of redesigning the introductory course civil engineering was just as important as the concept itself.

To ensure a continuous reflection process there were regular meetings with all participants. During these meetings it was possible to make diversity dimensions and the need of implementing diversity aspects into engineering teaching a subject of discussion. As a result, the opinions of the involved persons changed and open-mindedness concerning diversity-themes and orientation towards interdisciplinary increased. In addition to the group meetings, there were also individual interface-conversations which also fostered an interdisciplinary exchange. In addition, these meetings made it possible to trigger processes of rethinking the relation between diversity aspects and the consideration of human needs with the own subject.
Even a change in behaviour was noticeable as a result of the ongoing personal involvement with diversity-themes. In the end there was a genuine effort concerning the use and implementation of gender-neutral language as well as diversity-aspects.

3.2 Preparing students for professional challenges - The approach

Most of the future engineers are going to deal with global challenges in their professional careers. The aim of future-oriented teaching must be to prepare young people for this enormous task. In order to achieve this, teaching should be problem- and application-oriented [37]. The results of the participant observation confirms this effort. As part of the new concept of the introductory course civil engineering, a real construction project has been used as common theme of the whole lecture. As previous analytical research indicates, examples which connect the real life of young students with scientific contents are integrated into the long-term memory much more efficient and are stored for a longer period of time [22], [38]. Through the used didactical approach a strong connection of every participating discipline was assured.

[2] Chair in “Energy Efficient and Sustainable Building” (E3D), Research Group “Gender and Diversity in Engineering” (GDI), Chair of Geotechnical Engineering (GIB), Institute of Structural Concrete (IMB), Institute of Infrastructure Planning and City Traffic (ISB), Academic and Research Department Engineering Hydrology (LFI), Chair of Building Materials Research (IBAC), Chair of Construction Business and Project Management (IBP), Institute of Transport Science (VIA)

In the course of the team meetings there were many discussions until a common theme that represented the whole bandwidth of engineering was found. After finding this common theme, the chronology of the contents was fixed. Lecture blocks were developed which summarised the related topics. The succession of the subjects and the contents closely correspond to real building processes. By using this approach a strong practical relevance was assured. *Fig. 1* shows the lecture-concept and the thematic structure. A presentation in the chronological order of a real construction project helped the students to classify the subject areas that they will meet during their further studies. The participant observation showed that the association of theoretic contents with the field of activity in the future career increases attention towards these topics and induce the motivation to grapple with these themes.

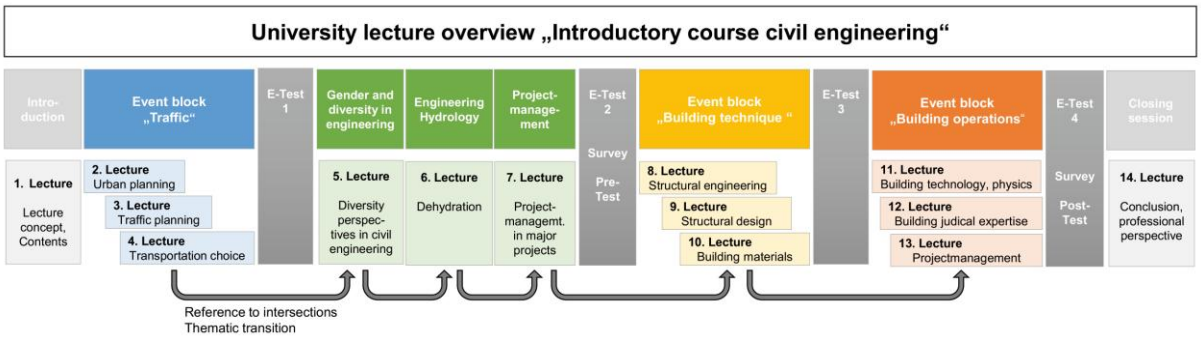

Fig. 1. Content concept (Copyright GDI)

The next step was to point out the intersections between the different subjects (*Fig. 1*). In view of the current demand for interdisciplinary competences, it was very important to emphasise the common ground between the different subjects. Especially, the connections between the contents from the engineering core fields and the research field “gender and diversity” was important, since the qualitative examination showed that not a single diversity dimension was addressed during the lecture. Therefore, one requirement of the newly designed course was the connection between technology and engineering-oriented trains of thought with the diverse needs of humans. To ensure this, a guideline concerning the use of gender-neutral language and diversity-sensitive presentation style was developed in order to create a basis for further reflections of diverse human needs and requirements. During the redesign of the introductory lecture, the coordinating research group of gender and diversity in engineering ensured the communication with the project managers of the other research fields. Furthermore, the research group of gender and diversity in engineering carried out a quality control after the completion of the teaching-material.

3.3 Inventing a needs-oriented examination concept for sustainable learning

As shown in *Fig. 1* a cumulative examination concept was invented during the redesign of the course. Instead of the summative exam at the end of the semester, the new approach prevents an overload of teaching contents. To reach the final examination, the students complete four e-tests at regular intervals during the course. Every e-test is carried out after a block of three lectures and can be executed in a period of one week. In addition the e-tests are available online and can be solved at every time chosen by the students. This flexibility is a reaction to the different living conditions of students as well as social backgrounds and, therefore, an example of the structural reflection of the diversity of students.

Furthermore, a consideration of different learning types according to Vester (1975) [39], has been built into the course concept which is realised by the enhancement of blended learning formats. Influenced by different blended learning experiences, the project group developed a unified format of blended learning elements which considers the needs of all learning types. *Fig. 2* visualises the elements of the blended learning concept and shows that e-testing is an element of this approach.

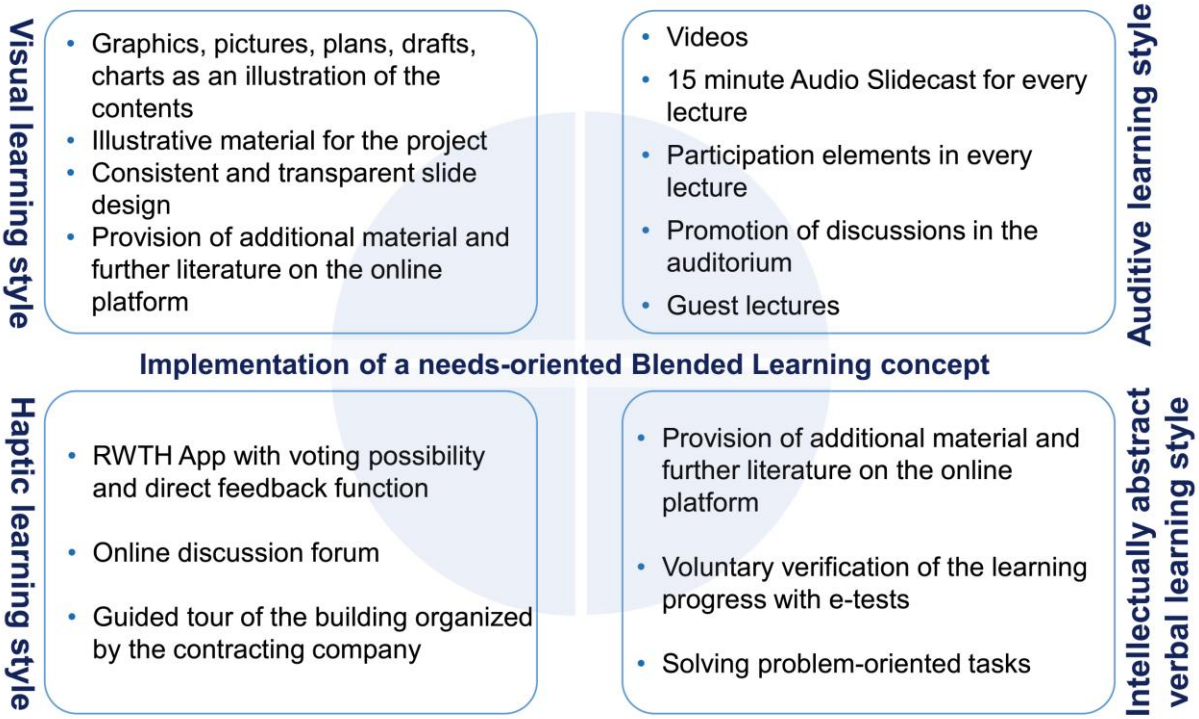

Fig. 2. Blended Learning Concept (Copyright GDI)

The first evaluation of the survey results shows a very positive feedback of the students. Especially the thematic structure, the strong application orientation and the examination system which is based on the thematic arrangement, were rated as very positive. The test results led to the assumption that the developed concept is a promising method of ensuring a successful, future-oriented and sustainable learning process among today's students.

4 CONCLUSION

In order to cope with present and future challenges, engineering education has to adapt towards gender and diversity-friendly, interdisciplinary and functional teaching approaches. Past research as well as present findings in the context of this research project show that there is still a need of sensitation concerning various issues.

One basic finding of the presented qualitative approach is that the lecturers indicated the importance of gender-neutral wording and examples after a continual reflection process during the concept development of the introductory course civil engineering. This project has been a first step in this direction, but needs to be continued by further sensitising different stakeholders in order to benefit and thereby contribute to a coherent strategy which should lead to a sustainable development of a gender and diversity-sensitive teaching and learning environment.

Moreover it is important to promote a multidisciplinary exchange within and outside the borders of the faculty. This results in teaching concepts that reflect work processes in practice rather than being exclusively theoretical.

In an addition to an established multidisciplinary personal exchange, the development of a binding criteria catalogue and a useful guideline which provides clues and hints on implementing gender and diversity aspects in lectures is considered very important and currently developed within the framework of the project.

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