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Facing Future Challenges: Building Engineers for Tomorrow

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Abstract
Future engineers are increasingly confronted with the so-called megatrends which are the big social challenges societies have to cope with. These megatrends, such as for example "Silver Society", "Globalization", "Mobility" and "Gender Shift", require an application-oriented perspective on diversity especially in the engineering field. Therefore, it is necessary that future engineers not only look at the technical perspectives of a problem, but are also able to see the related questions within societies they are developing their artefacts for. The aim of teaching engineering should be to prepare engineers for these requirements and to draw attention to the diverse needs in a globalized world.
Bringing together technical knowledge and social competences which go beyond a mere training of the so-called "soft skills", is a new approach followed at RWTH Aachen University, one of the leading technical universities in Germany. RWTH Aachen University has established the bridging professorship "Gender and Diversity in Engineering" (GDI) which educates engineers with a transdisciplinary approach to expand "engineering limits". In the frame of a sustainable teaching concept the research group has developed an approach which imparts a demand-oriented gender and diversity expertise to engineers. Students gain theoretical knowledge about gender and diversity and learn how to transfer their knowledge in their major field of study and later work. To substantiate this, course participants have to solve case studies from concrete research practice. The cases which are developed in collaboration with non-profit organizations and enterprises from economy introduce the students to challenges which are inspired by professional life. Evaluation shows the success of this approach as well as an increasing demand for such teaching formats.

1. Future challenges in engineering
Topics like urbanization, neo-ecology, mobility as well as health, demography and the increasing trend of individualization will influence our future society significantly [1]. With regard to the so called megatrends, society will be faced with numerous challenges. Upon closer examination, it becomes evident that these trends, with a predicted period of 30 years [2], are directly related to the engineering sciences. In this rapidly changing world the need for innovation is closely related to global interconnectedness, open standards and diverse users within an increasing heterogeneous population. Therefore the education of engineers for tomorrow has to enable students to cope with these challenges. So, the megatrends need to be also discussed from an engineering perspective. The encounter of these challenges will also be reflected in future technical developments. Thereby, engineers have a key role, as they shape future with developments decisively. Due to this it is essential that engineers discuss their solutions taking into regard the megatrends and the change of social structures as well as human needs. Especially with regard to the human efforts behind the megatrends and the associated needs, social constructs like heterogeneity and the ability to identify and derive the diverse human needs as well as the ability to include the resulting requirements in engineering developments, should be a core competence for future engineers [3].
The associated new requirement profiles for engineers necessitate, that teaching formats in higher education go beyond the straight specialist knowledge. Since in the early nineties Boeing has published the list of "Desired Attributes of an Engineer" [4], changing higher education in engineering has been the subject of an on-going discussion in the US and Western Europe among industries and engineering universities. But achieving the change has become a serious barrier. To enable a sustainable consideration of these demands at universities, an adjustment of university structures to the new challenges is needed [5]. For this reason as the first technical university in Germany, RWTH Aachen University has established a new research department that forms a bridge between engineering sciences and gender and diversity studies.

2. Creating structures – establishing interfaces

RWTH Aachen University is one of the leading technical universities in Germany. In the winter term 2014/2015 57% of students were registered for engineering studies, followed by students signed up for natural sciences [6]. Famous for its cutting-edge research and with the greatest amount of external research funding in the national comparison as well as appreciated for its excellent education, RWTH Aachen University is always anxious to ensure its position in science technology with innovative approaches. Therefore it followed new paths with the establishment of the 'bridging professorship' "Gender and Diversity in Engineering" (GDI) in 2012.

Structurally located at the faculty of civil engineering the GDI is working at the interface between social sciences and technology. The chair presents a new format of professorship which intends to bridge the disciplinary gap between technological, engineering, natural, human, social and economic sciences. The aim of the chair is to open up new perspectives in engineering and technology through the cross-disciplinary integration of gender and diversity issues into the broad range of subjects within research and teaching.

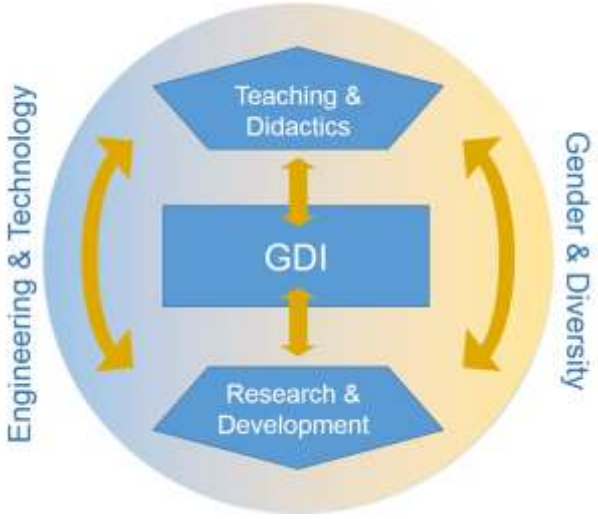

Fig.1: Concept of the GDI

Research and teaching are linked to each other interactively whereby the two fields enrich themselves mutually. With establishing the GDI, RWTH Aachen University has created an institution that unites interface themes between engineering and social sciences. In the following paragraph the teaching approach of the GDI is described in detail.

3. New approaches in engineering education

Although new requirements are placed on future engineers and have been discussed for a long time engineering education is still focused on its classical core disciplines [7,8]. Interdisciplinarity is often just reflected in the combination of engineering disciplines with economics [3]. In the rarest cases, future engineers have the possibility to learn about social science issues, although they are closely related with the respective engineering discipline [9,10]. This implies a lack of interdisciplinary exchange-possibilities in the student body and constitutes a contradiction with regard to the working reality. Further insights which are basing on the research findings of different projects which were conducted at the GDI show, that there is still a necessity to promote a multidisciplinary exchange within and outside the borders of the faculty and to make diversity a subject of discussion [11].

Research has shown that diversity is a key for entrepreneurial success [12,13]. With regard to the importance of reflected future engineers for society, the GDI has developed teaching formats that realize a restructuring of teaching at three levels.

3.1 Contents and learning objectives

The fundamental assumption for structuring the teaching contents is that technology always has a social context. Thereby, technology is understood as socially constructed. Humans and technology are in a reciprocal relationship, because humans create technology. The other way around technology influences people and changes their actions and thoughts. Indirectly, technology characterizes in this

way our culture and society and affects the environment fundamentally. Figure 1 visualizes this coherent interaction.

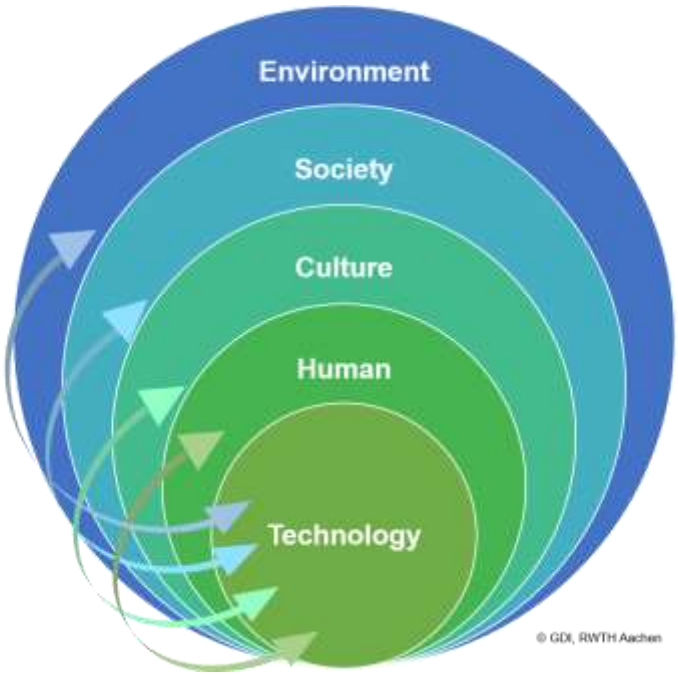

Fig.2: Technology in context

Basing on these insights the central learning goal of the teaching concept at the GDI is, to enable future engineers to reflect their responsibility as future engineers. The responsibility lies in the approach that engineers shape through their views and perceptions influenced developments the way technology is understood and used.
Thus, the mediation of knowledge in the field gender and diversity is a central aspect of building engineers for tomorrow. Students learn about the diversity categories and recognize the transfer between their own working field and the user of buildings and technology. For this reason a central aspiration, next to the understanding of diversity and the reflection of the own role and responsibility, is to recognize possibilities for action in the later field of profession. Furthermore, it is important to introduce students to the challenges in their future professional field. In this context it is significant to make the megatrends a subject of discussion and to bring them in a direct connection with the engineering discipline. As engineering is closely linked to the creation of innovation, the active dealing with problem-based questions and the mediation of innovation-generation methods is a vocational preparation. The ability for critical and interdisciplinary thinking, developing a global mindset referring to gender, diversity and mobility as well as the competences to communicate and collaborate are main skills of social responsible engineers of tomorrow.
The mediation of contents which have a strong interface character, requires a teaching concept, which operates with different teaching methods.

3.2 Teaching method

The GDI is pursuing a transdisciplinary research approach, which enables a research based perspective enhancing teaching. Insights from social sciences are placed in a direct reference to the engineering sciences. Thereby, the generation of basic knowledge is premised on literature work. This workload is seen as a preparatory element to the face-to-face seminaries. It requires the engagement and commitment as well as collaborative work of the students from the very beginning.
In order to achieve the defined learning objectives ‘transfer thinking’ and ‘broadening of perspectives’, the GDI uses a participatory teaching approach. The aim is to engage students and to ensure a sustainable learning success. In addition to the discussion oriented format, group work is a fundamental element of the teaching concept. Tasks are given to heterogeneous groups of students. In the independent teamwork students learn on the one hand to solve problem-based tasks and on the other hand to work in diverse teams. Thus, students have the possibility to collect experiences for professional life and to learn to cope with challenges in diverse teams.

Figure 2 visualizes the event chain of knowledge-generation.

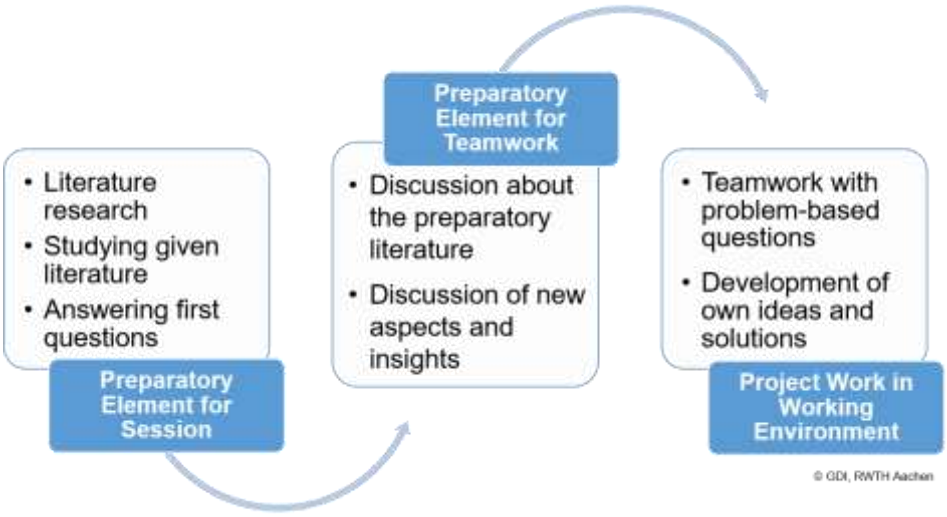

Fig. 3: Event chain of knowledge generation

A further important component is the integration of companies as well as specialists from science and industry. Through the processing of real business cases and discussions with experts, students get a better idea of the working world.
The implementation of such a holistic approach requires the support of relevant higher education structures.

3.3 Structural integration

To enable interdisciplinary work on the above discussed issues, universities and faculties need structures that allow teaching concepts which focus on teaching interface knowledge. That includes the performance related accessibility of lectures and seminaries for students from the different disciplines in master as well as bachelor programs. The curricular anchoring of lectures that allow the perspective on interfaces between the different disciplines at an early point of studies is important. For this reason, the GDI is anchored with an obligating lecture in the bachelor program of civil engineering. So all students get a first idea of alternative perspectives on engineering.

4. Conclusion

“There has never been a better time to be an engineer with special skills or the right education, because these people can use technology to create and capture value. However, there has never been a worse time to be an engineer with only “ordinary” skills and abilities to offer: Employability competition is worldwide. Engineering students all over the globe, computers, virtual assistants and other thinking machines are acquiring these skills and abilities at an extraordinary rate.*”* [14]

Fundamental societal changes as well as global megatrends led to new requirements for sustainable technical solutions and innovations. To meet these challenges, future engineers have to be prepared for future tasks. Therefore, engineering education needs to be up-dated and its profound technical contents have to be extended by transdisciplinary abilities and skills considering social heterogeneity being crucial for leadership but also for responsible and sustainable technical solution approaches in the long run. The GDI provides an approach which shows that gender and diversity perspectives provide a precious pool of issues strongly relevant for innovative and suitable solutions, techniques, and applications to be developed. To unlock this innovative potential and the added value the consideration of diversity issues and transdisciplinary perspectives provides for research and teaching, the extension of future-oriented technical curricula towards these competences is indispensable. Furthermore, the new approaches have to be tested and evaluated in detail. Another

task represents their structural implementation. Subsequently, future research will focus on the transferability of the developed concepts.

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