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New approaches to engineering education in the wind power sector in northern Germany

Abstract

Wind power is a dynamically developing sector in Germany, fuelled by the need to combat climate change and by the German government's decision to shut down all nuclear power plants following the 2011 Fukushima disaster. The sector needs an appropriately educated and trained workforce, both at the skilled workers' and the academic (engineering) levels. At the same time there is a shortage of well-educated engineers on the German labour market. Together with political initiatives for "advancement through education" and for enhancing the permeability between vocational and higher education this has encouraged the University of Applied Sciences in Bremerhaven in cooperation with the Fraunhofer Institute for Wind Energy and Energy System Technology to embark on the development of a Bachelor program in wind power technology. This program can be studied in conjunction with work, especially by practitioners with a vocational education background. This article provides some information on the German wind power sector and its competence requirements, on the opening of German universities for "non-traditional" students and their specific learning needs, and finally presents the overall concept of the aforementioned Bachelor program for the wind power sector.

Keywords: *wind power, engineering, higher education, Germany, nontraditional students, competence requirements, permeability between vocational and higher education*

1 The wind power sector in Germany

Following the Fukushima disaster, Germany decided in 2011 to successively shut down all its nuclear power plants until 2022 (WEA 2015). Since its goal at the same time is to reduce greenhouse gas emissions by 40% by 2020 compared to 1990 levels, and by 80% by 2050 (BMUB 2014), replacing fossil fuels and extending power production from renewable energy sources is mandatory.

1.1 Usage of wind power

In 2014, 11% of primary energy consumption in Germany came from renewable sources (see figure 1). During that year, Germany produced 29.7% of its primary energy consumption, with 37.4% (1453 PJ) of it coming from renewable sources (AGEB 2015, 12). 201 PJ, which is 1.54% of total primary energy consumption or 9.1% of gross electrical energy production (AGEB 2015, 30 and 39), came from wind power, onshore and offshore.

Still the biggest share of energy from renewable sources comes from biomass of various sources, followed by wind, photovoltaic, water, geothermal and solar-thermal power (BMUB 2015, 49). Since, in Germany, the inland-supply of biomass is limited, most watercourses are already used for energy production, geothermal energy is not easily available, and also solar energy is limited due to geographical and climate conditions, wind power is the source of choice to be extended.

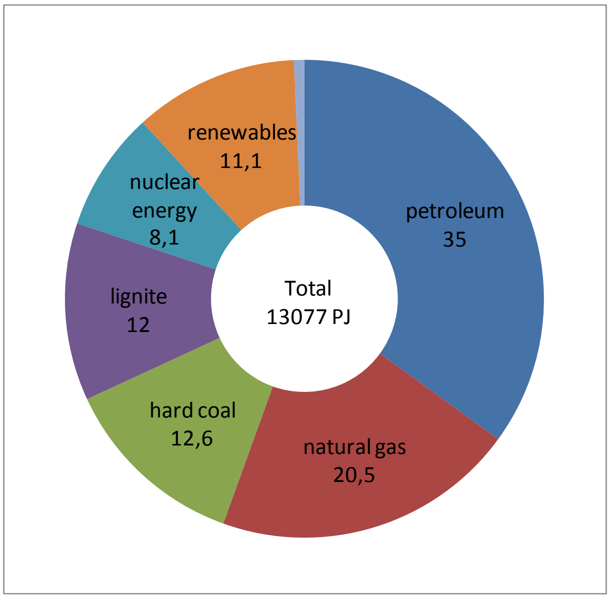

Figure 1: Primary energy consumption in Germany, 2014, in percent (provisional figures). (AGEB 2015, 4).

Figure 2 shows the wind power development in Germany over the past decade. While onshore wind power developed steadily since the beginning of the 1990's, the first installations of offshore wind power in the North-Sea and the Baltic Sea were only available from around 2010 on. It must be noted, however, that work on it started much earlier, since planning, administrative procedures and installation typically take several years - administrative procedures alone take 4 years on average (Schwieters et al. 2012, 87) - until offshore wind power systems are connected to the grid. In 2014, 2.34 GW offshore wind power were installed ready to run after 0.903 GW in 2013. According to the German Wind Energy Association, installed power will reach about 3.3 GW by the end of 2015 and at least 6.5 GW by 2020 (GWEA 2015).

1.2 Political and economic environment

In Germany most of the energy producers are private companies. Only few power stations are owned by public administration entities, and also the electric grids are largely owned by private enterprises. Nevertheless, the business development in Germany's wind power sector depends largely on political framework settings, since electricity production via wind still is not competitive compared to traditional, coal and lignite-fired or nuclear power plants. Germany has a Renewable Energy Sources Act (for a non-official translation into English see

EEG 2014), which provides funding for energy from renewable sources fed into the grid, and which is altered from time to time. In addition, lengthy and complex administrative procedures have to be passed until the erection of wind energy systems can start. Major hurdles are mandatory environmental compatibility assessments and public participation procedures, the necessary land acquisition, as well as grid integration, at least for larger wind-farm projects. Profitability of investments in wind power plants also depends on the state of the European electrical energy market. This has witnessed a decline of prices over recent years due to low economic growth and the related weak growth of electricity consumption.

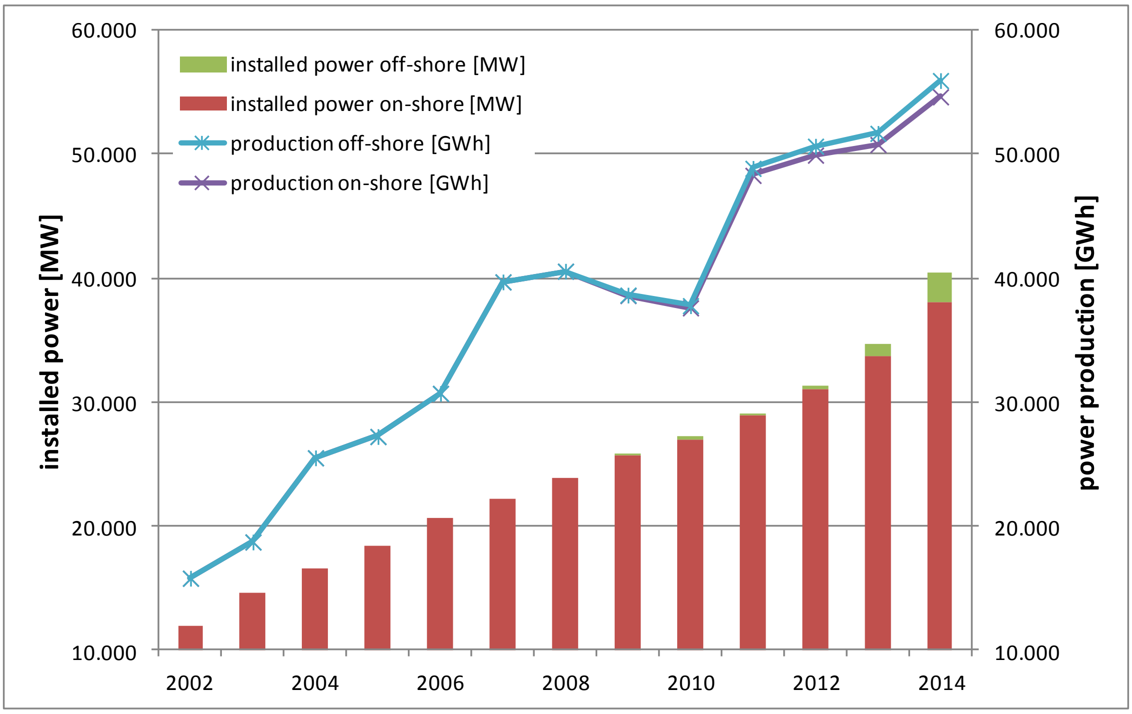

Figure 2: On- plus offshore wind power development in Germany (AGEEstat 2015)

Currently, quite a number of big wind farms in the North Sea and the Baltic Sea - in the North of Germany - are under development as an answer to Germany's announced nuclear power exit from 2011. They are meant to successively replace nuclear reactors - the oldest first - of which quite a number are located in the south of Germany, far away from the sea. However, the high voltage grid in its current state cannot cope with the large amount of power that has to be transferred from the north to the south. This poses a major problem in the networked national electrical grids in Europe. Electricity flows through neighbouring countries like Poland and France, stressing their grids, sometimes close to safety limits. At the same time, finding feasible routes for additional transmission lines is not easy in a densely populated and federally governed country.

As a result of these and other factors, which we cannot discuss here in detail, the wind power sector faces quite some uncertainty with respect to its medium-term development. Experts, however, believe that employment in the sector will rise and that wind-power-specific skills and competences will be in high demand in the near future (see e.g. Lutz et al. 2014).

1.3 Companies and employees

In recent years, since the small depression in wind power development (see Figure 2), some consolidation took place among companies in Germany's wind power sector. Some companies were not able to withstand the competition and subsequently folded, and several developers merged or were taken over by other companies. Nevertheless, there are still many companies engaged in one or another - or a number of - stages of the wind power value chain. Figure 3 gives an idea of its complexity. According to a study commissioned by the German Federal Ministry for Economic Affairs and Energy (Lehr et al. 2015, 3), about 138,000 persons worked in Germany's wind energy sector in 2013, roughly doubled from 2004. This figure denotes gross employment and includes all persons who work directly in companies who provide wind energy products and services, and also persons who are involved with providing supplies, such as parts and components, to these companies (indirect employment in the sector). With this definition the figure includes all types of professions, starting from CEOs, over engineers, economists and lawyers, via skilled workers of many types, to kitchen, cleaning, and messenger staff. Even though it seems not to be possible to decipher the number of engineers, economic planners and skilled technical workers, who need deeper knowledge of wind energy issues and technology, it is apparent, that the demand cannot and should not be neglected. Each economic sector needs enough well educated and trained manpower with appropriate skills and competences.

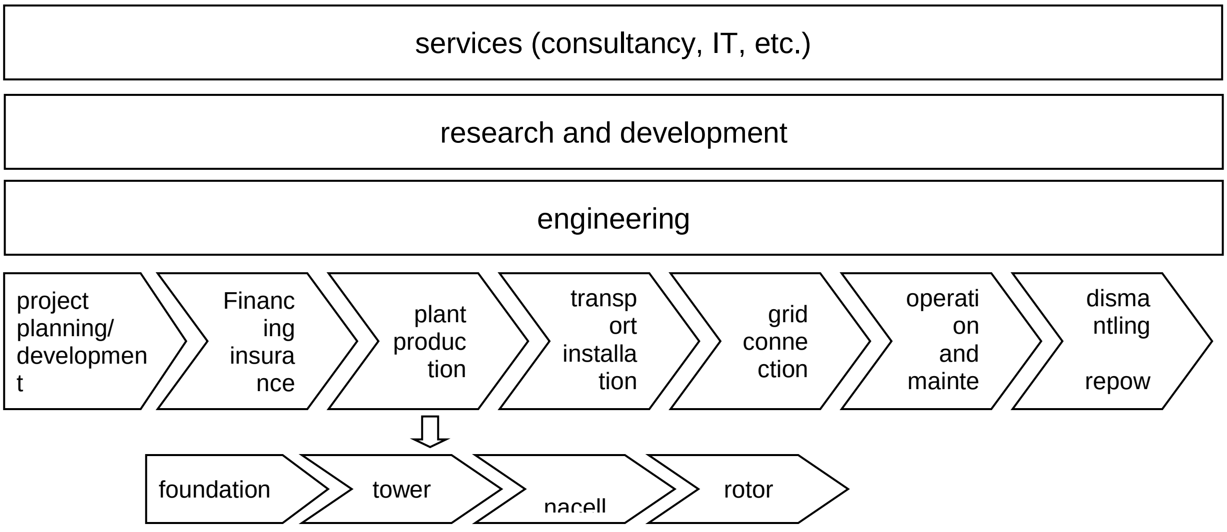

Figure 3: Value chain of the wind energy industry (Schwieters et al. 2012, 63)

In the following section we will elaborate a little bit on these skills and competences, concentrating, however, on the manpower that is chiefly concerned with the technical aspects of wind power, leaving out CEOs, lawyers, economists (even though they should also have some technical knowledge if they work in the field), and all the general support functions, that can be found in all parts of the economy.

2 Competence requirements at TVET-level in the wind power sector

Grantz et al. (2013) researched qualification structures and competence requirements at the skilled workers level with respect to the German labour market and with a focus on the off-shore wind power sector. As one can imagine, this issue is complex, so we can only cite some of the key findings to illustrate the situation.

Despite of Germany's well developed initial technical and vocational education and training (TVET) system with its currently (2014) 327 officially recognised training occupations at skilled workers level (BIBB 2015, 126), there is no officially regulated initial training occupation specifically for the wind power sector. Nevertheless, only about 0.9% of the workforce in the wind power sector do not hold a vocational (about 80%) or academic (about 27%) qualification, and some hold both. Most of the skilled workers have vocational certificates from electrical or mechanical engineering, mechatronics, as service technicians, from process (plastics) engineering, or from steel or concrete construction. These occupational profiles seem to be the most adequate ones to work in the production, erection, operation and maintenance of wind power plants, and the skills and competences acquired during the respective legally regulated and usually 3 – 3.5 year long training are sought after by the employers.

However, there are sets of additional skills and qualifications, that are needed in certain parts of the wind power sector. In the production of the parts of the plants, handling of big, thick, and heavy structures is required. Sizes are most similar to those in shipbuilding and other sectors of power engineering. Specifically for offshore applications special knowledge is needed in the field of corrosion protection. For erection, operation and maintenance several additional qualifications are required by HSSE (health, safety, security and the environment) regulations, such as for example in firefighting, tower climbing, rescue, first-aid, and in the offshore case, seamanship-related qualifications. In operation and maintenance competences in automatic control as well as in remote condition monitoring play a major role since onsite inspections and downtimes are important cost factors, both, on- and offshore.

For the academic degree level (Bachelor, Master, Ph.D), unfortunately, such a structured analysis is not (yet) available. The authors of this paper have started a survey among wind power companies in Germany, in order to find out which competences at the academic level are most sought after by the sector's employers. Since the survey is still ongoing, results are not yet available.

Almost all existing wind-power-related academic programs in Europe, however, stress the need for interdisciplinary knowledge. Already when looking at the construction of a single wind turbine, a number of engineering disciplines are involved: engineering mechanics for almost all components of the structure, soil mechanics for the grounding, construction engineering for tower and foundation, aerodynamics, fibre and plastics engineering for the rotor, mechanical engineering for the whole mechanical power transmission system, and electrical engineering for electrical power generation and transmission, not to forget metrology for wind load considerations and control engineering for all the measurement and control functions. Simulation is an important field to analyse structures, aerodynamics, aeroelasticity and interactions between all parts of the wind turbine. For erection, operation and maintenance, logistics and project management are of high importance, and for planning, legal and financial aspects play a major role, including environmental considerations, such as the protection of habitats of endangered species onshore, minimizing the impact on marine animals during the construction phase of offshore plants, or the possibility of bird strike. While the development and production of components according to experience largely can draw on established engineering disciplines, this interdisciplinary knowledge without doubt is needed for the construction and erection of complete wind turbines, and even more for setting up, operating, and maintaining wind farms.

3 Opening of German Universities for "non-traditional" students - permeability between the vocational and higher education systems

Not long ago, in Germany, there have been relatively strong demarcation lines between vocational and higher education (Mayer et al. 2003). In general, only somebody who had passed the "Abitur", a school leaving examination after grade 13 of general upper secondary education (only provided at a secondary school type called "Gymnasium"), was allowed to enter a full university. Holders of a grade 12 examination or of a final examination of a "subject-specific" gymnasium (Fachoberschule, Fachgymnasium) were entitled to enter a university of applied sciences, a type of - at that time - lower level university without the right to award PhD degrees, and for those not attending those types of schools it was tiresome to pass equivalent examinations (for comprehensive information on the current state of the German education system see e.g. Lohmar & Eckhardt (2014)).

Meanwhile, a lot has changed, and is still changing. The reasons for these changes include, but are not limited to, the following:

- In the course of the creation of the European Higher Education Area via the so-called Bologna Process, German higher education institutions changed their degree structures and adopted the academic degrees Bachelor and Master. That way the formal difference between the degrees of general universities and universities of applied sciences disappeared.
- The analysis of results of international comparative studies on education quality like PISA, TIMMS, among others also initiated discussions about the strict borderlines between different educational pathways in Germany, which had to be chosen at a comparably low age, typically when entering grade 5 or 6. The best performing countries apply a much more inclusive approach.

- Over the years, students' interest in the so-called STEM (sciences, technology, engineering, mathematics) fields declined, so that politicians and industry representatives see the technological base of the German economy endangered, and try to encourage a bigger share of young people to enter these fields.
- For quite some time, development and policy analysts, among others from OECD, have criticised Germany for having a too small portion of university graduates in order to keep its position as an innovative and technology-based economy and at the same time master the global development trend towards serviced-based economies.

As one of the answers to these challenges, the requirements for admission to university have been loosened by legislative means. Higher education institutions have been entitled by changes in the higher education laws of the federal states of Germany to widen their criteria for the enrolment of students. What was possible before on a pilot project basis at some universities and in some special study programmes, now has become the rule: higher education institutions, in addition to the criteria mentioned above, now are allowed to enrol students who hold a technician's certificate, a Meisterbrief (master craftsman certificate), and even those who hold a skilled worker certificate and have some years of practical work experience in their profession.

So, according to legal regulations, universities are expected to be open to students with such an alternative university entrance permit. In reality, however, universities are not (yet) so open. Study program entrance regulations are defined at each university for each study program separately. So, the respective study entrance regulations have to be revised in order to admit these non-traditional students. At the same time, universities do have only little experience with this, for them new, type of students. In addition, experience indicates, that it would be wise to apply some changes to the learning and management concepts of the study programs when opening them to the new clientele. All in all, universities experience these new developments as a challenge, on which many of them are reluctant to embark.

To encourage universities to nevertheless start working on the issue, the German Federal Ministry of Education launched a competitive funding program (BMBF n.d.), where universities can submit their concept and apply for financial support to develop and implement it. This program is embedded in a larger political initiative called "advancement through education", which aims to enhance everybody's educational opportunities. The specific targets of the program are to secure the availability of academic professionals, to increase the permeability between vocational and academic education, to quickly integrate newly developed knowledge into practice, and to strengthen the academic system's international competitiveness through profile development in the areas of academic learning and academic studies along with the job. Target groups of the concepts to be submitted therefore are persons who have to care for their families, people already in the job, for example vocational certificate holders also without a traditional university entrance qualification, persons returning into working life, students previously having aborted their studies earlier, or for some reason job-less degree holders. This collection includes virtually all groups of people, who do or did not follow the mainstream educational paths.

4 Experiences of "non-traditional" students in academic studies

Considering the specific needs of non-traditional students becomes more and more important for German universities, in some subject areas more than in others. Who are those non-traditional students? In a narrow sense, the term "non-traditional" means those students who do not have a "traditional" university entrance qualification as mentioned in Section 3. In a broader sense, however, non-traditional students are all those mentioned in the previous paragraph, including those who already have a degree. This, on the other hand, means that traditional students (in a broader sense) are those students, who come via the common path without any deviation from the "standard". The common path in that sense means, students graduate from upper secondary school either at the end of grade 12 or 13, and that way earn their university entrance qualification. More or less directly after they graduated from school, these students start university studies, maybe just with a break while waiting for the opportunity to enrol in their preferred study program, for working as a volunteer for a good purpose, or for travelling around the world before embarking on higher education.

Non-traditional students usually are older and more mature than traditional students. Most of them already have work experience, many are used to a proper income, and also many already have their own family for whom they have to earn a living. This culminates in those students being more targeted, often more engaged, and more demanding concerning the organisation of the study programme. They want to achieve their study goals in the shortest time possible while having a restricted time budget available under the triple load of study, work and family duties. This heavy load, together with the little flexibility of traditional study schedules causes many non-traditional students to abort their studies in early semesters.

Many of these "non-traditional" students, at least in engineering-related studies, perceive study content related issues as major hurdles for proceeding in their studies. One of these topics is engineering mathematics. It can be argued, that this is due to mathematics being taught in a way that is difficult to digest for anybody who is not used to learning largely abstract matters without a close linkage to applicability in real world problems. This idea is supported by experiences made in an experimental setting applied at the Bremerhaven University of Applied Sciences, where mathematics and engineering mechanics are taught in a highly coordinated manner by one and the same lecturer. Surveys among the students, which have not been published yet, have shown, that the drop-out rate of the students is much lower than at the time when such a program didn't exist.

5 The concept of a Bachelor programme on wind power, which can be studied along with the job

The concept which currently is under development at the Bremerhaven University of Applied Sciences in cooperation with the Fraunhofer Institute for Wind Energy and Energy System Technology addresses quite a number of the above mentioned issues under specific perspectives (see figure 4). Graduates of the program shall be able to work as wind farm planners, experts for wind turbines, plant and works managers, or in similar jobs, or even continue to a master's program. The program therefore has to address relevance to work practice and academic quality in parallel.

The study program shall open the academic world to people, who do not belong to the usual clientele of university-based study programs, but shall not exclude fresh graduates from upper secondary education with a regular university entry certificate. Therefore it addresses specifically people with vocational education background and work experience in a related field, like candidates with a master craftsman certificate, a technicians certificate, or a skilled worker certificate with some years of relevant work experience, but also career changers from cognate disciplines or people who did not embark on academic studies because of early family commitments. The first group is especially important for two reasons: first, the wind power sector is still relatively young and companies are interested to raise the qualification level of their staff, and second, work in erection and maintenance of wind turbines is physically very demanding, and when getting older people are interested in moving to less straining job duties.

5.1 Organisational aspects and cooperation in the Bachelor program

The organisational aspects will be fairly conventional. The Bachelor program will have a volume of 210 credits, which is equivalent to 3.5 years full-time study. In the European higher education area one credit (ECTS) represents an anticipated workload for an average student of 25 to 30 hours. Bachelor programs can have between 180 and 240 ECTS, Master programs between 60 and 120 ECTS, and for a Master degree a total of at least 300 ECTS from Bachelor and Master programmes must be collected.

A blended learning scheme will be applied, minimizing the need to be on campus, but at the same time assuring sufficient face-to-face contact between students and lecturers and among students, as well as the necessary contact with hardware and practical work.

Recognition of prior learning (RPL) schemes will be implemented to provide the option to reduce the study load for those who can prove that they master specific subject areas at the required competence level. For this purpose, equivalence studies will be conducted with standardized educational programs that lead to a master craftsman certificate or a technician certificate, which are certificates of advanced vocational education and can be earned by attending the respective programmes in advanced technical schools after having worked for some time as a skilled worker. Since these programs, despite standardization, are specific to the school where they are offered, equivalence studies will be conducted with a number of specific programs, from where students are expected. In addition, there will be a possibility to get practical experience recognized, thus reducing the volume of credits to be earned in industrial internships. Being more specific, it might be possible that master craftsmen get credits recognized in the field of human resource management and their practical work experience, technicians might get recognition in certain engineering basics areas. For other areas individual RPL will be applied. This includes special courses attended at higher or further education institutions which cover parts of the content of the study program, work practice, and previous learning on the job. The last points require close cooperation with employers in order to verify competences.

Close cooperation in the study program between organisers and employers (i.e. companies) is also necessary, because most of the practice-related part of the program shall be implemented in close contact with the world of work. The industry internship requires students to get an internship position in a company. Therefore, the study program organisers must agree with the corporate management on what the "engineering apprentice" should do and learn at her or his workplace. Also the Bachelor thesis should deal with practical problems, thus contributing to knowledge development and/or business development in the wind power sector.

Bremerhaven University of Applied Sciences and the Fraunhofer Institute for Wind Energy and Energy System Technology, a German apex wind energy research institute, by cooperating in the development and later the delivery of the program are meant to ensure that up-to-date and even new knowledge is covered in the program. In addition, having several providers of vocational education and training in the partnership will assure mutual access to education and training resources and information flow and knowledge exchange between academic and occupational organizations. Together with additional partners like the political administration, the respective industry associations and the above mentioned individual companies a "Wind Power Further Education Alliance" is about to be formed which is meant to be the basis for seamless competence development for the wind energy sector in North-West Germany.

5.2 Content-related and didactical aspects

The content of the study program will be structured according to a number of different principles in order to provide an optimal setting for learning. Throughout the course of study there will be project-based learning, starting with an introductory project on exploring a wind turbine, its physical, environmental, social, and economic environment, and the respective complex interconnections and interactions. At the end of the program there will be another major student project related to wind park planning, where everything learnt so far will have to be applied in a real-world setting. Industrial internship will be organised as a project, the situation in the host company permitting. Also each student's Bachelor thesis will address a real world wind power research and development problem out of company or research practice, possibly emerging from industry internship, thus also being project based.

For other wind power specific topics, in the narrower sense, a problem-oriented approach will be taken looking at the purpose and function of the different major parts of the wind turbine and at their interrelation and with the environment. That way, the study program organizers hope, students will develop the necessary holistic understanding of the complex wind power system, and will also have a high motivation for learning since throughout the study program they will be able to recognize, where and how the contents to be learnt fit into the whole picture.

Engineering basics are a special, somewhat problematic, but inherently necessary issue. As mentioned above, engineering basics are challenging subjects for students coming from the vocational track, especially because they have to be learnt "on stock", usually without immediately knowing the intended relevance of the new knowledge. A proper solution to this problem would be, if students could acquire these basics at the time of study, when their knowledge is needed for solving practical problems. To realize this approach, all the engineering basic subjects would have to be modularized, which can then be digested exactly when needed. As an ancillary condition, the modularized content would have to appear in an ordered manner during the course of study, since most of the modules will rely on the knowledge contained in other, subordinate modules. Very likely it would be hard to convince accreditation agencies as well as the engineering teaching community, that this way students will acquire all knowledge in engineering basics that is needed to take up Master level studies in engineering. That is why for the time being, the study program organisers deferred this idea to be realised at a later time.

It was decided, however, to implement the idea at a smaller scale, integrating as a first step only engineering mathematics into the other engineering basics subjects. This will lead to "tailored modules" in engineering basics. The blended learning approach opens the possibility to structure mathematics that way. Mathematics is organised in a collection of pieces, which can be accessed from everywhere in the course of learning, and that way learnt, exactly when its first application is needed. Even in advanced modules, there will always be the reference to the required mathematics content, so that learners are able to review it again. The mathematics module, however, is not dissolved completely. There will be a condensed mathematics module, which collects all the various mathematical chunks and puts them in relation to each other to enable learners to understand the internal structure of this fundamental science. Also there will be assessments where students can prove that they have mastered the subject area. This is done because most German engineering educators think that an engineer who does not master engineering mathematics cannot be a good engineer, and also as learners will need proof of these mathematics competences when they want to take up studies in a Master's program in engineering.

6 Additional considerations and summary

Readers only superficially familiar with the German dual vocational education system might be interested in the fact that German dual vocational education currently is losing learners.

The reasons lie in demographic developments - school leaving cohorts are getting smaller - and in the academic drift - a higher percentage of school leavers study in higher education. In 2014 the number of first-year students in higher education was as high as students entering dual vocational education and training, while in 1998 the ratio was 1:2, a dramatic change over only a few years (BIBB 2015, 13). The current initiative to open higher education to graduates of vocational education also is meant to help slowing down this development by raising the awareness, that vocational education is not a dead end path.

Especially for universities of applied sciences, the option to enrol students with vocational education and additional work experience is promising at least for two reasons. Some decades ago, the majority of students at Universities of Applied Sciences (at that time named "Fachhochschulen" in German) came via the so-called "second educational track", which means that they already had graduated in a vocational program before they enrolled for academic studies. Especially in technical study subjects these students had a much more developed understanding of technology and work requirements than the fresh general school graduates, which benefited the learning process of all. This has changed over time, and now most of the students come directly from general school without comprehensive work experience. Explicitly encouraging practitioners with work experience to study at Universities of Applied Sciences might help to restore this lost distinctiveness and quality.

In addition, there is the possibility that such study programs might open new business fields for Universities of Applied Sciences. Up to now, the regular study programs are completely government-financed, and students do not have to pay tuition fees for their first Bachelor and Master studies. Defining study programs as further education programs might allow universities to raise additional money from the students, which could create an additional pillar of institution financing to invest in quality development.

And last but not least, for innovative spirits, embarking on such new ventures offers the opportunity to rethink and revise learning organisation concepts in order to contribute to the development of a more permeable and inclusive education system, thus helping to solve some of the pressing societal issues like skills shortages and integration of socially disadvantaged groups of the society.

7 Acknowledgements

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