ECDEAST
Engineering Curricula Design
aligned with EQF & EUR-ACE Standards

Engineering Curriculum Design Aligned with Accreditation Standards

Edited by O. V. Boev, N. Gruenwald and G. Heitmann

Tempus

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Editorial

It is my pleasure and honour to be able to release this book titled "Engineering Curriculum Design Aligned with Accreditation Standards". The book presents results of the TEMPUS Project N°511121-TEMPUS-1-2010-1-DE-TEMPUS-JPCR "Engineering Curriculum design aligned with EQF and EUR-ACE Standards" (ECDEAST). With financial support of the European Union, the project ran from October 2010 to October 2013. The consortium of the project consisted of the following highly acknowledged European and Russian Universities and European Engineering Education Associations:

- *Wismar University (Germany) – Lead*
- *Lucian Blaga University of Sibiu (Romania)*
- *Kaunas University of Technology (Lithuania)*
- *Tomsk Polytechnic University (Russia)*
- *Bauman Moscow State Technical University (Russia)*
- *Saint-Petersburg State Polytechnical University (Russia)*
- *European Society for Engineering Education (SEFI)*
- *European Network for Accreditation of Engineering Education (ENAEE)*

Based on the initiative of Prof. Oleg Boev from Tomsk Polytechnic University and further developed with partners from Wismar University the main intention was the development of new engineering curricula (Master) at three Russian Universities taking into account the experiences of European partner universities within the Bologna process and ENAEE/EUR-ACE requirements with regard to graduates' competences. The main objectives of the project were:

- *Adapt the EUR-ACE Framework Standards and related quality requirements, learning outcomes, and QA-accreditation procedures to the State Educational Standards of the Russian Federation for engineering curricula.*

- *Develop/update Master engineering curricula and course materials at the three Russian partner universities in accordance with Russian as well as EQF and EUR-ACE requirements.*

- *Implement the new/updated programmes in the three Russian partner universities.*

Acknowledgement must be made to all participants in the project for their significant academic achievements, and for their willingness to share their ideas, time and experiences with others. It is my strong belief that this book will become an important source of information on engineering education and that readers will find the ideas and achievements presented herein relevant and applicable to their academic life and practice.
Finally, I wish to express my sincere appreciation and gratitude to Oleg Boev, Cyril Burkley, Ian Freeston, Günter Heitmann, Evgeniya Kulyukina and Marina Tayurskaya for their tremendous dedication and commitment in preparing and finishing this book, without which the publication of this book would not have been possible.

Prof. Dr. Norbert Gruenwald
Rector of University Wismar

Content

Introduction

The ECDEAST project, which was financed by the TEMPUS programme of the European Union, focused on the development of master programmes in engineering education in Russia based on systematic approaches to curriculum design with reference to internationally agreed quality standards such as the Dublin Descriptors, the European Qualifications Framework (EQF) and in particular the EUR-ACE standards for the accreditation of engineering programmes. These standards represent a paradigm shift in quality assurance as they are no longer based on input parameters but on outcomes. The application of an outcomes-based approach to the development and implementation of bachelor and master programmes within a two-cycle (or a three-cycle including the doctorate level) system of higher education is a topical issue for both Russian and European Universities.

The creation of the European Higher Education Area (EHEA) as the main aim of the Bologna process and of a common European quality assurance system are the responses to the challenges of globalisation, internalisation and commercialisation of higher education. The engineering profession is affected by societal, economic, industrial, political and other trends of modern world developments and thus needs highly-qualified specialists to meet the requirements of the modern economy. One of the priorities of the Russian Higher Education system is the improvement of the quality and global competitiveness of engineering education to ensure the equivalence of national programmes in engineering and technology to the international quality assurance standards in engineering education. Equivalence and comparability with international quality assurance standards will certainly contribute to the integration of the Russian Federation into the international community and to the promotion of the Russian system of higher education abroad as well as facilitating the mobility of students and graduates of engineering programmes. Thus, the experience of European Universities in the development and implementation of first and second cycle degree programmes (Bachelor and Master), is very important for Russian universities.

In the context of the Bologna Process based European quality assurance system and related subject specific qualification frameworks, in particular in engineering education, the Russian HEIs have to review and modify their programmes in accordance with the international quality assurance standards. The introduction of the third generation of the Federal Education Standards (FES) in 2011 provides Russian HEIs with new opportunities for the development of programmes (both bachelor programmes, but mainly master programmes that are currently being widely introduced in Russia) which correspond to the requirements of both national and European standards.

International recognition of degrees and the quality of engineering education is implemented through a system of international agreements based on the principle of substantial equivalence in requirements of the national accreditation systems (e.g. the European Network for the Accreditation of Engineering Education, ENAEE – which is in charge of the EUR-ACE system). The EUR-ACE Standards define the engineering graduates' competences required for first and second cycle degree programmes (FCD and SCD), internationally known as bachelor and master degrees. Successful programme accreditation by ENAEE results in the awarding of either the EUR-ACE Bachelor or the EUR-ACE Master and signifies that the respective programme corresponds to the common European quality assurance standards. This book is one of the results of the ECD-EAST project. It starts with a brief description of the most important current challenges for engineering education in Europe and globally. Together with the various requirements of the Bologna Process these challenges constitute the context of programme development today. Included also are discussions of the overarching European Qualifications Frameworks. Chapter 2 offers an introduction to various approaches to outcomes based systematic curriculum design with a special focus on those related to engineering education. Chapter 3 describes the accreditation of programmes as a means of external quality assurance. Chapter 4 goes into details regarding the requirements of national and international quality assurance standards in engineering, in particular the requirements for graduates' attributes / programme learning outcomes. Besides a detailed description of the EUR-ACE Framework Standards requirements, various national (Russia, France, UK, Germany) and international approaches are explored. The discussion of the FES of Russia includes a comparison with EUR-ACE and EQF standards. These approaches are complemented by the ABET/USA and Washington Accord ones and the increasingly influential approaches of international University Networks like CDIO.

The core activity of the ECD-EAST project was the development of a systematic curriculum design approach and its pilot application to master programmes in electrical and mechanical engineering and computer science at three outstanding Russian Research Universities and the activity was supported by the various European partners. The approach developed by the ECDEAST project partners is presented in Chapter 5. The methodology proposed in these guidelines is based on the theoretical considerations outlined in Chapter 2 and on the experiences and good practice of European countries in the implementation of the two-tier system (Bachelor-Master) in engineering education with reference to "European" requirements regarding learning outcomes and competencies (Dublin Descriptors, EQF, EUR-ACE Standards) and Russian Federal Educational Standards.

The guidelines formed the basis for a dedicated training programme in curriculum design for faculty and staff of the relevant departments of the three participating Russian Universities and this training was complemented by a staff exchange programme with partner Universities. As a result of the actual programme design and implementation by the departments involved and an evaluation of the recently started programmes by an international team of experts, the guidelines have been refined and enhanced by practical recommendations. It is hoped that these guidelines can serve as a model for systematic curriculum development in other departments and universities in the future. An example of the development of a programme from conception through the development of programme objectives, learning outcomes, credit allocation for learning outcomes and module syllabi is given in the Annex 2, where the curriculum in Electrical Engineering, developed at Tomsk Polytechnic University, is described. The other two cases are available on the web-site of the project (www.ecdeast.tpu.ru).

A glossary, a list of acronyms and a list of references complement the publication and may be helpful for further investigations.

1. Engineering Education in Europe: Current challenges and developments

1.1. Need for change and continuous improvement

The design of new programmes, the continuous improvement of curricula and the development of new teaching and learning methodologies are key tasks and duties of Higher Education Institutions (HEI). In the framework of the increased autonomy of Universities and Colleges on one side and the corresponding call for accountability on the other, a focus on accreditation, quality evaluation and quality management becomes increasingly important.

More recently this focus has become a powerful and necessary approach for Universities in order to increase their competitiveness in a national or transnational, or even a global, educational market.

In addition, in engineering education more than in many other academic branches, continuous innovation is essential in order to adapt to the fast growing body of knowledge, to new research and problem-solving approaches and to the changing demands from society, students and employers.

Adapting to new content and methods is not sufficient and certainly not the only criteria for innovative curricula development. In general "innovative curricula" are understood as curricula which reflect responsiveness to new demands and possibilities, but changes should not be restricted to those driven by demand alone. The development of programmes, the design of curricula and the enhancement of teaching and learning should also aim to create and provide new offerings with regard to modern subject areas and promising qualification profiles, exploiting the potentials of innovative teaching/learning arrangements as well as ICT, and promoting entrepreneurship and economic growth.

Future requirements are difficult to predict and depend to a great extent on the societal, economic and political context. In USA and in the UK the Academies of Engineering have recently undertaken inquiry or scenario based attempts to give an idea of "The Engineer of 2020"[1] or even the "Engineer of the 21st Century"[2] and draw conclusions from them for engineering education and actions which different stakeholders will have to undertake in the future. The American Society of Civil Engineers (ASCE) transferred foreseeable demands into a "Civil Engineering Body of Knowledge for the 21st Century", which will be necessary to prepare engineers for the future[3].

On a more general political and strategic level the European Union has embedded the discussion of education and training needs and improvements in a mid- to long-term political vision and comprehensive strategic concept. In 2000 the Lisbon Strategy aspired to make the EU the most dynamic and most competitive economy in the world by 2010. Innovation was identified as one of its main pillars. In 2005 the focus of the Lisbon Strategy was redirected in order to achieve the objectives relating to 'job opportunities and growth'. In conjunction with the development of the European Research Area and consideration of the future of the Lisbon Strategy after 2010, the European Council in December 2008 called for the launch of a European Innovation Plan which would meet all the conditions for sustainable development and support the most important technologies of the future. Recently the EU launched its "Europe 2020" plan[4]. As described by the President of the European Commission: *"‹Europe 2020› is the EU's growth strategy for the coming decade. In a changing world, we want the EU to become a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should help the EU and the Member States deliver high levels of employment, productivity and social cohesion. Concretely, the Union has set five ambitious objectives – on employment, innovation, education, social inclusion and climate/energy – to be reached by 2020. Each Member State has adopted its own national targets in each of these areas. Concrete actions at EU and national levels underpin the strategy"*[5].

Education and training is perceived as a key driver of the Lisbon strategy. Related to the Europe 2020 plan a "Strategic Framework for the European cooperation in education and training (ET 2020)"[6] has been deve-

1) National Academy of Engineering, 2004, The Engineer of 2020
2) The Royal Academy of Engineering, 2007, Educating Engineers for the 21st Century
3) American Society of Civil Engineers, 2008, Civil Engineering Body of Knowledge for the 21st Century
4) European Union, 2013, Europe 2020: Europe`s growth strategy
5) Barroso, Juan Manuel, http://ec.europa.eu/europe2020/index_en.htm
6) European Commission, 2010, http://ec.europa.eu/education/lifelong-learning-policy/policy-framework_en.htm

loped. The 2006 "European Framework for Key Competences for Lifelong Learning" [7], identifies and defines 8 key competences necessary for personal fulfillment, active citizenship, social inclusion and employability in a knowledge society:

1) Communication in the mother tongue;
2) Communication in foreign languages;
3) Mathematical competence and basic competences in science and technology;
4) Digital competence;
5) Learning to learn;
6) Social and civic competences;
7) Sense of initiative and entrepreneurship;
8) Cultural awareness and expression.

The majority of the benchmarks set for 2010 has not yet been reached and are now references for Europe 2020 as well. Provisions for the achievement and development of these competences are required from all levels of the educational system, including higher and continuing education. For engineering education all of them are essential, as outlined in various qualification frameworks and are discussed in Chapter 3. These developments are also becoming a focal point for curriculum and educational reforms like lifelong learning skills, social and civic competences and entrepreneurship.

From the various sources available, a set of challenges and demands can be derived which engineering education in Europe and to a major extent globally has to deal with and which affect programme development and curriculum design and implementation.

1.1.1. Increasing speed of knowledge expansion

Incorporating new scientific and technological developments into engineering programmes and courses is an ongoing challenge. Academia in natural sciences, engineering sciences and technology, informatics and mathematics are themselves contributing significantly to the rapid expansion of knowledge, processes and products. Students and graduates are being confronted and introduced to these research activities and results during their studies. A major challenge is the ever increasing speed and volume of knowledge production. Due to the limitation in the duration of programmes of study and as syllabuses in engineering education are generally already full to capacity an increase of content or duration is no longer a solution. In addition, due to changing work environments employers are increasingly seeking certain skills and competences of graduates in addition to a sound knowledge base.

Staff involved in curriculum design and teaching have a range of options available to help them react to this situation but to date there still seems to be too much focus on delivering content. Often very specialised and narrow programmes are favoured. A better solution for engineering programmes would be, in addition to a sound fundamental knowledge, to focus on skills and competence achievement and in particular on the ability to organise a process of self-directed life-long learning and the competences to deal with open-ended problems in various social contexts.

1.1.2. New engineering disciplines and approaches

The expansion of knowledge continuously results in new engineering disciplines and branches of engineering practice, like bio- and bio-medical engineering, nanotechnology, eco-engineering, photonics, etc., which are predominantly the outcome of inter- and multi-disciplinary approaches. With regard to engineering practice and the increasing complexity of problems to be solved a systems perspective is necessary. "Systems engineering is based on the principle that structured methodologies can be used to integrate components and technologies. Hence, there is a need for greater breadth so that broader requirements can be addressed. Because of the increasing complexity and scale of systems-based engineering problems, there is a growing need to pursue collaborations with multidisciplinary teams of experts across multiple fields.

7) European Parliament and Council, 2006, Recommendation on key competences for lifelong learning

Essential elements for these teams include excellence in communication, an ability to communicate using technology, and an understanding of the complexities associated with a global market and social context. Flexibility, receptiveness to change, and mutual respect are essential as well" [8].

The curriculum provider and the curriculum designer are required to provide appropriate teaching and learning situations for the achievement of these competences and attitudes, in particular project work in multi-disciplinary and maybe even trans-national teams as well as internships in collaboration with industry and research institutes.

1.1.3. Innovation and contribution to economic growth and sustainability

The financial and economic crisis has resulted in a call for economic recovery and growth. The call has focussed on increased innovation and is reflected in the Europe 2020 strategy. The "Innovation Union" is one of the seven flagship initiatives. "At a time of public budget constraints, major demographic changes and increasing global competition, Europe's competitiveness, our capacity to create millions of new jobs to replace those lost in the crisis and, overall, our future standard of living depends on our ability to drive innovation in products, services, business and social processes and models. This is why innovation has been placed at the heart of the Europe 2020 strategy. Innovation is also our best means of successfully tackling major societal challenges, such as climate change, energy and resource scarcity, health and ageing, which are becoming more urgent by the day." [9]

The European Union strongly supports a stronger collaboration between Universities, Businesses, Research Institutes, Regions and Communities in creating target oriented clusters and facilitating the working of the so called knowledge triangle, the fruitful relation and cooperation of research, education and innovation. The concerns in this context are the speeding up the processes from research to innovative products, the facilitation of spin-offs and entrepreneurship and the support of Small and Medium size Enterprises (SME). These aims and measures are all relevant for education, not least engineering education, and are reflected in the EU Horizon 2020 programme [10].

One major requirement is the improvement of design education as expressed in the Commission staff working document of 2009:
"As the concept of design has developed, the role of the designer has evolved too. Design as a strategic, cross-functional and multidisciplinary innovation activity implies a broader role for the designer, linking other functions and ensuring that the customer is always in focus. It requires a new and broader set of skills in the designer, including better understanding of business-related matters. It also requires that the designer sees him/herself as part of a collective effort towards user-centred innovation, rather than an independent form giver.
The development of co-creation and user-driven innovation means that more and more people are involved in design activities, and that the role of the designer is diffused. Recent developments in ICT, such as computer aided design and rapid prototyping technology, are also changing the skills requirements of designers. Computer-aided design is a prerequisite for computer-aided manufacturing, an area of technology which is promising great efficiency gains in the coming years. The growing significance of service and experience design, and design as a tool for innovation in services, are among the more recent developments — all areas which call for research and an updated skills base among designers."[11]

Connected with striving for innovation and economic growth is the call for socially responsible, environmentally sustainable and resource efficient development which requires a more relevant education and training of the labour-force, and in particular of engineers, in addition to the need for a general change of attitudes. Curriculum designers and teaching staff are under pressure to insert appropriate learning outcomes and content as well as relevant problem-solving approaches

8) National Academy of Engineering, 2004, The Engineer of 2020, p. 34
9) European Commission, 2010, Communication on Europe 2020 Flagship Initiative Innovation Union SEC
10) European Commission, 2013, Horizon 2020 – The framework programme for research and innovation
11) European Commission, 2009, Design as a driver of user-centred innovation

and tools into the programmes and the teaching/learning arrangements.

1.1.4. Global economy and changing work environments

The requirements of employers in relation to qualification profiles and competences of engineers and engineering graduates reflect the changing work environments, research development and manufacturing and service processes and structures. Globalisation is having an increasing impact on these requirements and also affects SMEs striving for competitiveness in a global market. Outsourcing and locating off-shore not just of manufacturing but of engineering research and development and executing it in countries with much lower salary levels has raised the question in some industrially advanced economies of what kind of engineering work will remain at the parent company and what should be the focus for education and training.

In USA and to some extent also in the UK this concern and debate has resulted in the requirement for "global education" and "leadership" courses. Specific leadership courses have been developed as part of or as an add-on to engineering undergraduate education or as master programmes[12, 13]. Leadership competences have been added also to the required learning outcomes of engineering curricula based on the CDIO approach, and these are explained in some detail in Chapter 2.5.

In Europe, curricula and accreditation standards in engineering do not as yet address this requirement explicitly but pursue the achievement of the required competences in an indirect or embedded way, e.g. project based learning in teams, system engineering approaches, specific internship formats and management courses and modules.[14]

1.1.5. Lack of students and graduates in STEM areas

In many European countries as well as in USA the static or decreasing interest of students in studying Science, Technology, Engineering or Mathematics (STEM) and the envisaged or already experienced lack of qualified engineers is a major concern. In addition, the students applying for admission are on average not the best performers of their respective student generation and age group. This often results in low retention and success rates, particularly in engineering, where in some countries only approximately 50% of the students, that initially enroll, graduate with a first degree in engineering. Even where the student population in STEM areas is satisfactory there is still an underrepresentation of female students and of so called non-traditional students which in turn increases the problem of recruiting the "best brains".

Currently a range of approaches and measures are being developed to try to improve the situation. As well as raising the interest in the STEM areas during school education, the HEIs are trying also to increase the attractiveness of their programmes. In addition, with curricular amendments and improvements in student support, guidance and counselling, universities and colleges are attempting to achieve better retention and graduation rates.

With regard to curriculum development, more flexible and motivating programmes are being designed, starting with introducing engineering problems and projects at the very beginning of the studies, addressing diversity of interests and abilities of students in an often very heterogeneous student population, recognising prior and experiential learning and supporting individual learning paths. In master programmes an increasing variety of research curricula or practice related curricula is on offer, with often a high number of optional modules and challenging learning opportunities in research projects, internships, community services, trans-national teamwork, study abroad and extracurricular activities. The competition for international students requires attractive programmes, for which students will be willing to pay high tuition fees. In many cases the internationalisation of studies is supported by national governments or transnational bodies, for example by the European

12) MIT Leadership Center, 2013, Developing Innovative, global leaders, http://mitleadership.mit.edu/
13) Gordon-MIT Engineering Leadership Program, http://web.mit.edu/gordonelp/
14) Gordon-MIT Engineering Leadership Program, 2009, document: Engineering Leadership Education: A snapshot review of international good practice

Union mobility programmes. The "European master courses" in the Erasmus Mundus programme are a particular example and also provide examples of good practice for other universities that are not directly involved.[15]

1.1.6. New learning environments and ICT based tools

A particular challenge for curriculum designers and teaching staff is the increasingly expanding opportunities and tools for ICT based or supported teaching and learning. This is reflected also in new formats of Open and Distance Learning (ODL), e.g. the currently much debated promotion and delivery of inter-active "Massive Open On-line Courses" (MOOCs) which started a few years ago in the USA. This may result in the development of new flexible ODL and blended learning formats and programmes, with the latter depending to a great extent on the recognition of these courses and their outcomes by traditional programme providers.

In addition to developments in the ODL area and in continuing education, ICT based learning facilities contribute and increasingly influence the teaching and learning situations in traditional curricula and formats of content delivery as well as in labs and in student PBL and project work in collaboration with practice or even trans-nationally. They have the potential to speed up the "shift from teaching to learning" and to promote the competence of self-directed and independent learning for students and graduates. The effectiveness and the efficient use of these tools will be increasingly a concern for programme providers and teaching staff, which will also be influenced by financial constraints, the reduction of public funding and the requirement for greater accountability. Many universities have started to develop a strategic position and play a pro-active role with regard to these developments in order to exploit the potentials of ICT based teaching and learning and programme delivery in a systematic and coherent way. However, for the majority of HEIs this is still a challenge to be dealt with.

1.2. Bologna Process related reforms

Like other disciplines, engineering education in Europe since 2000 has been challenged by new transnational political aims and measures resulting from the Bologna Declaration of 1999 and the subsequent Bologna Process, which was organised to specify the aims and measures and to facilitate and monitor their realisation.

The Bologna Declaration started a coordinated activity to establish a common European Higher Education Area (EHEA) in order to increase transparency, mobility and mutual recognition and to enhance quality and competiveness. By identifying 10 different action lines and measures the Bologna Process aimed to achieve this target and to implement a common and flexible three cycle structure of higher education including a common European Credit Transfer System (ECTS) and shared approaches to quality assurance by 2010.

For many national higher education systems and in particular for traditional continental European Universities with integrated programmes of study of 5 to 6 years duration leading to a degree that was equivalent to a master degree with a strong research profile, the implementation of an additional degree level after 3 to 4 years of study seemed to be the most demanding challenge. As the Bologna Declaration and Process was just an agreement concerning certain aims and action lines between the signatory countries but with no legal power supporting it, some countries initially did not fully implement the recommended measures and tools. However, by 2013 the majority of the 47 signatory countries of the Bologna Process had changed their system to a three cycle structure. Nevertheless, despite the common structure, the diversity in Europe increased and the mobility and recognition aims have not been achieved to the extent initially expected. The monitoring and stock-taking of the Process and the discussions at the Bologna Seminars and Follow-up Conferences highlighted the fact that more time will be needed to implement some developments, such as the shift towards learning outcomes and agreed standards of quality and for programmes to be enriched by additi-

15) EU Erasmus Mundus Programme, 2013-2014, http://eacea.ec.europa.eu/erasmus_mundus/results_compendia/selected_projects_action_1_master_courses_en.php

onal aspects and conditions such as the inclusion of the social dimension. The Bologna Process was therefore extended to 2020, with ongoing stock-taking, Seminars and Follow-up Conferences.

In general the three cycle system of higher education, including the third cycle doctorate level, meanwhile is the predominant structure. In addition, many countries offer sub-degree programmes of usually two years duration, which in other countries would be part of the Vocational Education and Training (VET) system. This structure also applies to Engineering Education, apart from integrated programmes at more practice oriented HEIs which award an engineering degree after 3 to 4 years of study. In relation to the agreed Bologna structure various countries adopted different approaches. Some countries even had to force their Universities and other HEIs to introduce a First Cycle Degree (FCD) level. Some countries immediately adopted this new structure (e.g. Italy), while others continued for some time to provide the old system in parallel to the new one (e.g. Germany). However, in engineering education a number of European countries still continue to offer their traditional programmes (e.g. France, Sweden) or newly introduced integrated programmes (UK), which are often accompanied by extremely narrow and specialised short "master" programmes as part of continuing education.

The new Bologna first cycle degree after three to four years of study or the achievement of 180 to 240 ECTS credits should prepare graduates for the labour market and guarantee their employability. Globally this first degree, usually after 4 years of study, is the regular entrance qualification into engineering practice and is sometimes linked with additional requirements concerning practical experiences in a phase of "Initial Professional Development" (IPD) and an exam in order to become a registered or licenced "Professional Engineer" (PE).

Many of the traditional European Research Universities with 5 or 6 year integrated programmes in engineering education did not welcome the new structure and they still expect the majority of their students to continue to a Second Cycle Degree (SCD) or even a doctorate. They perceive the newly introduced First Cycle Degree level as a kind of distribution or pivot point towards a differentiated second cycle programme level. They appreciate this new second cycle level because of its potential to allow a diversification of the programme offerings at graduate level and to attract national and international students who already carry an appropriate first degree. Some of these Research Universities thus try to enroll more students at the graduate rather than at the undergraduate level.

In addition to the structural changes the Bologna Process, in striving for transparency, mutual recognition and mobility challenged HEIs with the recommendation that they use agreed learning outcomes and qualitative level indicators as reference for curriculum development and quality assurance. This will be addressed in detail in later chapters.

Associated with the shift to learning outcomes was the requirement to introduce a common European Credit Transfer and Accumulation Scheme (ECTS) based on student workload, but also related to outcomes for different levels of programmes. The study workload should not be expressed by student contact hours with teaching staff, like for instance in the USA credit system, but by the total time of all learning activities necessary for an average student to achieve certain outcomes of a module or course unit. This approach of calculating the total learning time using the unknown "average student" is highly speculative. Only in an iterative process of continuous adjustment based on student feed-back and data collection can the teaching staff arrive at valid and reliable figures with regard to their lectures and modules. In addition, what was expected to establish a more or less automatic recognition of credits on a transnational level resulted in quite a lot of confusion as HEIs or individual signatory countries calculated the overall credits with different workloads, ranging from 20 to 30 or even more hours, per credit. In addition, in most cases it was and is still not clear what level of quality and achievement is connected with certain credits.

At times this has resulted in a problem of recognition of credits even at national level. To reduce recognition problems HEIs constituted networks where the members guarantee automatic recognition of credits for mobility students of the HEIs involved in the network, but not for those from external HEIs.

Problems with regard to recognition of credits also arise from the assessment and grading regulations in the ECTS system.

Programme developers and teachers are advised to make use of the official ECTS Guide which has been updated several times based on the experiences and data collected.[16, 17] However, the problems mentioned above still persist with different approaches being used to arrive at satisfactory solutions.

1.3. Quality assurance and enhancement

1.3.1. The shift to outcomes -based approaches

Traditionally achievements and quality in higher education have been measured based on evidence of input and output data with regard to students, graduates, staff, facilities, funding, research and services and by referring to tradition, status, reputation and ranking of universities and other higher education institutions (HEI). National frameworks and governmental regulations for programmes of study and the curricula at HEIs have been determined by discipline, branch and subject related specifications of content, teaching hours and examination requirements. Accordingly, governmental approval or external accreditation of programmes was based on checking long lists of input data with regard to various criteria and requirements.

Since around 1990 as a result of the global trends of expansion, diversification, internationalisation and commercialisation of higher education, performance- and outcomes-based approaches have increasingly influenced the debate and actions on reform and quality assurance in higher education. Different factors and driving forces have shaped the discussions and developments: At the system and institutional level of higher education, it was principally the requirement for increased efficiency and the accountability of spending public funds, which resulted in the shift to measuring the outcomes achieved. In addition, increasing tuition fees in many countries raised the interests of students in the outcomes of their studies and in the "value for money" they received. New public governance and institutional management approaches also helped push the orientation towards outcomes and performance indicators.

At the programme level, the public interest in assuring certain quality standards and in the comparability and in national and international recognition of qualifications and achieved competences, promotes the orientation towards outcomes. This is reflected in the shift in orientation from inputs to outcomes in qualifications frameworks, state directives and regulations, subject benchmarks and accreditation standards. They describe, in generic and subject specific terms, the type and level of the capabilities that graduates should have achieved at certain qualification levels.

At the level of teaching and learning, as a result of this paradigm shift and the new requirements in quality assurance and improvement, curriculum development, provision of learning arrangements and assessment of students are all undergoing significant changes in order to focus on the required or intended learning outcomes. Even independently of the described changes and demands at system, institution and programme level, outcomes-based teaching and learning can be a strong tool for quality enhancement, in particular when embedded in an approach of "constructive alignment"[18]. This concept constitutes a process whereby the stated aims and objectives of a university and its programmes, with detailed specified learning outcomes, are aligned with the appropriate content teaching and provision of learning arrangements and an adequate assessment to ensure the achievement of the stated outcomes. Comparing achieved learning outcomes with the intended ones will close the feed-back loop resulting

16) European Commission, 2009, ECTS User Guide, http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf
17) European Commission, 2013, European Credit Transfer and Accumulation System (ECTS), http://ec.europa.eu/education/lifelong-learning-policy/ects_en.htm
18) Biggs, J. and Tang, C., 2007, Teaching for Quality Learning at University

in measures of change and quality enhancement and thus creating a process of continuous quality assurance and management.

Outcomes based approaches in higher education are increasingly a common feature on a global scale. A strong driving force for the implementation of outcomes-based higher education in Europe is still the Bologna Process, which has resulted in the development of national and subject related qualification frameworks and the spread of external quality assurance approaches like programme accreditation and evaluation.

1.3.2 Qualifications Frameworks

In 2003 at the Bologna Follow-up Conference at Berlin it already became obvious that comparability and transparency and thereby increased mobility can only be achieved by strengthening the qualitative dimension of the process. The development of a shared Qualifications Framework based on learning outcomes as a common reference for comparison of qualifications, recognition of course credits and degrees and for the design or revision of curricula evidently was necessary. At the 2005 Bergen Bologna Follow-up-Conference agreements were reached which resulted in the" Framework for Qualifications of the European Higher Education Area (QF-EHEA)" and the "European Standards and Guidelines for Quality Assurance in Higher Education (ESG)". Signatory countries of the Bologna Process, that had not already done so, were requested to develop and implement national and institutional quality assurance systems and in particular a National Qualifications Framework in accordance with the adopted and overarching European one.

In a recent study on the applications of learning outcomes associated with the Bologna Process it was stated: "Learning outcomes are acknowledged as one of the basic building blocks of European higher education reform. Learning outcomes are statements of what a learner is expected to know, understand and/or be able to demonstrate at the end of a period of learning. They are explicit assertions about the outcomes of learning - the results of learning. Learning outcomes are concerned with the achievements of the learner rather than the intentions of the teacher (expressed in the aims of a module or course). They can take many forms and can be broad or narrow in nature. They are usually defined in terms of a mixture of knowledge, skills, abilities, attitudes and understanding that an individual will attain as a result of his or her successful engagement in a particular set of higher education experiences. In reality, they represent much more than this. They exemplify a particular methodological approach for the expression and description of the curriculum (modules, units and qualifications) and level, cycle and qualifications descriptors associated with the 'new style' Bologna qualifications frameworks." [19]

The overarching Framework for Qualifications of the EHEA, based on the previously developed "Dublin Descriptors", defines learning outcomes for the three degree levels of the Bologna structure and a possible sub-degree level within the first cycle with regard to five dimensions: [20]

- knowledge and understanding
- applying knowledge and understanding
- making judgements
- communication skills
- learning skills

The resultant defined outcomes are generic and do not address specific disciplines, qualification profiles or types of higher education institutions. They therefore need to be complemented by domain specific frameworks dealing with different disciplines or professions and serving different purposes. As will be outlined later, this has already taken place with the support of the European Commission in quite a number of disciplines like Engineering (EUR-ACE), Informatics and Computing (EQUANIE), Chemistry, Economics and Management (EQUIS), Music, mainly for the purpose of transnational professional recognition and embedded in accreditation or labeling procedures.

19) Adam, S., 2008, Learning outcomes, current developments in Europe
20) Bologna Working Group on Qualifications Frameworks, 2005,

One advantage of the Framework for Qualifications of the EHEA is that it covers not only cognitive dimensions of qualifications but also learning outcomes with regard to social and personal skills. An additional advantage is that learning outcomes for the five dimensions are defined for different degree levels. As a consequence, European domain specific frameworks and related accreditation standards like EUR-ACE specify learning outcomes for the first as well as for the second cycle degrees. It differs from the approach of the Washington Accord [21] and its accreditation standards for engineering programmes in which expected learning outcomes are phrased as "graduate attributes" to be achieved by the first degree, usually a bachelor degree after 4 years of study.

Looking at the current status of the Bologna Process, the 2009 stocktaking report clearly indicated that the envisaged changes and a comprehensive introduction of a lifelong learning culture based on full implementation of a learning outcomes approach across the EHEA, still needs a lot of additional effort. As a consequence, one of the recommendations of the stocktaking report states the need to "Work towards achieving coherence in describing all higher education programmes using learning outcomes, to enhance the transparency of qualifications and to facilitate the full implementation of ECTS and the diploma supplement." [22]

In addition to the Bologna Process, the European Union (EU) in 2008 formally adopted a more comprehensive "European Qualifications Framework for Lifelong Learning (EQF-LLL)" with 8 levels covering not only higher education but also all secondary and vocational education qualifications which follow on from the compulsory education at primary and secondary level. [23] The EQF-LLL uses the 3 dimensions of knowledge, skills and competences to specify the expected outcomes at each of the 8 levels. Even if the phrasing is slightly different it is argued that the 4 levels of the Bologna Framework are substantially equivalent to the levels 5 to 8 of the EQF: level 6 corresponds to the first cycle degree level of the Bologna Framework, usually termed bachelor level, level 7 to the second cycle degree or master level and level 8 to the doctorate level.

The EQF applies to all types of education, training and qualifications, from school education to academic, professional and vocational education. Like the Bologna Framework for higher education qualifications this approach shifts the focus from the traditional system which emphasises ‚learning inputs', such as the length of a learning experience and the type of institution towards learning outcomes. It also encourages lifelong learning by promoting the validation of non-formal and informal learning.

The EU member countries are currently required to develop National Qualifications Frameworks (NQF) and reference them against the EQF-LLL. Countries that already had NQFs with more than 8 levels are not required to adapt these frameworks to the 8 levels of the EQF as long as an appropriate and convincing mapping between different levels can be demonstrated. In some countries a controversial debate arose between different stakeholders because of the differences in focus and wording of the Bologna Framework for Qualifications compared to the EQF-LLL. In Germany the Universities prefer to stick to the Bologna agreements and the corresponding 3 level German qualifications framework for higher education of 2005 whereas the Federal Government and the Federal States as well as the vocational education sector would favour a comprehensive 8 level framework with learning outcomes phrased as competences. As a result, in May 2013 Germany has formally adopted a respective NQF with 8 levels which was successfully referenced against the EQF.

This case illustrates the fact that, at national and HEI level, a range of different but increasingly outcomes based directives and references can be in place. France for example applies a special set of standards, administered by the Commission de Titres d´Ingénieur, to accredit Grandes Ecoles and their programmes leading to the degree and title of "Ingénieur diplômé", which in theBologna structure is recognised as a second cycle

21) The Washington Accord (WA) is a network of 15 national Accreditation Agencies for engineering programmes aiming at mutual recognition of their accreditation decisions. Russia through AEER is a member since 2012. Together with 5 other Networks and accords the WA forms the International Engineering Alliance (IE) http://www.washingtonaccord.org/washington-accord/

22) BFUG Working Group on Stocktaking, 2009, Bologna Process Stocktaking Report

23) European Communities, 2008, European Qualifications Framework for Lifelong Learning (EQF-LLL)

degree. Germany for the purpose of programme accreditation and curriculum development decided that at the second cycle level there should be a distinction between more practice oriented and more theory and research oriented profiles reflected in different learning outcomes and even names of degrees, like "master of engineering" or "master of science". The Universities and HEIs in the UK, in addition to offering 3 years bachelor and honours bachelor programmes, followed by 1 to 2 years master programmes, also provide 4 years integrated programmes directly leading to a "Master of Engineering" (MEng) degree. This arose as a result of a master degree becoming the required qualification for entry into the phase of Initial Professional Development (IPD), which after completion and respective application can lead to the award of the professional title and registration as "Chartered Engineer".

State directives and regulations, qualifications frameworks or accreditation guidelines usually function as references describing threshold standards in terms of learning outcomes, subjects, contents and credits. Many Higher Education Institutions, in particular research intensive Universities, based on their autonomy have the interest and right to set standards above these threshold standards, for various reasons. They increasingly apply an outcomes based approach in order to develop and implement their programmes and to assure their quality. Also recognition and promotion of programmes on a global education market becomes much easier and transparent for stakeholders and potential customers. Nationally and internationally quite a number University networks exist with a special mission and a specific range of learning outcomes they are committed to. Some examples will be given later.

Thus, referring to national or international directives, qualification frameworks or accreditation standards is one issue. Going beyond threshold requirements and striving for more ambitious aims is another one. Both strategies profit from approaches based on learning outcomes if handled properly.

1.3.3. Learning outcomes in the Bologna Process: QF-EHEA and EQF-LLL

As mentioned previously the Bologna Process Framework, based on the Dublin Descriptors, details the expected outcomes for each level with regard to 5 dimensions, whereas the EQF-LLL specifies outcomes with regard to 3 dimensions: knowledge, skills and competences. The term "competence" is only marginally used in the Bologna Framework in the context of application, whereas in the EQF–LLL it is essential and describes the responsibility and autonomy with regard to work and learning situations, which the holder of a qualification at a certain level should be able to deal with.

In both frameworks it is possible to progress from one level to the next by achieving the higher level in each dimension, but in practice this does not mean that the holder of a higher level qualification has achieved all the knowledge, skills and competences requirements of the previous level. However, when considering the master or second cycle level outcomes it should be realised that they usually extend the outcomes already achieved during the first cycle of studies. This is reflected in the Bologna Framework specifications of outcomes for the second cycle level, the master level: "Qualifications that signify the completion of the second cycle are awarded to students who:

- have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with Bachelor's level, and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context;
- can apply their knowledge and understanding and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study;
- have the ability to integrate knowledge and handle complexity and to formulate judgements with incomplete or limited information and includes reflec-

ting on social and ethical responsibilities linked to the application of their knowledge and judgements;

- can communicate their conclusions, and the knowledge and rationale underpinning them, to specialist and non-specialist audiences clearly and unambiguously;

- have the learning skills to allow them to continue to study in a manner that maybe largely self-directed or autonomous."[24].

The European Qualifications Framework (EQF-LLL) specifies the master level in the three dimensions as follows:

"Knowledge:
- highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research;
- critical awareness of knowledge issues in a field and at the interface between different fields;

Skills:
- specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields;

Competences:
- manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches;
- take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams."

It should be noted that the EQF-LLL, at the bachelor level, already expects "advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study." Concerning competences it requires graduates at this level to be able to "manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts and take responsibility for managing professional development of individuals and groups"[25].

The overarching Qualification Frameworks described function as a reference for respective National Frameworks and also for discipline or profession oriented national or transnational frameworks, and for accreditation standards or benchmarks as will be illustrated with regard to engineering education in Chapter 4.

24) Bologna Working Group on Qualifications Frameworks, 2005, A Framework for Qualifications for the European Higher Education Area

25) European Parliament Council, April 2008, Recommendation on the establishment of the European Qualifications Framework on lifelong learning

2. Systematic approaches to curriculum development and revision

2.1. Practical approaches and theoretical concepts of curriculum design in higher education

In the past curriculum development was often focused on actions limited in scope like up-dating syllabi, introducing new courses or modules or implementing new teaching/learning approaches like collaborative learning or problem based learning (PBL). These activities were generally not embedded into a strategic, comprehensive and systematic process of curriculum design and quality enhancement. On the contrary, curriculum development or revision in practice seemed to be more a bargaining process in a certain prescribed framework or on the basis of existing experiences and facilities than an educational research based systematic approach to achieve a certain goal or product. These processes were mainly focused on reaching agreements for a particular programme about necessary subjects, the lists of syllabi and their content, the number of teaching hours and examination requirements.

In the seventies more comprehensive approaches to curriculum development and revision in engineering education were developed as a result of various complaints about deficiencies and the lack of a coordinated assembly of subjects in the predominant curricula delivered. This resulted in the students themselves having to integrate these programme elements for the purpose of problem solving and the creation of technical products and systems and the critical consideration of their impact and societal context. Superficially it seemed to be a curriculum reform focussing on the structures of curricula. Besides the first experiments with modularised curricula, (e.g. in the UK and at the Danish Technical University), a strong movement towards curricula structured mainly by projects and courses contributing to these projects, with a share of up to 75% of the semester study load, challenged the traditional curricula. The most prominent example in engineering education in Europe was and is still Aalborg University in Denmark. In the USA, Worcester Polytechnic Institute became quite prominent, employing similar ideas of project orientation. In many ways this curriculum development was already a paradigm shift from teaching to learning and towards competence orientation by the creation of a new learning environment, giving students a greater freedom in organising their study and learning processes in teams starting from challenging problems to solve and which became increasingly complex over the duration of their studies. Correspondingly the role of the teaching staff has been changed from experts delivering content into coaches for comprehensive learning and competence achievement processes and consultants for practice and research linked student group work[26]. The Aalborg experiences inspired other European Universities to introduce project based curricula, in engineering education e.g. Manchester University, Twente University and the University of Louvain la Neuve[27].

Comparably influential was the Problem Based Learning (PBL) movement, which started in the eighties with changes in Medical Education at McMasters University in Canada[28]. After influencing medical education also in Europe, starting from its first implementation at Maastricht University in the Netherlands, it spread to engineering and other disciplines and is increasingly contributing to the revision of curricula and the provision of learning arrangements in courses or modules. One of the advantages is that a vast range of practical examples and related educational research now exists and that the PBL concept is based on sound theoretical grounds, mainly with regard to student learning, but less with respect to comprehensive curriculum development.[29]

During the nineties, more systematic and comprehensive approaches to curriculum design or revision came into existence, which were based on new and theoretically grounded concepts. These resulted from the increased requirements on sustainable quality assurance and enhancement and from external accreditation approaches. John Heywood in his publication "Engineering Education: Research and Development in Curriculum and Instruction" started with a definition of curriculum as of being "the formal mechanism through which intended educational aims are achieved. Since educational aims are achieved through learning, the curriculum process is described by those factors that

26) Heitmann,G. 1993, Project study and project organised curricula: a historical review of its intentions
27) De Graaff, Erik, Kolmos, Anette (Eds) 2007, Management of Change
28) Barrows, H.S., 1980, Problem-based learning: An approach to medical education
29) Boud, D., Feletti,G., 1991, The Challenge of Problem-Based Learning

bring about learning"[30]. This definition puts a strong focus on educational aims and learning processes and not on content. The syllabus is just one part of the curriculum and its design. Providing an overview of various models of curriculum design he demonstrated that the increasingly complex models, in addition to aims and learning objectives and to learning processes, put a strong emphasis on assessment and evaluation dealing with the achievement of the objectives.

More recent and comprehensive approaches to curriculum development have shifted explicitly to a learning outcome based approach. Some of these have even been developed specifically for tertiary level science and engineering education and formed the basis for the ECDEAST project and its curriculum design approach. The following section briefly introduces these concepts.

2.2. The concept of "Constructive Alignment"

Curriculum theory for a long time and in particular at school level has being dealing with the question of what kind of content should be delivered with regard to certain educational aims and objectives and how it should be taught. Recently the focus has shifted towards learning based on placing the learner at the centre of all educational activities and focussing on his or her achievement of necessary or valuable knowledge, skills, attitudes and competences. This so called "paradigm shift from teaching to learning" put the focus on the learner and on the curriculum as a system, which comprehensively investigated all the necessary contributors to a successful learning process. Besides input and context factors, these contributors embrace aims and objectives, related learning outcomes, content, teaching/learning arrangements and activities, performance and outcomes assessment and continuous feedback and quality improvement.

This is reflected in a quite influential concept developed by Biggs in 1996 under the heading of "Constructive alignment", and which was adopted by some HEIs in Australia and Asia and in 2002 for application in higher education by the UK Learning and Teaching Support Network (LTSN), a network which meanwhile has been replaced the UK Higher Education Academy. John Biggs explained the concept in the following way:
"The 'constructive' aspect refers to what the learner does, which is to construct meaning through relevant learning activities. The 'alignment' aspect refers to what the teacher does, which is to set up a learning environment that supports the learning activities appropriate to achieving the desired learning outcomes. The key is that the components in the teaching system, especially the teaching methods and the assessment tasks, are aligned to the learning activities assumed in the intended outcomes"[31].

Figure 1 illustrates the components of the teaching system. In practice the alignment process can encompass more components than learning outcomes, teaching activities and assessment, as for example the alignment to a certain learning culture, the alignment to student interests and abilities, the alignment to facilities, the alignment of teachers and student perceptions, the alignment of approaches taken by different faculty members. An approach was developed in Germany already in the seventies in the context of general didactics for schools, primarily for guiding and structuring research in processes of learning, but quite soon evolved as a tool for teachers to plan and evaluate their lectures.[32]

Biggs "constructive alignment" concept is primarily devoted to teaching staff in higher education in order to enhance the quality of teaching and learning based on the definition of "Intended Learning Outcomes" at course level. Under the title "Teaching of Quality Learning at University" Biggs together with C. Tang published a more detailed version which in its most recent edition of 2011 comprises many examples of good practice of how to implement sustainable "Outcome Based Teaching and Learning" (OBTL) using various ways and tools of aligning the key components of teaching and learning.[33]

From the examples it becomes obvious that the concept with its focus on learning can be successfully ap-

30) Heywood, J., 2005, Engineering Education: Research and Development in Curriculum and Instruction, p. 3
31) Biggs, John B., 1996, Enhancing teaching through constructive alignment
32) Heimann,Paul, Otto, Gunter, Schulz, Wolfgang, 1979, Unterricht: Analyse und Planung
33) Biggs, John B. and Tang, Catherine, 2011, Teaching for Quality Learning at University

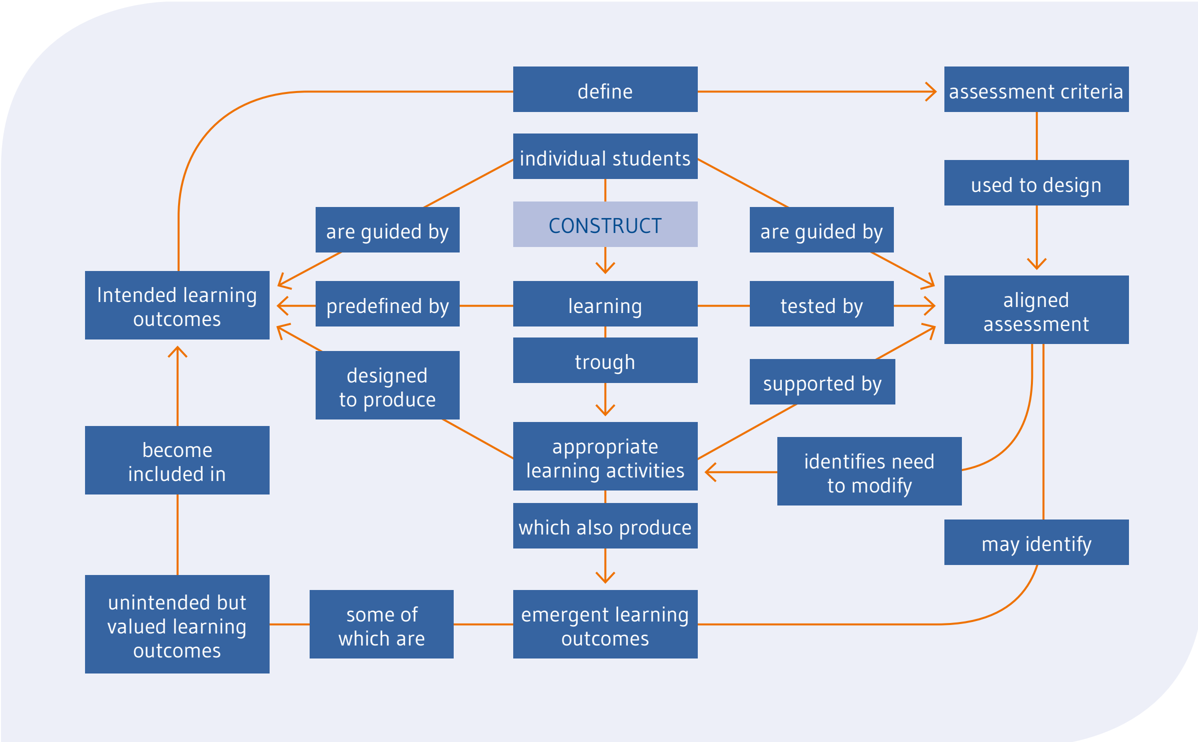

Figure 1: Constructive alignment

plied also at programme level and even at the institutional level, provided it is driven by faculty and teaching staff and based on a scholarly culture of teaching and learning and not a primarily "managerial" approach, striving only for accountability and the satisfaction of externally required outcomes, including those from accreditation activities. Nevertheless, the focus on learning and achievement of programme outcomes and the alignment with appropriate teaching and learning arrangements and assessment procedures corresponds perfectly to current outcomes based accreditation and curriculum design approaches, as does OBTL based planning and execution of courses or modules.

2.3. The two loop approach of ABET

A more practical approach to curriculum design was provided by the Accreditation Board for Engineering and Technology (ABET), which is recognised by the USA Council of Higher Education Accreditation (CHEA) as the sole agency responsible for the accreditation of engineering and technology related programmes in the USA. With regard to quality enhancement and accreditation of engineering programmes ABET changed its accreditation approach from a basically input related controlling check-list approach to an outcomes based approach. Programme providers have to present evidence that the ABET accreditation criteria are satisfied and also that the programme objectives and learning outcomes are achieved by the curricula and teaching

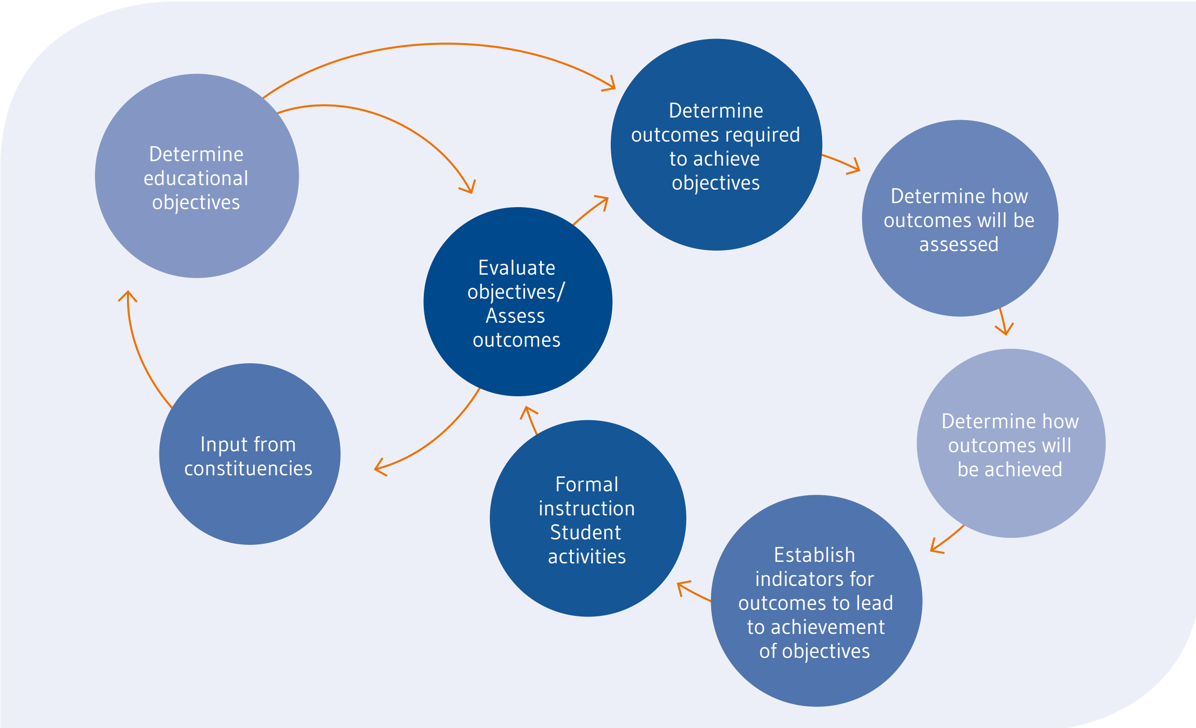

Figure 2: The ABET "Two loop process"

and learning arrangements provided. This paradigm shift started in 1997 with the first pilot applications of the so called "Criteria 2000" which are now the mandatory basis for ABET programme accreditation in engineering and 3 related areas: Applied Science, Computing and Engineering Technology. To date about 3100 programmes have been accredited based on the new approach on a voluntary basis.

ABET has defined 9 general criteria which have to be satisfied by the programmes applying for accreditation and probably the best known and most widely discussed one of these is criteria 3, which describes 11 generic learning outcomes that have to be achieved. These may also be increased by additional and subject specific learning outcomes which are defined by the various engineering disciplines represented in ABET by respective Professional Engineering Associations. This "3 a-k" list of learning outcomes is discussed in more detail in Chapter 4.3.4.

The shift towards a performance and outcomes based approach, and in particular the need to provide evidence of their achievement, challenged the programme providers and resulted in a significant revision of curricula and changes of assessment patterns. To assist the HEIs to adapt to the new accreditation requirements and procedures, ABET recommended a step by step strategy to be followed for curriculum revision and assessment planning, based on a "Two loop process" as shown in Figure 2.

The first cycle represents the contribution of the "external" world and stakeholder involvement and uses the inputs from students, alumni and employers to assist in the determination of the programme objectives. The second cycle represents the internal steps and procedures in a department or school responsible as programme provider and includes the determination of the outcomes necessary to meet the stated objectives, how these outcomes will be achieved and assessed and the establishment of performance criteria. Both cycles contribute to the evaluation and revision of the objectives. It results in a repeatedly undertaken cyclical evaluation process that controls the work flow in each cycle.

While initially developed as a procedure for assessment and evaluation planning and implementation, the two loop approach also functions well as a system for curriculum design and continuous quality enhancement. It should be noted that a distinction is made between "educational objectives" and "outcomes" satisfying the objectives. In the ABET terminology programme educational objectives are "broad statements that describe the career and professional accomplishments that the programme is preparing graduates to achieve." Programme outcomes are "narrower statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the program". [34]

To demonstrate that the required or intended learning outcomes are achieved programme providers need to define performance criteria or indicators. These are specific, measurable statements, which identify the performance(s) required to meet the outcomes and which can be confirmed through evidence. These qualitative and measurable statements can be embedded in different formats like tests and exams, benchmarks, rubrics, assignments, products, process observations, portfolios, etc. The predominant written or oral exams of courses or modules and the associated grading are normally not sufficient to provide evidence that the full range of outcomes has been achieved. It should also be noted that in the ABET terminology a distinction is made between "assessment" and "evaluation". Assessment is defined as "one or more processes that identify, collect and prepare data to evaluate the achievement of programme outcomes and programme educational objectives." Evaluation is "one or more processes for interpreting the data and evidence accumulated through assessment practices. Evaluation determines the extent to which programme outcomes or programme educational objectives are being achieved and results in decisions and actions to improve the programme" .

Evaluation is therefore not only the basis for the accreditation decision but also for "closing the loop" and providing feedback to help identify possible improvements and quality enhancements. Programme providers should continuously evaluate and undertake improvement activities and not to wait until the date of the next re-accreditation, but instead they should implement a process oriented quality management system and report on actions taken. This is defined in General Criteria 4 on continuous improvement and states: "The programme must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being achieved. The results of these evaluations must be systematically utilised as input for the continuous improvement of the programme. Other available information may also be used to assist in the continuous improvement of the programme" [35].

Programme providers have the freedom to decide on necessary courses and appropriate teaching and learning arrangements to ensure the achievement the programme objectives and the required or intended learning outcomes and also on how to prove that they have been achieved. General Criteria 5, which deals with curriculum matters, only identifies some minimum requirements for certain areas in the four year undergraduate curriculum: [37]

"(a) one year of a combination of college level mathematics and basic sciences (some with experimental expe-

34) ABET 2010-2011 Accreditation Policy and Procedure Manual
35) Ibid.
36) ABET 2013-2014 Accreditation Policy and Procedure Manual
37) Ibid.

rience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences.
(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design, appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further towards creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

(c) a general education component that complements the technical content of the curriculum and is consistent with the programme and institution objectives.
Students must be prepared for engineering practice throughout the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints. One year is defined as the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation."

In general and from the experiences gained, programme providers are strongly advised not only to implement a certain curriculum but also to develop and execute a documented assessment plan with regard to accreditation as well as quality enhancement. One concern often raised is that the teaching and learning processes should not be driven, distorted or even dominated by assessment activities. Only sufficient data should be collected to meet the needs of the various processes of outcome achievement, student grading, accreditation and quality assurance. Not every course or every learning outcome must be assessed each year for the purpose of accreditation. HEIs in the USA in the past decade have made significant efforts to develop appropriate assessment measures, in particular for complex non-cognitive learning outcomes, to design comprehensive assessment plans, to use electronically supported tools to gather data and to implement regular and structured evaluation procedures.

2.4. The TUNING approach to curriculum design

"Tuning educational structure in Europe" was a project launched in 2002 by a group of European Higher Education Institutions (HEI) and funded by the European Commission. Its goal was to contribute to the main objectives of the Bologna process by the transformation of traditional degrees into bachelor and master degrees and the reconstruction of the logic of their underlying study programmes. "Tuning" aimed to implement the Bologna process at university level and initially concentrated on transparency and the development of a common language in the description of HE programmes, not least to enhance comparability and to foster their international recognition. Over time Tuning has developed into a process for (re-)designing, developing, implementing, evaluating and enhancing the quality of first, second and third cycle degree programmes, and thus has become a reference point for curriculum design also.

The Tuning outcomes as well as its tools are presented in a range of Tuning publications, which institutions and their academics are invited to test and use in their own setting.[38]

The Tuning approach has been developed by and is meant for higher education institutions. Meanwhile the process has been further disseminated and spread to other non EU member countries including Russia and even to the continents of Latin America and Asia. Parallel to the Tuning project, which initially comprised only a limited number of disciplines, other subject areas like Engineering, Civil Engineering and Electrical Engineering collaborated in EU funded "Thematic Networks" like E4 or EUCEET with similar and often enhanced aims. Subsequently "synergy groups" were established between these Networks and the Tuning project in or-

38) Tuning, see website: http://www.unideusto.org/tuningeu/

der to test the Tuning approach also in these subject areas and contribute to its enhancement.

In the beginning Tuning concentrated on developing a terminology applicable to all kinds of disciplines and levels of programmes and courses for describing learning outcomes in terms of competences and made a distinction between generic and subject specific competences.

"Competences represent a combination of attributes (knowledge and its application, attitudes, skills and responsibilities) that describe the level or degree to which a person is capable of performing them".[39]

Within the generic competences 30 items have been determined and used to identify demands and achievements through questionnaires distributed to employers, graduates and academic faculty:

Instrumental competences:
- Capacity for analysis and synthesis;
- Capacity for organisation and planning;
- Basic general knowledge;
- Grounding in basic knowledge of the profession;
- Oral and written communication in your native language;
- Knowledge of a second language;
- Elementary computing skills;
- Information management skills (ability to retrieve and analyse information from different sources);
- Problem solving;
- Decision-making.

Interpersonal competences:
- Critical and self-critical abilities;
- Teamwork;
- Interpersonal skills;
- Ability to work in an interdisciplinary team;
- Ability to communicate with experts in other fields;
- Appreciation of diversity and multiculturalism;
- Ability to work in an international context;
- Ethical commitment.

Systemic competences:
- Capacity for applying knowledge in practice;
- Research skills;
- Capacity to learn;
- Capacity to adapt to new situations;
- Capacity for generating new ideas (creativity);
- Leadership;
- Understanding of cultures and customs of other countries;
- Ability to work autonomously;
- Project design and management;
- Initiative and entrepreneurial spirit;
- Concern for quality;
- Will to succeed.

The Tuning Methodology or approach included asking stakeholders from various disciplines by means of a questionnaire to identify and rank the 10 generic competences most relevant for their subject area and also to determine and rank additional competences which are specific only for their subject area. Despite the advantages of this approach for comparison and the involvement of stakeholders, the engineering education community collaborating in the previously mentioned Thematic Networks expressed their concern about this distinction. In cases where an academic subject or discipline and a profession are closely linked, like in engineering, many of the generic competences are essentially subject related and have to be seen as dimensions of complex engineering capabilities. They preferred an approach which identified the necessary or desirable learning outcomes derived from professional practice as represented in EUR-ACE or ABET outcomes or in the CDIO approach.

In a later stage of the project and related to the discipline oriented sets of learning outcomes expressed in terms of generic and subject related competences the Tuning partners enhanced their concept with recommendations about approaches to improving learning, teaching and assessment and about quality enhancement in the educational process emphasising a systems based internal institutional quality culture. A

39) Tuning project report, see Tuning web-site: http://www.unideusto.org/tuningeu/

more recent result of the project is the development and provision of a concept for curriculum design, which is comparable to what has been developed in engineering and applied already in both the ABET and EUR-ACE accreditation approaches and in CDIO.

The so called "Tuning model" was developed for designing, implementing and delivering curricula offered within one institution, or, jointly, by two or more institutions. "The following main steps in the process for designing a study programme either a local programme or an (international) integrated programme / joint degree were identified:

1. Meeting the basic conditions:

For all study programmes:

- Has the social need for the programme on a regional/national/European level been identified? Has this been done on the basis of a consultation of stakeholders: employers, professionals and professional bodies?
- Is the programme of sufficient interest from the academic point of view? Have common reference points been identified?
- Are the necessary resources for the programme available inside or, if required, outside the (partner) institution(s) concerned?

For international degree programmes offered by more than one institution:

- Is there commitment of the institutions concerned? On what basis: an (official) agreement or a strategic alliance?
- Is there sufficient guarantee that the programme will be recognised legally in the different countries?
- Is there agreement with regard to the length of the programme to be designed in terms of ECTS-credits based on student workload?

2. Definition of a degree profile.

3. Description of the objectives of the programme as well as the learning outcomes (in terms of knowledge, understanding, skills and abilities) that have to be met.

4. Identification of the generic and subject-related competences which should be obtained in the programme.

5. Translation into the curriculum: content (topics to be covered) and structure (modules and credits).

6. Translation into educational units and activities to achieve the defined learning outcomes.

7. Deciding the approaches to teaching and learning (types of methods, techniques and formats), as well as the methods of assessment (when required, the development of teaching material).

8. Development of an evaluation system intended to enhance its quality constantly.

This process is reflected in figure 3 flow chart. The model is based on the assumption that programmes can and should be enhanced on the basis not only of feedback but also of 'feed forward' by taking into account developments in society as well as the academic field concerned. This is illustrated by the progressive loops in the model".[40]

This model is less elaborated than the ABET two loop model, which was discussed in Chapter 2.3, where the distinction of objectives, learning outcomes and performance indicators and the related steps and the requested link of the HEI internal processes and the stakeholders offer a better operational format. Besides being embedded in an accreditation and quality assurance context related to engineering this is the reason why the ECDEAST project decided to refer to curriculum design and assessment concepts used and experienced by EUR-ACE and ABET.

40) Tuning model, see: http://www.unideusto.org/tuningeu/tuning-methodology.html

41) Tuning Russia, see: http://www.tuningrussia.org/

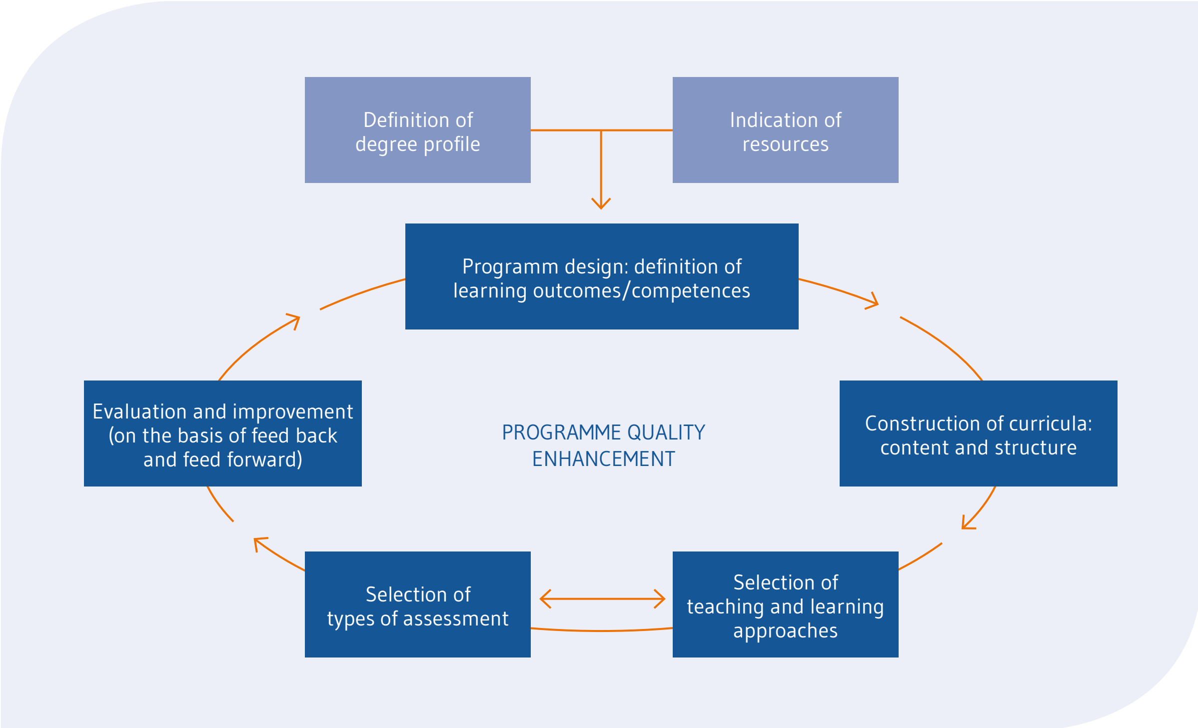

Figure 3: The TUNING Dynamic Quality Development Circle

However, almost in parallel to ECDEAST a project has been undertaken also in Russia to apply the Tuning methodology and model to the design and implementation of bachelor and master programmes at some Russian Universities covering different disciplines.[41]

2.5 The CDIO concept of curriculum design and implementation

The most recent and successful example of a widespread approach to systematic and comprehensive curriculum design and curriculum development in engineering education is the CDIO concept. The abbreviation stands for Conceive, Design, Implement and Operate. It is derived from the overall goal that engineers should be able to conceive, design, implement and operate complex value-added engineering systems in a modern, team-based environment.

In October 2000, Chalmers University of Technology (Chalmers), the Royal Institute of Technology (KTH), Linköping University (LiU), all from Sweden, and the aerospace department of Massachusetts Institute of Technology (MIT), MA, USA started a joint four-year project focussed on the development and implementation of a new model for Engineering Education, based on a differentiated set of learning outcomes. The concept is applicable to all the various engineering disciplines. The CDIO Initiative is a continuously growing network of Higher Education Institutions globally which apply the CDIO approach as "an innovative framework for producing the next generation of engineers". The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving – Designing – Implementing – Operating real-world systems and products. Emphasising that engineering is about projects, the curriculum and pedagogic approach supports active, collaborative and experiential learning and requires a great variety of teaching and learning arrangements.

The concept provides a framework for curriculum design but to some extent also for organisational development and quality management. It is based on what misleadingly is called the "CDIO syllabus", which actually is not a list of contents in various subject areas but a formal statement of the intended learning outcomes of an engineering programme. The condensed version of the CDIO syllabus addresses qualification attributes on three levels of detail, starting at the first level with 4 broad categories of attributes:

1. Technical knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: Teamwork and communication
4. Conceiving, Designing, Implementing, Operating systems in enterprise, societal and environmental context.

The detailed and complete version contains 4 levels with increasing specification. To establish the learning objectives and outcomes of the syllabus, the partner universities used questionnaires and a survey among different groups of stakeholders to determine what level of proficiency should be achieved for each of the 17 attributes on the second level of detail using a five point proficiency-scale:

- to have experience or been exposed to,
- to be able to participate in and contribute to,
- to be able to understand and explain,
- to be skilled in the practice or implementation of,
- to be lead or innovate in.

Meanwhile the first CDIO syllabus version from 2002 has been amended and enlarged based on new demands, critical contributions and comparisons with other lists of desired or requested outcomes, including those of ABET and EUR-ACE. The CDIO syllabus version 2.0, which will be discussed in more detail in Chapter 4.4, also contains attributes dealing with entrepreneurship and leadership.

Curriculum design in an actual case starts from the determination of objectives and learning outcomes with reference to the CDIO syllabus, taking the vision and mission of the respective HEI or department into account. Since 2004 the CDIO provides a set of 12 "Standards" which structure the processes of curriculum design, implementation and evaluation. These guiding principles were developed in response to programme leaders, alumni, and industrial partners who wanted to know how they would recognise CDIO programmes and their graduates. As a result, these CDIO Standards define the distinguishing features of a CDIO programme, serve as guidelines for educational programme reform and evaluation, create benchmarks and goals with worldwide application, and provide a framework for continuous improvement. The 12 CDIO Standards address programme philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-build experiences and workspaces (Standards 5 and 6), new methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12). Of these 12 standards, seven are considered essential because they distinguish CDIO programs from other educational reform initiatives. The five supplementary standards significantly enrich a CDIO program and reflect best practice in engineering education ".

Figure 4 illustrates the relationship of the 12 standards. The framework can be taken as a comprehensive blueprint, not only for the design and implementation of a CDIO curriculum but also for organisational learning and development. For the design of a CDIO curriculum, K. Edstroem, who was involved and has experience of

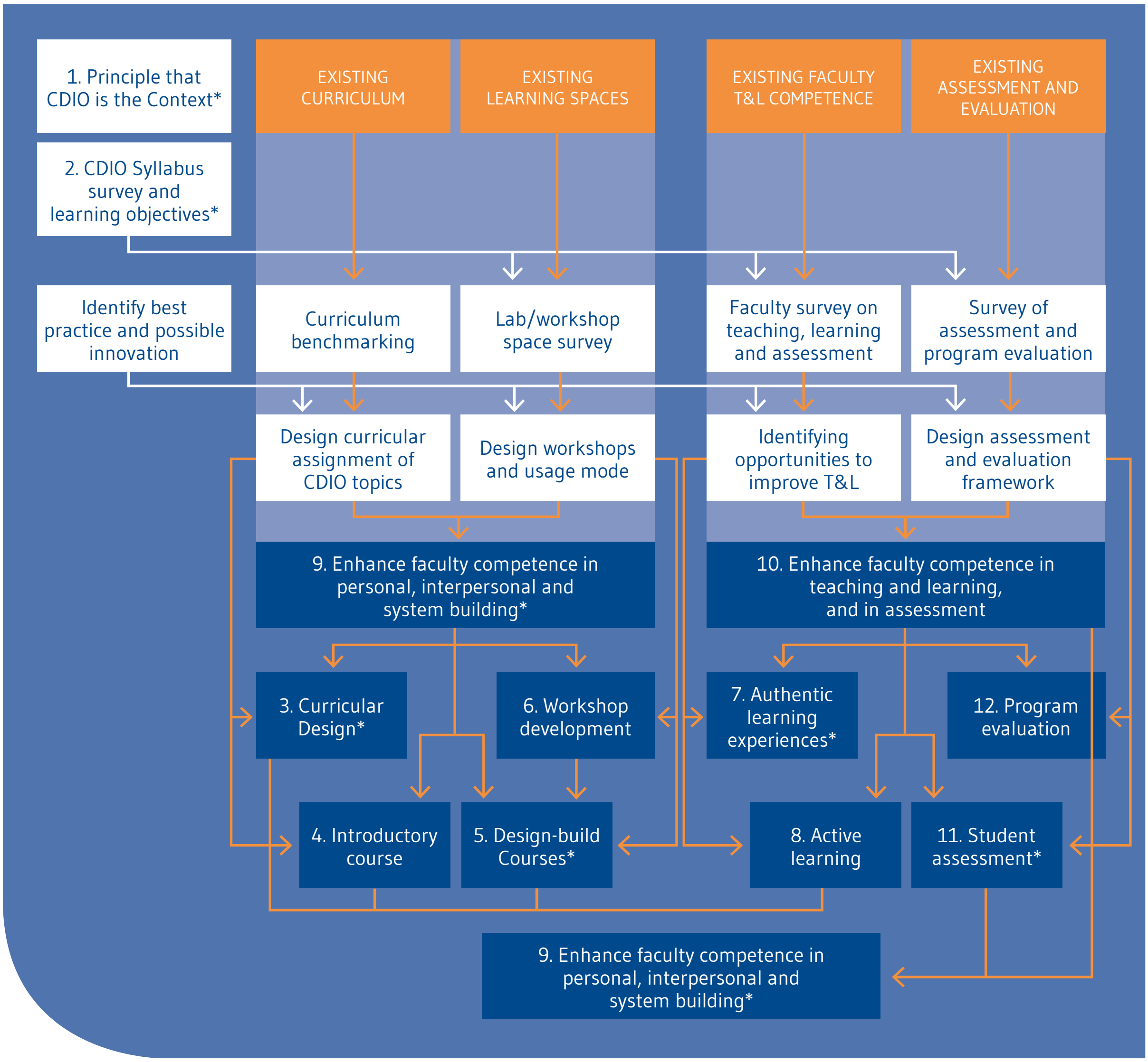

Figure 4: Relationship of the CDIO Standards

CDIO development and application at KTH Stockholm, proposes the following steps:

- Set programme learning outcomes in dialogue with stakeholders
- Map out responsibilities to courses – negotiate intended learning outcomes (knowledge and e ngineering skills)
- Create integrated learning experiences: subject courses as well sequences of design – implement experiences
- Execute course development with constructive alignment
- Provide faculty development
- Implement evaluation and continuous programme improvement [42]

In dealing with ABET accreditation requirements the HEIs and programme providers place a major emphasis on the assessment and evaluation aspects of programmes, whereas the CDIO Initiative is much more focussed on appropriate teaching and learning arrangements. In an accreditation context, the means by which programme providers achieve the required outcomes is not investigated or evaluated. On the other hand, in the CDIO context it is part of the standards to address and require certain learning formats to achieve the label of a "CDIO programme":

Standard 3 requires an integrated curriculum, in other words "a curriculum designed with mutually supporting disciplinary subjects and with an explicit plan to integrate personal, interpersonal, and product and system building skills".

Standard 4 proposes an Introduction to Engineering course, "that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills".

Standard 5 requires "Design-Build Experiences: A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level".

Standard 7 complements Standard 3 and requires "Integrated Learning Experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills".

Standard 8 recommends "Active Learning: Teaching and learning based on active experiential learning methods".[43]

Thus the CDIO community is much more involved in discussing CDIO related teaching and learning arrangements. However, the assessment of student learning and programme evaluation also are addressed, but more with a focus on feedback and continuous improvement and not primarily as evidence of the achievement of the required outcomes. Standard 11, dealing with CDIO skills assessment, states that "if we value personal, interpersonal, and product and system building skills, set them as learning outcomes, and design them into curriculum and learning experiences, then we must have effective assessment processes for measuring these skills. Different categories of learning outcomes require different assessment methods". Respective hints to alternative assessment formats are given, even if no coherent assessment planning is required like in some accreditation settings.

A comparative analysis of the EUR-ACE Framework standards and the CDIO approach (Standards, Syllabus, and self-evaluation model) was given recently by J. Malmqvist [44]. The author also gave an example of Swedish national engineering degree requirements in comparison with those of the EUR-ACE Framework Standards. An additional paper [45] provided a very detailed example of accreditation against EUR-ACE Standards in Portugal and its compliance with the CDIO approach. Authors concluded "...that CDIO implementation is a relevant success factor to achieve EUR-ACE accreditation/certification by the ENAEE association".

As a result of this brief introduction into current curriculum design approaches it can be concluded, that all the general or engineering education specific con-

42) Edstroem, Kristina, ppt presentation at the VDI Quality Dialog, Hannover, 2011
43) The CDIO standards, see: www.CDIO.org
44) J. Malmqvist, International Journal of Quality Assurance in Engineering and Technology Education, 2(2), 9-22, April-June 2012
45) A. Costa, Â. Martins, F. Rodrigues, J. Rocha. CDIO@ISEP: "A Stairway To Heaven" (A CDIO Contribution to EUR-ACE Certification). Proceedings of the 8th International CDIO Conference, Queensland University of Technology, Brisbane, July 1 - 4, 2012

cepts of curriculum design or revision that have been described are based on learning outcomes and require a process of alignment of the various components of curricula, some with a stronger emphasis on teaching and learning and others with a focus on assessment and proof of the achievement of the outcomes. They all have their particular advantages. The ECDEAST project focussed on curriculum design with reference to accreditation standards and qualification frameworks and relies on processes of curriculum design aimed at satisfying the external evaluation by peers for the purposes of accreditation and recognition but nevertheless takes into account also other concepts with their focus on student learning and competence achievement, as will be shown in chapter 5.

3. Accreditation of Engineering Education

3.1. Purpose of Accreditation

Accreditation can be defined as a process to certify that the standard of a particular programme meets a pre-defined level. In engineering education, accreditation is primarily concerned with the quality of programmes that lead to qualification as a professional engineer. In some countries there are different grades of engineering qualification, Engineering Technologist, Engineering Technician, etc., for which qualification also requires graduation from accredited programmes, but for simplification only the educational programmes for qualified engineers are considered here. The focus on education excludes any periods of training or experience after graduation from an accredited programme that are required in some countries in order to qualify as an engineer.

It should be noted that in English, the word accreditation has a second meaning in addition to the process of verifying quality. It is sometimes used to describe the outcome of the process, in sentences such as 'This programme has obtained accreditation'. This second meaning is not used here.

Where it is necessary to illustrate the discussion using a specific example of standards, those published by the European Network for Engineering Education[46] (ENAEE) in the Engineering Accreditation Framework Standards (EAFS) are used. It is recognised that these Programme Outcomes are intended to be applied to the standards of accreditation agencies, and not directly to those of individual programmes. However, this discrepancy does not affect their use as illustrative examples, and it avoids the possibility of any partiality, misinterpretation or misunderstanding in using the standards of any particular agency.

3.2. Types of Accreditation

The term accreditation is used to describe a number of processes of quality assurance in higher education that have slightly different aims. Although these different processes describe their aims and processes in various formats and structures, in general they have overlapping and complementary objectives and procedures. In the discussion here of the accreditation of engineering education programmes, only a brief summary of the differences between the different processes is necessary, rather than a detailed discussion of their individual features and implementation.

Programme Accreditation is the process by which an external agency evaluates the outcomes of the taught programme, usually referred to as Learning Outcomes. The required standards of the Learning Outcomes are specified by the external agency in general terms, to allow some flexibility of interpretation by the HEI, to enable innovation in teaching methods and subject matter. Programme Accreditation should also be concerned with assessing that the HEI facilities and infrastructure are adequate to support the taught programme; in some countries these aspects are accredited separately using different agencies that carry out Institution or System Accreditation.

System Accreditation describes accreditation by an external agency that focusses mainly on ensuring that, within the HEI, an elaborated system of quality assurance is operated, in order to maintain the standards of quality or outcomes of teaching and learning. System Accreditation does not concern itself directly with the quality of individual programmes, except for examining selected programmes as examples of the implementation of the HEI quality assurance procedures. The German Accreditation Council[47] and the authorised accreditation agencies operate such an accreditation process.

Institutional Accreditation is the term used to describe the process of assessment and evaluation by an external agency of all the procedures of the Higher Education Institution (HEI), including those for quality assurance of teaching and learning. Such accreditation also assesses if the HEI meets specified minimum standards of learning facilities, staff qualifications, student intake, etc. Examples of compulsory Institutional Accreditation can be found in USA and Russia. The German Science Coun-

46) European Network for Engineering Education, see: http://www.enaee.eu

47) German Accreditation Council, see: http:// www.akkreditierungsrat.de

cil (Wissenschaftsrat) operates Accreditation of Institutions, but only for private HEIs. In the UK, the Quality Assurance Agency[48] (QAA) reviews HEIs using the Quality Code that specifies the expectations of HEIs regarding academic standards, academic quality, and information about HE provision.

A significant development in establishing standards within the European Higher Education Area has been the publication of Standards and Guidelines for Quality Assurance in the European Higher Education Area (usually referred to as ESG, 3rd edition 2009). This document, published by the European Association for Quality Assurance in Higher Education[49] (ENQA), sets out codes of practice for three different aspects of quality assurance procedures in higher education:

- internal quality assurance within the HEI;
- external quality assurance of the HEI by an external agency;
- external quality assurance accreditation agencies.

These codes of practice identify in general terms the important features of quality assurance required in higher education. It is of course necessary to interpret these general guidelines for any particular accreditation agency, HEI or programme, but they provide a framework for consistent quality assurance throughout the EHEA.

The standards and procedures outlined above are particular applications of the general principles of quality assurance that are used in a wide range of organisations, industrial, commercial and administrative. They are most commonly identified with ISO 9000[50] and comprise a set of standards for managing quality in a wide range of organisations. They provide guidance and tools for any organisation seeking to implement a quality assurance system. Because ISO 9000 is of very wide applicability, it needs to be interpreted for particular applications, and can therefore in principle be used in higher education. Some HEIs prefer more process related concepts for quality assurance, such as Total Quality Management (TQM), and some have developed their own tailor-made system.

3.3. Types of Accreditation Agencies

The different types of accreditation outlined in the preceding section are capable of being applied by a variety of organisations including HEIs. In this section the discussion is focused on the different types of agencies, that undertake accreditation in Higher Education, and particularly those that accredit programmes of engineering education that form part of the process of qualifying as a professional engineer. Although these different types of agency have very similar aims and objectives, their organisation and administration can be very different arising more from different historical traditions than from different purposes of accreditation. However, whatever the structure and administrative arrangements of the agency, the processes and procedures have many common features as outlined in the following section.

Considering only agencies that accredit engineering programmes, the simplest type of agency is one which evaluates the standard of engineering programmes only. An example of this is Engineers Ireland[51]. Engineers Ireland is the professional body for engineers in Ireland, and it provides many services to its members and for the profession. Accreditation is one of the services to the engineering profession.

Another agency that concentrates exclusively on the accreditation of engineering programmes is the Commission des Titres Ingénieur[52] (CTI). CTI was established by the French government in 1934 to accredit engineering education institutions and programmes, and it has since expanded its portfolio to include computer science, applied mathematics, and other technically related disciplines.

In Germany ASIIN[53] accredits a range of technical and science based disciplines (engineering, computer science, natural science, mathematics, etc.). It is a state-

48) Quality assurance Agency, see: http://www.qaa.ac.uk
49) European Association for Quality Assurance in Higher Education, see: http://www.enqa.eu
50) International Organization for Standardization, see: http://www.iso.org
51) Engineers Ireland, see http://www.engineeersireland.ie
52) Commission des Titres Ingénieur, see: http://www.cti-commission.fr
53) ASIIN, see: http:// www.asiin-ev.de

independent membership organisation, the standards and procedures of which must comply with requirements specified by the German Accreditation Council for Higher Education. Members of the organisation are professional and employer associations, respective Unions and HEIs. Like other German accreditation agencies ASIIN is authorised by the state installed Accreditation Council (Akkreditierungsrat) based on the fulfilment of certain criteria of the Council and regular external evaluations.

In the United Kingdom engineering accreditation is decentralised and voluntary. The standards of accredited programmes and of the assessment procedures are established and monitored by the Engineering Council[54], a body licensed to do so by the government. The accreditation process is executed by the professional engineering institutions such as the Institution of Mechanical Engineers[55], Institution of Engineering and Technology[56] which are authorised by the Engineering Council to perform these activities according to the UK-SPEC standards.

These examples are not intended to provide a comprehensive survey of the various types of accrediting organisations, but even in this brief overview they illustrate the diversity of agencies that undertake engineering accreditation. Further important factors are the financial arrangements. In the UK and France accreditation of degree programmes is a service to the profession, whereas in Germany and Ireland a fee is charge to the HEI for the accreditation activities.

Despite these structural and administrative differences, agencies that accredit engineering programmes apply and use very similar standards and procedures, which have become evident from the development of international recognition of accreditation. At present, two organisations have established international standards of accreditation for engineering programmes. The older one is the International Engineering Alliance (IEA), the origins of which can be traced back to the Washington Accord signed in 1989. The signatories to this Accord agreed to recognise each other's decisions on the educational standard for registration as an engineering professional. The IEA has subsequently established further Accords covering engineering technologists (Sidney Accord) and technicians (Dublin Accord) and also Networks dealing with the professional practice and development required after education in order to qualify as an engineering professional. There are currently agencies from 15 different countries that are signatories to the Washington Accord: Europe is represented by UK and Ireland since the beginning in 1989, and recently by Turkey (2011) and Russia (2012). Agencies from 7 additional countries, applying for full signatory membership, are holding a provisional status, among them China, India and Germany.[57]

A similar process started in Europe as a consequence of the Bologna Process, and the European Network for Accreditation of Engineering Education (ENAEE) was founded in 2006. The ENAEE has established agreed standards for First and Second Cycle Degrees in engineering and guidelines for the accreditation procedures. Accreditation agencies that satisfy these standards are authorised to award the EUR-ACE Bachelor or EUR-ACE Master to accredited programmes. At present there are ten authorised agencies with many additional agencies currently applying for membership.[58]

The further development of these international agreements on quality assurance and mutual recognition are important. They confirm that although agencies have diverse and varied administrative and organisational structures their standards and procedures are sufficiently equivalent to support mutual recognition. They guarantee a certain quality of engineering education and facilitate the mobility of engineering graduates and professionals. Furthermore, international networks such as the IEA and ENAEE provide a forum for sharing good practice, and for the development of engineering standards to accommodate new and evolving technologies.

54) Engineering Council, see: http:// www.engc.org.uk
55) Institution of Mechanical Engineers, see: http// www.imeche.org
56) Institution of Engineering and Technology, see: http:// www.theiet.org
57) See: http://www.washingtonaccord.org/
58) See: http://www.enaee.eu

3.4. Procedures and Methods

Although there are a variety of agency structures and traditions, in general for evaluating engineering education the accreditation standards, methods and procedures follow similar lines. Accreditation is an open process and most agencies publish explicit information about their standards and the procedure for evaluating programmes. In general there are three aspects to the evidence that is sought by accrediting agencies in Programme Accreditation:

- the content of the programme;
- the level of the programme;
- the infrastructure to support the programme.

The format in which each agency seeks this information may differ, but essentially the focus is the evidence that is needed in order to assess if the standard of the programme is consistent with the educational requirements needed to qualify as an engineering professional.

The Programme Outcomes in the EUR-ACE Framework Accreditation Standards (EAFS) developed by ENAEE are used here to illustrate the considerations that enter into the procedures and methods of making accreditation decisions.

Content is the range of topics included in the programme. The requirements of different agencies show general agreement about the content of engineering programmes, although the format of presentation will differ, and there may be different emphasis on certain aspects. As an example the EAFS programme outcomes are classified under six headings:

- Knowledge and Understanding
- Engineering Analysis
- Engineering Design
- Investigations
- Engineering Practice
- Transferable Skills.

Details of learning outcomes with regard to the areas are discussed in chapter 4.

Level refers to the academic standard and challenge of the programme. This is usually the most difficult to specify and assess. Within EAFS the Level is specified at Second Cycle by the statement that graduates should have:

- a critical awareness of the forefront of their branch.

In the recently completed EUGENE project[59], in which ENAEE was a partner, a glossary was developed that included a definition (or description) of forefront as: "Forefront of a branch of engineering or specialisation is the knowledge of recent developments in practice and research. In a field of study that combines knowledge from different branches, the forefront relates to that of the combination and not of the individual branches."

Accreditation agencies or respective networks as well as HEIs may have additional requirements which relate to the level, for instance specified levels of achievement with regard to certain outcomes, as will be outlined in chapter 4.

Infrastructure includes all the resources of the HEI necessary to ensure that the programme delivery achieves the required standard. This might include for example the laboratories and facilities for practical work, the number and qualifications of the teaching staff, the number of support staff, and quality assurance procedures. Within EAFS the infrastructure requirements are classified under the following headings:

- Needs, Objectives and Outcomes
- Educational Process
- Resources and Partnerships
- Assessment of the Educational Process
- Management System.

Many of the Infrastructure requirements are also assessed within Institutional Accreditation.

59) EUGENE project, see: http:// www.eugene.unifi.it

The procedure for conducting Programme Accreditation is well established, and though there may be variations within the traditions of individual accreditation agencies, all of them will incorporate the following standard features in some form or another:

a. Self-Assessment Report. The HEI documents in detail how the programme being assessed claims to satisfy the Learning Outcomes and other requirements specified by the accrediting agency. The format of the Self-Assessment report is usually specified by the agency.

b. The agency nominates a team to evaluate the evidence that the programme satisfies the agency requirements. This team should consist of a balance of academic and practicing engineers with experience of the specific subject matter of the programme.

c. The evaluation team has the responsibility for investigating the evidence presented in the Self-Assessment Report, and of gathering any further evidence necessary during a visit (usually of about two days duration) to the HEI. The evidence is summarised in a written report.

d. The report is presented to the committee of the agency that has the responsibility for making accreditation decisions. The standard practice is that the committee can make one of three possible decisions:
(i) Accreditation for the maximum permitted period;
(ii) Accreditation for a period shorter than the maximum to enable some necessary changes to be made to the programme;
(iii) The programme is not accredited.

This basic structure is common to many accrediting agencies, but there are variations depending on local practice and tradition. For example, some agencies require that there should be a student representative on the assessment team, but others specifically exclude students. Examples of other variations in procedure that arise are: length of accreditation period; procedure for correcting any observed shortcomings in the programme; the format of any appeal system; how much feedback is given to the HEI by the assessing team at the end of the visit and whether or not the assessment report is a public document. These variations in practice and procedure however do not affect significantly the judgements and decisions about the standard of programmes, as is evident from the development of international agreements on accreditation standards.

3.5. Benefits and Costs

The principle motive for accrediting engineering programmes is to provide recognised standards for the achievements of graduates from such programmes. The accreditation of programmes to an agreed standard is of immediate and direct value to prospective students, HEIs, graduates and employers. Because all the stakeholders benefit from accreditation, they share a mutual interest in ensuring that it is implemented efficiently and effectively. Furthermore accreditation provides both a means of sharing good practice between HEIs, and the opportunity for a critical and constructive evaluation of course development.

The development of international networks such as the IEA, in which the signatories to accords mutually recognise decisions, and the ENAEE, which authorises the award of EUR-ACE Labels (EUR-ACE Bachelor or EUR-ACE Master) to accredited programmes, has added further value to accreditation for all the stakeholders. Accredited engineering qualifications are becoming global qualifications.

The major costs of accreditation fall principally on the HEIs, mainly in the time resource of staff to prepare documentation, including the Self-Assessment Report, and in hosting the visit of the evaluation team. Furthermore some agencies make a charge to the HEI for the complete accreditation exercise. Nevertheless, these costs to the HEI are balanced by the opportunity to have a detailed and informed audit of the teaching programme, by a team of experienced engineers with expertise in the specific engineering discipline, and therefore contributes to programme development.

For accreditation to achieve its full potential it is essential for the accrediting agency to have a procedure that is able to support the development in HEIs of new engineering disciplines as technology evolves, and the introduction of innovative teaching methods. Engineering is a dynamic discipline, and accreditation agencies need to ensure that their procedures are able to respond to new and original methods, while at the same time maintaining the necessary standards. In fact agencies should be encouraging HEIs, as part of the accreditation assessment, to develop new programmes and teaching methods. Innovation begins in HEIs; auditors do not innovate.

In summary the accreditation of engineering programmes has major benefits for the engineering profession. It is designed to ensure the provision of an education leading to qualifying as an engineering professional and is now well established and accepted internationally. Although the accreditation is carried out by agencies that have different organisations and structures, there is considerable agreement on the standards and how they should be implemented and assessed. Accreditation is of value to students, graduates and employers, and particularly to HEIs. It provides an opportunity for a detailed audit by informed professionals, a means of sharing good practice, and for reviewing programme development.

4. Transnational and national accreditation standards and outcome specifications in engineering education

Proving to an external panel of peers that certain required outcomes and quality standards have been achieved by a programme under consideration is a central feature of programme accreditation. Therefore for curriculum development, as well as for comparison and mutual recognition, accreditation standards or national requirements with regard to outcomes play a key role. Usually these are threshold standards which are specified by the external accreditation agencies and must be met by the programme provider. However, HEIs should go beyond these threshold standards and define intended learning outcomes with regard to each programme taking into account their particular mission, profile and strengths.

One problem concerning comparison and recognition is the use of different terminology or same terminology but different meaning. This will be illustrated in the following examples of transnational and national standards and outcome specifications. Curriculum developers and programme providers in the HEIs are challenged to transfer the often generic lists of required programme outcomes into measurable learning outcomes and to prove that they can be or have been achieved by the provided teaching and learning arrangements and adequate assessment procedures and tools.

As one of the ECDEAST project aims was the development of a curriculum design approach with reference to EUR-ACE accreditation standards, the EUR-ACE Framework Standards will be considered initially. This will be followed by examples from various countries where national agencies have been authorised to execute programme accreditation and in addition award the EUR-ACE First and/or Second Cycle labels: EUR-ACE Bachelor or EUR-ACE Master. It will be complemented by reviewing the approaches of ABET in the USA and by the Washington Accord. Finally some networks of HEIs are briefly discussed in order to demonstrate the various ranges and possibilities in specifying intended learning outcomes.

4.1. EUR-ACE

In the EUR-ACE Framework Standards (EAFS), Programme Outcomes are expressed in general terms so that they can be interpreted for different branches of engineering. As already described they are classified under six headings:

- *Knowledge and Understanding;*
- *Engineering Analysis;*
- *Engineering Design;*
- *Investigations;*
- *Engineering Practice;*
- *Transferable Skills.*

In total there are 21 Programme Outcomes for First Cycle programmes and 19 for Second Cycle. Integrated programmes leading directly to a second cycle degree would need to satisfy both the First Cycle and Second Cycle outcomes, although in practice some of the former are subsumed into the latter.

Knowledge and Understanding

The underpinning knowledge and understanding of science, mathematics and engineering fundamentals are essential to satisfying the other programme outcomes. Graduates should demonstrate their knowledge and understanding of their engineering specialisation, and also of the wider context of engineering.

First Cycle graduates should have:

- knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering;
- systematic understanding of the key aspects and concepts of their branch of engineering;
- coherent knowledge of their branch of engineering including some at the forefront of the branch;
- awareness of the wider multidisciplinary context of engineering.

Second Cycle graduates should have:
- an in-depth knowledge and understanding of the principles of their branch of engineering;
- a critical awareness of the forefront of their branch.

Engineering Analysis
Graduates should be able to solve engineering problems consistent with their level of knowledge and understanding, and which may involve considerations from outside their field of specialisation. Analysis can include the identification of the problem, clarification of the specification, consideration of possible methods of solution, selection of the most appropriate method and correct implementation. Graduates should be able to use a variety of methods, including mathematical analysis, computational modelling, or practical experiments, and should be able to recognise the importance of societal, health and safety, environmental and commercial constraints.

First Cycle graduates should have:
- the ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods;
- the ability to apply their knowledge and understanding to analyse engineering products, processes and methods;
- the ability to select and apply relevant analytic and modelling methods.

Second Cycle graduates should have:
- the ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications;
- the ability to formulate and solve problems in new and emerging areas of their specialisation;
- the ability to use their knowledge and understanding to conceptualise engineering models, systems and processes;
- the ability to apply innovative methods in problem solving.

Engineering Design
Graduates should be able to realise engineering designs consistent with their level of knowledge and understanding, working in cooperation with engineers and non-engineers. The designs may be of devices, processes, methods or artefacts, and the specifications could be wider than technical, including an awareness of societal, health and safety, environmental and commercial considerations.

First Cycle graduates should have:
- the ability to apply their knowledge and understanding to develop and realise designs to meet defined and specified requirements;
- an understanding of design methodologies, and an ability to use them.

Second Cycle graduates should have:
- an ability to use their knowledge and understanding to design solutions to unfamiliar problems, possibly involving other disciplines;
- an ability to use creativity to develop new and original ideas and methods;
- an ability to use their engineering judgment to work with complexity, technical uncertainty and incomplete information.

Investigations
Graduates should be able to use appropriate methods to pursue research or other detailed investigations of technical issues consistent with their level of knowledge and understanding. Investigations may involve literature searches, the design and execution of experiments, the interpretation of data, and computer simulation. They may require that data bases, codes of practice and safety regulations are consulted.

First Cycle graduates should have:
- the ability to conduct searches of literature, and to use data bases and other sources of information;
- the ability to design and conduct appropriate experiments, interpret the data and draw conclusions;
- workshop and laboratory skills.

Second Cycle graduates should have:

- the ability to identify, locate and obtain required data;
- the ability to design and conduct analytic, modelling and experimental investigations;
- the ability to critically evaluate data and draw conclusions;
- the ability to investigate the application of new and emerging technologies in their branch of engineering.

Engineering Practice

Graduates should be able to apply their knowledge and understanding to developing practical skills for solving problems, conducting investigations, and designing engineering devices and processes. These skills may include the knowledge, use and limitations of materials, computer modeling, engineering processes, equipment, workshop practice, and technical literature and information sources. They should also recognise the wider, non-technical implications of engineering practice, ethical, environmental, commercial and industrial.

First Cycle graduates should have:

- the ability to select and use appropriate equipment, tools and methods;
- the ability to combine theory and practice to solve engineering problems;
- an understanding of applicable techniques and methods, and of their limitations;
- an awareness of the non-technical implications of engineering practice.

Second Cycle graduates should have:

- the ability to integrate knowledge from different branches, and handle complexity;
- a comprehensive understanding of applicable techniques and methods, and of their limitations;
- a knowledge of the non-technical implications of engineering practice.

Transferable Skills

The skills necessary for the practice of engineering, and which are applicable more widely, should be developed within the programme.

First Cycle graduates should be able to:

- function effectively as an individual and as a member of a team;
- use diverse methods to communicate effectively with the engineering community and with society at large;
- demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice;
- demonstrate an awareness of project management and business practices, such as risk and change management, and understand their limitations;
- recognise the need for, and have the ability to engage in independent, life-long learning.

Second Cycle graduates should be able to:

- fulfil all the Transferable Skill requirements of a First Cycle graduate at the more demanding level of Second Cycle;
- function effectively as leader of a team that may be composed of different disciplines and levels;
- work and communicate effectively in national and international contexts." [60]

The Programme Outcomes under the headings Knowledge and Understanding and Engineering Analysis contain statements of the requirements of the fundamental scientific, mathematical and technical knowledge of a graduate from an accredited programme, and of their ability to apply it. The Programme Outcomes, under the headings Engineering Practice and Transferable Skills, describe the expectations of the skills, both technical and non-technical, of a graduate. The Programme Outcomes under the headings Engineering Design and Investigations are concerned with what engineers do in

60) See: www.enaee.eu/eur-ace-system/eur-ace-framework-standards

practice, and require accredited programmes to provide the opportunity for graduates to demonstrate their capability to integrate knowledge and skills in engineering activities.

4.2. Requirements for learning outcomes of various European countries

The regular documented reviews of the Bologna process show that in the signatory countries the learning outcome approach has been implemented gradually with reference to the European Qualifications Framework and in many countries to their existing National Qualifications Framework. Sets of more or less specified or required programme learning outcomes constitute references for curriculum and module design as well as for internal and external quality assurance. Sometimes additions or differentiations are made due to national traditions and degree profiles.

A recent survey by the European University Association (EUA) on the implementation of master degree programmes shows that since an earlier survey in 2002 several different types of programmes have been developed and implemented in the context of the Bologna process. The survey output states: "Master-level provision takes three principal forms. Firstly, taught Master courses with a strong professional development application, available in full-time, part-time, distance and mixed modes. Secondly, research-intensive Master programmes, many of which are integrated into innovation and knowledge transfer activities and function as pre-doctoral studies for the career researcher. Thirdly, Master-level courses of varying duration, which are delivered mainly to returning learners on in-service, executive release or self-referral bases. There is no reason to assume that patterns of demand will become less varied in the future." [61]

But even within the three forms the diversity is high and the interest in and suitability of these degrees beyond the national context is still low, even if master level programmes are the most widely marketed ones internationally and contribute increasingly to the expansion of transnational mobility. One reason for this is that based on their autonomy HEIs have a great deal of freedom to shape their programmes taking into account their mission and strengths, research or application specialities, market needs and societal requirements as well as student demands and new and often ICT based modes of delivery. The Bologna process agreements on master programmes besides the already described Bologna Qualifications Framework descriptors are very generic:

- "Normally carrying ECTS 90-120, of which at least 60 should be at Master Level
- Typical duration of one to two full-time equivalent years
- Disciplinary content consistent with generic level descriptors
- Curriculum design and pedagogy defined by learning outcomes
- A recognised point of entry to the European labour market" [62]

Only a few Bologna signatory countries continue to specify requirements for master programmes in a very detailed, traditional subject and content related approach, which programme designers and providers must rely on. Others have moved to generic outcomes-based recommendations. The majority of countries, while requiring that the general regulations are covered, leave decisions on specific requirement to the Universities and the other HEIs, but require additional external quality assurance procedures (like accreditation, evaluation, governmental approval, collaboration and contracting with funding bodies and stakeholders). Therefore in engineering education, analysis of national and transnational accreditation standards and of University programme specifications provide an indication of what kind of learning outcomes at the threshold level or beyond should be achieved by bachelor and master level graduates.

National formats have arisen because of different traditions and therefore the focus may be different. Nevertheless, accreditation decisions increasingly are based

61) European University Association (EUA), 2009, Survey of Master Degrees in Europe, p. 7

62) Ibid, p. 13

on evidence of the achievement of the outcomes. Briefly four examples in the field of European engineering education will be presented and in addition the requirements of ABET in the USA and the Washington Accord will be discussed.

4.2.1. Russia

4.2.1.1. Federal Educational Standards of the RF

The new version of standards and the recently adopted "The Law on Education in the Russian Federation" [63] have been introduced to eliminate most of the incompatibilities between the Russian Higher Education system and the Bologna Process. The two-tier system (4+2) is becoming mandatory for majority of specialities/disciplines in higher education. Study programmes at the master level are now uncoupled from those at the bachelor level. The credit system which is based on the ECTS system is used to evaluate the workload of modules and programmes. The standards extend the universities' autonomy and grant the academic freedom for designing and implementing study programmes to HEIs, particularly in relation to defining the programme content and the use of educational technologies, together with their responsibility for the quality of education.

The third generation of state educational standards, the Federal Educational Standards for Higher Education (FES) of the Russian Federation came into force in the 2011-2012 academic year and superseded the previous ones of 2005. The national legislation obliges the Russian HEIs to modify and renew their study programmes in accordance with the new standards in order to be accredited by governmental body. It should be noted that some universities in Russia (in particular those entitled Federal University or National Research University) have been granted the rights of introducing and implementing their own standards.

The educational standards in Russia establish the set of requirements for the curriculum, learning outcomes, faculty, facilities etc. for any speciality and any level (cycle) of study programme. Each standard includes the following sections:

1. *Scope of programme*
2. *Acronyms*
3. *Field of study.*
4. *Description of the professional activity*
5. *Learning outcomes (graduate's competencies) requirements*
6. *Curriculum requirements*
7. *Programme implementation requirements*
8. *Quality assurance requirements.*

The first three sections of the standards provide descriptive information about the particular programme. The HEIs have been granted the right to define the profile of programmes within the specified discipline or speciality.

Section 4 describes the field, objects, types and tasks of professional activity that graduates from the programme are expected to be able to do or solve. The FES do not refer to "programme educational objectives" when describing the professional activity or activities, which the graduates of the programme are to be prepared for. The programme graduate competences are to be defined (next section) in such a way as to ensure that the successful graduate is capable of acting or performing the professional duties or tasks indicated.

Section 5 of the Standards includes the requirements for programme graduates. These requirements are given in terms of "competences". The Russian standards refer to "competence" as an integrated term used for knowledge, skills, attitude and experience.

Section 6 contains the requirements for the programme curriculum and includes its structure, student workload, mandatory modules, et cetera. The standards prescribe the following structure of the curriculum:

63) Law on Education in the Russian Federation, see: http://www.mon.gov.ru (available in Russian only)

M.1. General cycle (courses in sciences, maths, humanities, economics, etc. related to discipline);
M.2. Professional cycle (advanced courses in science, maths, etc., special courses dealing with profession);
M.3. Internship and research work;
M.4. State attestation (final exams, thesis defence).

The workload of the different cycles and sections vary depending on field of study, speciality and programme level.

Section 7 provides the requirements for programme implementation and includes

- list of the obligatory programme documentation;
- learning technology requirements;
- workload requirements (electives, maximum workload per week, maximum contact hours per week, vacations);
- faculty requirements;
- library and information resources requirements;
- programme financing;
- facilities requirements.

Section 8 is devoted to quality assurance. Each programme is required to have a quality assurance system in place which includes external evaluation with the involvement of stakeholders including employers. This section also describes final state exams and thesis requirements.

At present, the new standards have become an important part of the education reform progression from an input-based to a learning outcomes based approach. In Russia, as mentioned previously, graduate attributes are given in terms of competences that are defined slightly differently from those of EQF. It should be noted that the FES distinguish between two groups of competences, professional and personal. Professional skills (competences) are related to different types of professional activity (industrial technology, management, project work, research, etc.). They cover a wide array of learning outcomes including disciplinary knowledge and ability to apply it in professional activity; experimentation and investigations; engineering design and analysis. Personal skills (competences) focus on individual students' cognitive and affective development (lifelong learning, critical thinking, social responsibility, ethics, etc.) and different forms of interactions, such as teamwork and communication.

The new FES authorise HEIs to differentiate study programmes between research- and practical-oriented profiles so as to prepare graduates for different types of professional activities, especially in engineering. Thus, master studies are no longer considered as a preparatory step to PhD studies. The universities are encouraged to design curricula which relate to their research traditions and academic policy, and to develop interdisciplinary and multidisciplinary programmes, which integrate knowledge from a number of co-fields of study.

4.2.1.2. Compatibility of the FES and EUR-ACE Framework Standards

The accreditation of higher education in Russia is divided between state accreditation (run by a governmental body, currently by the Federal Service) and professional accreditation (run by public organisations). The state accreditation is an institutional one while professional accreditation deals with educational programmes. The state accreditation is an evaluation process which focusses on the integrated assessment of HEI's teaching process, facilities, financial support and resources aimed at insuring that they meet the state requirements. It includes verification that the educational services, content, level, and quality of the education offered meet the requirements of the FES. The state accreditation issues state certificates (diplomas) granting to HEI the right of awarding degrees.

While the state accreditation evaluates a HEI as an institution, the professional accreditation focusses on the assessment of content and quality of a particular study programme measured against the accreditation criteria by public professional organisations. In Russia, the system of professional accreditation is well-developed in engineering education. The Association for Engineering Education of Russia [64] (AEER) is the body responsible for the professional accreditation of programmes in engineering and technology [65]. The accreditation by the AEER is recognised both by the Ministry of Education and Science of the RF and by professional organisations, including The Chamber of Commerce and Industry of the RF, The Union of Employers and Businessmen and The Union of Scientific and Engineering Associations. The accreditation criteria of the AEER are fully compatible with international standards of engineering education. The AEER was one of founding members of the ENAEE and has been authorised to award the EUR-ACE Label since 2008. The AEER has been a full member of the Washington Accord since 2012. State accreditation is a prerequisite for the AEER accreditation and all the AEER accredited programmes are presumed to meet the requirement of the FES.

The FES and other Russian documents relating to higher education refer "competences" to describe the combination of skills, knowledge and attitudes that students have to demonstrate at the end of study programme. In European standards this combination of students' abilities is usually referred to as "learning (or programme) outcomes (LOs)".

In the detailed and approved FES there are about 170 fields of study and more than 50% of them are related to engineering and technology. Prescribed learning outcomes are given in various forms; some of which are quite broad statements, while others are very narrow and also the number of specified LOs varies from few up to 70, e.g., 51 professional and 9 personal skills are prescribed for Electrical Engineering (MS), while FES specifies just of 7 professional and 7 personal skills for MS programmes in Informatics.

The EUR-ACE Framework Standards specify the student learning outcomes in generic terms, which can be interpreted for different branches of engineering.

A brief comparison of approaches adopted by the Washington Accord signatories, some European countries and FES in specifying the requirements for engineering programmes, that are important for programme design, are given below:

Common features:
1. The professional skills (competences) must include engineering design, engineering analysis, engineering practice and investigations.
2. The level of graduate's competences (both professional and personal) is defined by the programme developer and the level of the programme.
3. Educational programmes are required to have sufficient and adequate resources (infrastructure, staff, finance, etc.) to accomplish the programme outcomes.

Differences:
1. Different terms and definitions are used and even the Ministry of Education and Science of RF used various definitions and terms in standards and regulations.
2. FES has no definition for "programme educational objectives" and thus does not define the mechanisms for their achievement.
3. FES does not provide clear recommendations to describe the differences in the levels of bachelor and master competences. However, EUR-ACE Framework Standards contain requirements for graduates of engineering programmes that describe considerable differences in requirements for the engineering graduates' learning outcomes for the FCD and SCD programmes.
4. While the structure of EUR-ACE requirements is related to types of engineering activity, FES also includes requirements for structure and content of engineering programmes (including the credit

64) Association for Engineering Education of Russia, see: http://aeer.ru/
65) Accreditation Centre of Association for Engineering Education of Russia, see: http://ac-raee.ru/

value and the list of recommended disciplines).
FES regulates the credit value for programme cycles and modules (scientific, professional, etc.) and for different types of study (research work, internships) that is probably a legacy of the previous generation of educational standards.
5. FES also requires universities to ensure that the development of social and extracurricular activities within the educational process, including development of student governance, student involvement to public, sport and creative organisations and communities are an essential part of learning environment
6. Standards for some specialities contain a very detailed list of knowledge, skills and competences.

There is no contradiction between the Russian and European approaches and standards in general when the different structure of the standards and usage of some terms and definitions are taken into consideration:

- FES defines fields of study and objects of graduate's professional activity that are equivalents of programme educational objectives.
- Graduate's competences (definition used in the FES) are equivalent to both graduate's attribute (definition used by the Washington accord signatories) and learning outcomes (EUR-ACE Framework standards). In general, the set of requirements for graduate's professional and personal skills is equivalent in all three above mentioned documents/approaches.

One of the primary advantages of EUR-ACE Framework Standards is their universality. They consider trends in the latest developments of the engineering profession and the experiences of European countries in quality assurance of engineering education. Hence, EUR-ACE can be used for both design and evaluation of engineering educational programmes. The FES defines the minimum set of requirements for academic programme. The HEIs have the right to supplement and broaden the requirements for graduate's competences while developing their programmes, thus enhancing the Standard requirements.

As a conclusion, it can be stated that there is no fundamental inconsistency between the Russian and European approaches and standards in general, when allowance are made for the different structures of the standards and different usage of some terms and definitions.

4.2.2. France

In 1934, CTI (Commission des Titres d'Ingénieur - Engineering Degree Commission) was set up under French law and became one of the first evaluation and accreditation agencies in France and in Europe. The 1934 law, which was re-confirmed in June 2000 in the French Education Code, granted recognition to CTI as the authority for the external evaluation and accreditation of French engineering schools. CTI was also granted the authority to perform the evaluation and accreditation of establishments in other countries that grant their own engineering degrees.

Originally the CTI evaluation was a form of mandatory institutional accreditation for engineering schools. Accredited HEIs are authorised to award the "Diplôme d'ingénieur" at the end of a programme of study of usually 5 years of study and graduates from these programmes have the right to use the title of "ingénieur diplômé". In Bologna terms these programmes are recognised as second cycle degrees, equivalent to master degrees. In recent years the focus of the external evaluation by CTI has shifted increasingly towards programmes and their learning outcomes as described in the CTI document "Références et Orientations". This document is "designed as a framework within which the Engineering Schools have ample room to take their own initiatives and make innovations. In particular, the Engineering Schools are encouraged to define their own duties and responsibilities, as well as the skills they want to see in the engineers they educate. CTI has also made these guidelines compatible with those of other national, European and international higher education evaluation organisations, in particular, those concerning engineers." [66]

As a result of the freedom to decide on their specific programmes and respective learning outcomes quite a variety of profiles exist. In general they should be independent of particular engineering disciplines and they all should refer to the following generic set of outcomes:

- "Knowledge and understanding of a broad range of basic sciences and the related capacity to summarise and perform analysis,
- Aptitude to use the scientific and technical resources related to a specialty,
- Understanding of engineering methods and tools: identification and resolution of problems, even those that are not familiar and not fully defined, possibly using experimentation, innovation and research, the collection and interpretation of data, the use of computing tools, the analysis and design of systems,
- Capacity to join an organisation, to lead it and drive it forward: self-awareness, team spirit, commitment and leadership, project management, project coordination, communication with specialists and non-specialists alike,
- Aptitude to take on board professional issues: corporate spirit, competitiveness and productivity, innovation, intellectual and industrial property, respect for quality procedures, security, health and safety in the workplace,
- Aptitude to work in an international context: command of one or more foreign languages, cultural open-mindedness, international experience, business intelligence,
- Aptitude to put sustainable development principles into practice: environment, economy, labour and corporate governance,
- Aptitude to consider and foster societal values: endorsing social values, responsibility, ethics, health and safety,
- Capacity to follow through on their professional choices and fit into a professional context." [67]

In addition, the programmes should provide possibilities for practical experience and competence achievement by at least 28 weeks of internship, all or part of it can be abroad. A School is required to collaborate with its stakeholders, in particular its applicants, engineering students and the professional world with the following aims:

- "The school and its surroundings discuss what is needed to bring graduate engineers' profiles up to date according to their needs.
- The desired engineer profile is defined according to the professional skills and capacities. In addition to evaluating the capacities, the school has an approach to evaluating engineering students' skills, in cooperation with companies." [68]

CTI also checks that the school has a quality assurance and management system in place which evaluates the achievement of intended or required outcomes and supporting continuing improvement.

4.2.3. United Kingdom (UK)

In the UK the accreditation of engineering programmes is performed by the Professional Engineering Institutions and therefore is embedded in a concept of professional competence achievement and is based on three separate elements or phases (i) education and training in an accredited engineering programme (ii) initial professional development in appropriate engineering practice and finally (iii) a professional review leading to registration as a member of one of the Institutions. After the completion of this formation process the member is entitled to use the professional title of either "Chartered Engineer" CEng or "Incorporated Engineer" IEng. Not all of the graduates from engineering programmes apply for these professional titles and undergo the required formation process but instead go for regular employment.

66) CTI, 2010, References and guidelines, Introduction

67) CTI, 2010, References and Guidelines, p. 17

68) Ibid., p. 20

There are no state directives or regulations for engineering programmes in the UK and apart from restrictions caused by funding rules, the Universities enjoy a traditionally high degree of autonomy with regard to programme profiles and delivery. The UK Quality Assurance Agency for Higher Education (QAA) in 2005 decided no longer to rely on detailed subject benchmarks in engineering but on the more generic standards of the Engineering Council UK)[69] – the United Kingdom Standards for Professional Engineering Competence (UK-SPEC) – which are used in the accreditation of programmes by the Professional Engineering Institutions and which sets the standards for programme development and curriculum design.

Until recently the educational entry requirement on the route to a "Chartered Engineer" was a Bachelor Honours Degree in Engineering (BEng Hons.) after 3 to 4 years of study. The United Kingdom Standards for Professional Engineering Competence (UK-SPEC), which were developed in 2003, increased the requirement to a Master of Engineering Degree (MEng), which is normally acquired after completing an integrated course of study in engineering of 4 years duration. An alternative route to Chartered status is an Accredited Bachelor Honours Degree plus an appropriate accredited Master Degree or further learning to Master Degree level. Accordingly the standards have been increased to master level requirements and are based on learning outcomes.

Irrespective of whether it is at Bachelor or Master Level, certain General Learning Outcomes should be achieved and these are categorised in 4 dimensions:

- Knowledge and understanding
- Intellectual Abilities
- Practical skills
- General transferable skills

In addition 5 Specific Learning Outcomes in engineering have to be achieved and these are defined by broad areas of learning:

- *Underpinning science and mathematics, and associated engineering disciplines, as defined by the relevant engineering institutions*
- *Engineering Analysis*
- *Design*
- *Economic, social, and environmental context*
- *Engineering Practice*

These outcomes are detailed for the Bachelor Honours Level. With regard to the accreditation of Master of Engineering Degrees the following additional outcomes must also be achieved.[70]

"Concerning General Learning Outcomes:
- The ability to develop, monitor and update a plan, to reflect a changing operating environment;
- The ability to monitor and adjust a personal programme of work on an on-going basis, and to learn independently;
- An understanding of different roles within a team, and the ability to exercise leadership
- The ability to learn new theories, concepts, methods etc. in unfamiliar situations.

Concerning the Specific Learning Outcomes:
- Underpinning science and mathematics, etc., comprehensive understanding of the scientific principles of own specialisation and related disciplines;
- An awareness of developing technologies related to their own specialisation;
- A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations;
- An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

Engineering Analysis
- Ability to use fundamental knowledge to investigate new and emerging technologies;
- Ability to apply mathematical and computer-based models for solving problems in engineering, and the

69) Engineering Council (EC), UK, an association functioning besides other commitments as a kind of umbrella organization for the Professional Engineering Institutions

70) Engineering Council UK, 2010, UK Standard for Professional Engineering Competence, p. 15ff

ability to assess the limitations of particular cases;
- Ability to extract data pertinent to an unfamiliar problem, and apply in its solution using computer based engineering tools when appropriate.

Design
- Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations;
- Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

Economic, social and environmental context
- Extensive knowledge and understanding of management and business practices, and their limitations, and how these may be applied appropriately;
- The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

Engineering Practice
- A thorough understanding of current practice and its limitations, and some appreciation of likely new developments;
- Extensive knowledge and understanding of a wide range of engineering materials and components;
- Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

All the learning outcomes listed have to be specified with regard to the various engineering disciplines. This is done by the respective Professional Engineering Institutions through their evaluators in the accreditation panels and in many cases supported by discipline specific guidelines or handbooks.[71] Programme providers also have the possibility to go beyond these required outcomes or define additional outcomes they aim to achieve. During the accreditation process they have to provide evidence that at least the required learning outcomes are being achieved. In advance of the accreditation panel visit, the educational institution will make a submission that includes the following information:

- The learning outcomes of the programme(s)
- The teaching and learning processes
- The assessment strategies employed
- The resources involved – including human, physical and material
- Its internal regulations regarding compensation for underperformance
- Quality assurance arrangements
- Entry to the programme and how cohort entry extremes will be supported.

4.2.4. Germany

With the shift to the three cycle Bologna structure and the implementation of Bachelor and Master Degree programmes, Germany provided greater autonomy to the HEIs and cancelled all external discipline related, often very detailed in-put oriented requirements and recommendations for programmes. In addition, in most of the 16 German Federal States the governmental approval of individual programmes including their examination regulations was stopped. It was replaced by mandatory external accreditation procedures executed by newly established accreditation agencies which have to be authorised by the Accreditation Council (Akkreditierungsrat) for Higher Education, which was constituted in 2001. Some predominantly formal requirements for the accreditation procedures and the structure and design of programmes have been adopted by the Federal States and detailed by the Accreditation Council, but besides some generic qualification objectives and profile descriptions, only very few qualitative requirements have been adopted. However, it was agreed that programmes should focus on learning objectives and learning outcomes and that Universities and other HEIs should specify their aims and intended outcomes according to their mission and to the range of profiles and degrees officially adopted. References are also expected to be made to the German Qualification Framework for Higher Education, which was adopted in 2005. The in-

71) eg.: Institution of Engineering and Technology, 2006, IET Handbook for Learning Outcomes for BEng and MEng Degree Programmes

crease of autonomy of HEIs should contribute to more flexibility in responding to new demands and to the increase in quality of the education provided.

External programme accreditation is aiming to assure professional as well as academic quality and therefore stakeholders like employers, unions, professional organisations and students in addition to academia are involved, but no representatives from ministries or government participate in the evaluation panels and accreditation commissions. Accreditation procedures executed by the agencies as well as the internal quality assurance systems of the agencies have to comply with the European Standards and Guidelines (ESG).

ASIIN, the German Accreditation Agency for Degree Programmes in Engineering, Informatics, the Natural Sciences and Mathematics has specified generic as well as subject related learning outcomes that should guide the HEIs in their programme development. The learning outcomes refer to the EQF requirements in the dimensions of knowledge, skills and competences. The Bachelor Degree, either a Bachelor of Engineering or a Bachelor of Science, should guarantee professional employability as an engineer and therefore allow the achievement of respective competences during a 3 to 4 year programme of study. Learning outcomes listed by ASIIN as a reference for programme developers and providers are specified accordingly and refer to the generic outcomes required by the German Accreditation Council and also the German Qualification Framework for Higher Education, which was adopted in 2005. Master level outcomes are perceived as an extension of those already addressed at Bachelor Level.

As a result of the most recent re-accreditation process of ASIIN undertaken by the German Accreditation Council in 2012, ASIIN now offers different seals, which depend on different requirements for programme accreditation. The seal of the German Accreditation Council is based on more generic requirements for learning outcomes which have to be specified by the HEIs and on general rules with regard to the various programme dimensions and the procedures of accreditation itself. Details of this process are covered by the General Criteria for programme accreditation of ASIIN.[72]

In addition HEIs can apply for the ASIIN seal which is discipline related and oriented towards much more detailed specifications of learning outcomes provided by the respective discipline and branch related Technical Committees of ASIIN. In engineering they refer to EUR-ACE framework standards and thus, by special application, not only the ASIIN seal but also the EUR-ACE First or Second Cycle Label can be awarded to a successfully accredited programme. Detailed requirements are stated in the Subject Specific Criteria (SSC). In engineering 6 different sets of criteria currently exist covering the different branches of engineering.

Most of them also deal with the German distinction between two types of degree profiles: the "practice-oriented" and the "research-oriented". This is a distinction which is addressed neither in the French or UK learning outcomes nor in the transnational sectoral frameworks like EUR-ACE or the Washington Accord. It arises mainly because of the differing interests of the traditional German research intensive Technical Universities and the more practical demands of industry and the labour market which are particularly addressed by the Universities of Applied Sciences.

As an example some of the subject specific criteria of Mechanical Engineering for the dimension Engineering practice are listed below:

Engineering Practice
"Graduates of more research-oriented Bachelor's degree programmes have in particular:

- the ability to combine theory and practice with the aim to analyse and solve problems peculiar to engineering sciences with an orientation on methods and fundamentals;
- an understanding of applicable techniques and methods and their limits;

72) See: http://www.asiin-ev.de/media/ASIIN_General_Criteria_for_the_Accrediation_of_Degree_Programmes_2012-06-28.pdf

- the ability to responsibly apply and independently consolidate their knowledge in different fields under consideration of economic, ecologic and safety requirements as well as sustainability and environmental compatibility;
- an awareness of the non-technical effects of engineering activities.

"Graduates of more practice-oriented Bachelor's degree programmes are in particular:
- able to transfer new findings in engineering and natural sciences to industrial and commercial production under consideration of economic, ecologic and safety requirements as well as sustainability and environmental compatibility;
- able to plan, control and monitor processes and to develop and operate systems and equipment;
- able to independently consolidate the knowledge gained;
- aware of the non-technical effects of engineering activities.

Graduates of more research-oriented Master's degree programmes are in particular able to:
- classify and systematically combine knowledge of different fields and handle complexity;
- familiarise themselves speedily, methodically and systematically with the new and unknown;
- assess applicable methods and their limits;
- reflect non-technical effects of engineering activities systematically and to integrate them into their actions in a responsible manner.

Graduates of more practice-oriented Master's degree programmes are in particular able to:
- combine knowledge in different fields for fast realisation and to handle complexity;
- familiarise themselves in a fast and targeted way with the new and unknown;
- assess applicable techniques on the basis of their eminent knowledge and to assess their limits;
- recognise non-technical effects of engineering activities systematically and to integrate them into their actions in a responsible manner." [73]

The other 5 dimensions, which are identical to the EUR-ACE ones, are specified accordingly and cover more and differently phrased outcomes than the EUR-ACE Framework Standards. They are regularly revised by the responsible Technical Committees and function as references to curriculum development and the respective accreditation procedures.

4.3. USA and the Washington Accord

As already mentioned, ABET, the Accreditation Board for Engineering and Technology in the USA, was the first agency to pilot and later implement an outcomes based approach to programme accreditation. In their Criteria 2000 for engineering programmes, ABET defined 9 criteria for programme accreditation. General criteria 3, dealing with student outcomes, specified 11 generic learning outcomes covering all engineering disciplines. In its most recent version of their Criteria in 2013-14 they are phrased as follows :

"The programme must have documented student outcomes that prepare graduates to attain the programme educational objectives.

The 11 student outcomes are listed below as outcomes (a) through (k) and individual programmes have the freedom to specify any additional outcomes that they wish to add:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyse and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

73) See: http://www.asiin-ev.de/media/feh/ASIIN_TC_01_Mechanical_Engineering_and_Process_Engineering_2011-12-09.pdf

(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."[74]

The list of learning outcomes quoted applies only to the Bachelor Degree, which is normally obtained after 4 years of study. For the Master level, which is usually not accredited, no comparable list exists. For this cycle and degree level it is only stated:

"Masters level programmes must develop, publish, and periodically review educational objectives and programme outcomes. The criteria for master`s level programmes are the fulfillment of the baccalaureate level general criteria, the fulfillment of programme criteria appropriate to the master's level specialisation area, and one academic year of study beyond the baccalaureate level. The programme must demonstrate that graduates have an ability to apply master's level knowledge in a specialised area of engineering related to the programme area."[75]

The same approach holds for the list of "graduate attributes" of the Washington Accord. They also address only the first degree level and the Bachelor Degree is deemed to be the entry qualification into practice and/ or professional development and professional competence achievement.

However, the American Society of Civil Engineers (ASCE) is eagerly trying to "raise the bar" and to establish the Master Degree or the Bachelor plus 30 additional credits as the educational entry requirement into their profession. The Master level in their model is primarily devoted to a specialisation in a certain subject area, but additional outcomes are required. Extending the ABET list of 11 outcomes, ASCE defined 22 learning outcomes that must be achieved.[76] Even more interesting is the approach to specify the level of achievement which should be reached for each one of the listed outcomes during study, initial professional practice and later continuing professional development. These achievement levels are specified by referring to Bloom`s "Taxonomy of educational objectives"[77] and partly to the revised version published by Anderson and Krathwohl.[78]

The six Bloom levels in the cognitive domain comprise:

- Knowledge
- Understanding
- Application
- Analysis
- Synthesis
- Evaluation

Some European Universities and University Networks recently have also tried to specify achievement levels when defining their set of intended learning outcomes.

4.4 Learning outcomes in engineering education as specified by some networks of Research Universities

Apart from referring to governmental regulations or accreditation requirements Universities use their autonomy to define their own range of learning outcomes. Research Universities in particular often argue that the external learning outcomes requirements are only the minimum or threshold standards to be achieved and which they strive to extend. Some Universities have created a network approach by agreeing on the same joint set of learning outcomes. At a national level the

74) ABET, Criteria for Accrediting Engineering Programs, 2013 – 2014
75) ABET, Criteria for Accrediting Engineering Programs, 2013 – 2014, General criteria for masters level programs
76) ASCE, 2008, Body of Knowledge, 2nd. edition
77) Bloom, B.S. (Ed.), 1956, Taxonomy of educational objectives, A handbook
78) Anderson, L.W. and Krathwohl, D.R., 2001, A Taxonomy for Learning, Teaching and Assessing.

three Technical Dutch Universities Eindhoven, Delft and Twente (3TU) adopted a proposal from TU Eindhoven as their common reference. The 3TU system of learning outcomes focusses on competences.

"By `competence` we mean the integration of knowledge, skill and attitude. A student has a certain competence if (s)he has the relevant knowledge, if (s)he is able to apply this knowledge in appropriate contexts, and if (s)he has the attitude of using this knowledge in these contexts." [79]

The 3TU model is focused on three domains: the scientific discipline, the scientific method and the context of science and technology. Seven generic outcomes have been determined which have to be specified with regard to the respective engineering discipline. The following are the requirements for the master level:

1. Competent in one or more scientific disciplines: an example for an outcome would be: the graduate "has a thorough mastery of parts of the discipline extending to the forefront of knowledge",
2. Competent in doing research: e.g.: the graduate "is able to assess research within the discipline on its scientific value",
3. Competent in designing, e.g.: the graduate, "given the process stage of the design problem, chooses the appropriate level of abstraction",
4. A scientific approach, e.g.: the graduate "has knowledge of current debates about the scientific practice",
5. Basic intellectual skills, e.g.: the graduate "is able to recognise fallacies",
6. Competent in cooperating and communicating, e.g.: the graduate "is able to communicate about research and solutions to problems with colleagues and non-colleagues in a second language:,
7. Takes account of the temporal and social context, e.g. the graduate after analysing the ethical consequences of scientific thinking and acting "integrates these consequences in scientific work".

From this list of outcomes it is obvious that competences in engineering practice are not explicitly addressed in the 3TU model but that research is the field of practice that is focussed on in the master level degrees of the universities involved, independently of the needs of employers from industry and other sectors of the labour market. However, some German research intensive universities such as the TU Berlin are currently trying to adopt this 3TU model for their approach to quality teaching and learning and the implementation of an internal quality management system. [80]

Like the Body of Knowledge approach of the American Society of Civil Engineering (ASCE), which was described earlier, the 3TU model addresses different levels of outcomes, with the focus in this case on competences. Instead of Bloom`s Taxonomy or other concepts like the levels of complexity of problem solving, a different approach is proposed for this purpose, which is based on types of activity for which respective competences should be achieved. Four types of activity are identified:

1. Analysing,
2. Synthesising,
3. Abstracting,
4. Concretising.

For each of the activities a scale has been constructed with three, four or five levels based on examples of challenges and assignments in a particular discipline or subject. Developing rubrics, starting from assignments to be solved with regard to every level, is a useful tool not only for planning the curriculum based on outcomes, but also for planning and implementing an outcomes based assessment system. At TU Berlin a slightly different system and rubric has been developed using a scale of 5 levels for 4 dimensions of competence:

- Knowledge and comprehension
- Context
- Self-reliance
- Self-assessment.

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79) Meijers, Anthonie W. M., 2006, Academic Learning Outcomes: A Conceptual and Empirical Approach

80) Heiss, H.U., Raue, C., 2008, Outcome analysis of Bachelor Master Curricula in Electrical Engineering and Computing

An additional example of a University driven approach to quality assurance and development is the CDIO concept already described to some extent in Chapter 1. This differs from the previously discussed research oriented approach and is a more engineering practice oriented one based on a strong theoretical foundation. It is assumed that Conceiving, Designing, Implementing and Operating with regard to products and systems are activities at the center of engineering and for which engineering education graduates have to be qualified. Starting from these four areas of activity the CDIO syllabus was developed as one out of 12 CDIO standards which structure the comprehensive approach to curriculum design, quality improvement and organisational development. As earlier described the four broad areas of attributes on the first layer are:

1. Technical knowledge and reasoning,
2. Personal and professional skills and attributes,
3. Interpersonal skills: teamwork and communication,
4. Conceive, Design, Implement and Operate

These four areas consist of 17 knowledge categories, skills or activities to which additional specifications correspond. This results in more than 80 attributes on the third level of specification and constitutes the basis for the definition of respective learning outcomes. The 17 activities or knowledge and skills requirements are:

- Knowledge of underlying sciences
- Core engineering fundamental knowledge
- Advanced engineering fundamental knowledge
- Engineering reasoning and problem solving
- Experimentation and knowledge discovery
- System thinking
- Personal skills and attitudes
- Professional Skills and attitudes
- Teamwork
- Communication
- Communications in foreign languages
- External and societal context
- Enterprise and Business context
- Conceiving and engineering systems
- Designing
- Implementing
- Operating

As already mentioned the current version 2.0 of the CDIO syllabus has been enlarged by 2 areas of attributes: Entrepreneurship and leadership.[81]

With regard to the specified details under most of the 19 topics, stakeholders including employers, professors and students have been asked to what level of attainment the learning at university should strive for, and compare this with what level they estimate is achieved in the current curricula and teaching/learning activities. Comparing the results of the surveys from the different universities involved has also functioned as a form of benchmarking.[82]

The CDIO syllabus is not explicitly focused on either the bachelor or the master level and can be adjusted to both levels. Independently of the range of required or intended learning outcomes, it is necessary for curriculum and module design as well as for outcomes assessment to specify levels of outcomes to be achieved. Programme accreditation by external agencies on the other hand is based on a certain threshold level.

81) CDIO syllabus version 2.0, see www.cdio.org

82) Bankel, J., et. al., 2005, Benchmarking Engineering Curricula with the CDIO Syllabus

5. Methodology of engineering curriculum design aligned with EUR-ACE Standards

The methodology of engineering curriculum design described in this chapter has been developed with consideration and implementation of an outcomes-based approach, ECTS credit system, requirements of national and international accreditation criteria and other recent developments in higher education. The review of systematic approaches to curriculum development is given in Chapter 2. A main emphasis of the methodology presented here is put on direct and strong links to graduate attributes defined by accreditation bodies and professional societies (see Chapter 4).

The general requirements for graduates from engineering programmes and the study programmes themselves are formulated in the "EUR-ACE Framework Standards for the accreditation of engineering programmes" which is an agreed and recognised standard within Europe for engineering education. The EUR-ACE Framework Standards specify student learning outcomes in generic terms, so that they can be interpreted for different branches of engineering. In the following sections we describe how engineering courses might be designed, taught, and assessed in order to equip students with the intended attributes. The methodology has been developed and piloted within a TEMPUS project entitled "Engineering Curricula Design aligned with EQF and EUR-ACE Standards"[83] (the project review is given in Appendix 1).

5.1. Engineering curriculum design and continuous programme improvement

Curriculum design is a constituent part of a lifelong process of programme continuous improvement, which can be represented for example by the ABET two loop diagram (Figure 2, see Chapter 2.3). This is composed of two loops demonstrating the on-going improvement of educational processes based on evaluation of achievement of programme educational objectives (PEO) and programme learning outcomes (PLO).

The left loop shows the steps involved in establishing and assessing programme objectives while the right loop shows how outcomes that support the programme's objectives are developed and assessed. The interaction and overlapping between the loops assures (i) that the outcome assessment is used to verify if the programme objectives are met, (ii) that the learning outcomes can be modified (as well as the study process) to assure the achievement of programme objectives and (iii) that a programme objective can also be reviewed and updated, if it cannot be achieved for some reason. It should be noted that the external loop (left) is cycled through more slowly than the internal one (right), since the achievement of programme educational objectives can only be verified after several graduations. Meanwhile the internal loop completes the cycle for each graduation and hence is completed several times before the external loop is closed. The continuous improvement requires that a curriculum design/redesign is undertaken if needed to ensure PEO/PLO achievement.

In accordance with the Figure 2, a curriculum design includes the following steps:

Step 1: Programme conception
(a brief description of the programme)
Development of programme conception includes identification of the programme stakeholders (constituencies) and creation of a system, which ensures the interaction with the stakeholders and a study of their needs.

Step 2: Definition of programme educational objectives
A programme developer must define the programme educational objectives based on the needs of the stakeholders. The programme objectives are to be consistent with the mission of the institution and department to ensure a programme's market competitiveness and to meet the demands of the stakeholders.

Step 3: Definition of measurable programme learning outcomes
A programme developer formulates measurable learning outcomes – the knowledge, skills and attitudes that a student acquires during his study for the programme. The programme learning outcomes must cor-

83) ECDEAST web site: http://www.ecdeast.tpu.ru/

respond with the needs of the stakeholders and ensure the achievement of the programme objectives by the graduates.

Step 4. Modules and credit allocation
A programme developer must plan how the programme learning outcomes are to be achieved by defining the programme modules. Each module has its own module learning outcomes (MLO) which contribute to the achievement of programme learning outcomes (PLO). A module's syllabus, teaching methods and technologies, and supporting facilities must be focussed on the achievement of module learning outcomes.
The achievement of any MLO requires a certain student learning activity (or activities) which is determined by the nature of MLO, the learning environment, technologies etc. Each MLO is assigned a number of ECTS credits, which is related to the average student workload needed to achieve that MLO. Thus, a programme designer allocates the total number of (mandatory) programme's credits among the MLOs according to their contribution to the achievement of programme outcomes. The notional learning time (student workload required) for a module is defined in accordance with its credit value.
Each module must have assessment methods and tools in place to evaluate the achievement of the intended learning outcomes. Credits should not be assigned to a module if the module does not include an appropriate assessment of the outcomes to be achieved.

Step 5: Development of the assessment system for achievement of learning outcomes and programme objectives
The evaluation of the achievement of learning outcomes and programme objectives should be run systematically and used for programme continuous improvement. Accreditation of a programme by an accrediting agency is an important part of the assessment system of an institution/department.

A more detailed description of these steps, including examples, is given below.

5.2. Programme conception
The starting step in programme design is the definition of its conception. This includes the identification of the programme's stakeholders, the study of their needs and the definition of programme objectives based on the stakeholders' needs.

The requirements of the stakeholders are very important for each educational programme. A programme developer, taking into consideration the mission and development strategy of a HEI, must clearly understand who are the programme's stakeholders and design the programme so as to meet their expectations. The programme's stakeholders comprise federal and/or regional authorities, educational administration, employers of different branches of the industry, research institutions, students and their parents, faculty, alumni, accreditation agencies, etc.

The correct identification of a programme's main stakeholder (or stakeholders), a study of its needs and the development of the programme concept aimed to satisfy the stakeholder's needs and expectations, will help avoid difficulties in the development and delivery of the programme and ensure its success in relation to the demand for the programme, graduates' employability, programme financing, programme content, programme evaluation and quality assurance. A programme must be flexible to survive in a changing environment, so it is important that an effective feedback mechanism is in place.

The faculty or department which designs and delivers the programme must be the principle body responsible for programme. A programme developer must be aware of modern trends in higher education development (and, in particular, in their own discipline) as well as of the requirements of professional organisations and accreditation agencies with regard to graduates' attributes to ensure the recognition of the graduates' competences. To be competitive an educational programme must:

Example 1
PROGRAMME CONCEPTION

The programme "Computer Technologies for Design of Thermal and Nuclear Power Plants" is one of the programmes within the field of study 140100 "Heat and Power Engineering" of Tomsk Polytechnic University (TPU). It focusses on advanced studies in natural and engineering sciences and computer and information technologies. The graduates gain experience in usage of modern software and hardware tools for design equipment of power energetics and for the operation of Thermal and Nuclear Power Plants (TPP and NPP). The graduates are prepared for research, simulation of strength properties and technological processes of heat transfer, development and implementation of new technologies of conversion of natural energy into electricity.

The acquisition of managerial and economic competences is incorporated in the study process to ensure careers for prospective graduates in national power energy industry and research/design institutions. The graduates are employed at "Atomenergoproekt", "Teploelektroproekt", SibCOTES, All-Russian Thermal Engineering Institute, Russian Research and Design-Engineering Institute of Nuclear Power Machine Building and other institutions.

- be comparable in profile and quality or differ significantly from the similar programmes of other HEIs, while fully corresponding to the needs of its stakeholders;
- guarantee high standards of teaching and learning;
- have in place an effective mechanism for the continuous improvement of the programme.

A systematic investigation of stakeholders' needs and an updating of the respective programme's concept and its objectives in correspondence to these needs are vital for an educational programme in a changing environment. The institution or department responsible for the programme delivery must have an on-going system for continuous programme improvement including a study of stakeholders' needs, the definition of programme objectives and a systematic assessment of their achievement. The data collected by surveys of different groups of stakeholders (alumni, faculty, employers, etc.) must be analysed and used for the continuous improvement of the programme and for updating the programme's objectives.

5.3 Programme educational objectives

Definition of programme objectives is the next step in programme design. The programme objectives are brief descriptions of the programme concept in terms of the competences to be acquired by the students for graduation. Programme Educational Objectives are broad statements that describe the career and professional accomplishments that the programme is preparing graduates to achieve within the first few years after graduation.

The programme objectives describe the programme's uniqueness (specific features), but not the content. It is important to understand that programme objectives provide a mechanism for interaction with programme stakeholders. The objectives must be published and available for all the stakeholders as well as shared by every faculty member participating in programme delivery. Thus, the objectives have to correspond to the needs of society in training specialists of a specific field as well as the needs of potential employers and be attractive for students and underline the programme's uniqueness (specific features) with respect to the programmes of other HEIs in order to make the programme competitive.

The processes of teaching and learning must ensure the achievement of the programme objectives. It is worth noting that the objectives are expected to be achieved within the first few years after graduation, Some objectives can be achieved by all the graduates while others are achieved only by some of them.

The evaluation of the achievement of programme objectives is usually done through a survey of programme

Example 2
PROGRAMME OBJECTIVES

The graduates of the programme are prepared:
O1: for research and problem solving in development and optimisation of techniques and machinery for TPP and NPP using computer-aided technologies;
O2: for engineering design of TPP and NPP machinery and equipment taking into account the requirements and standards of process engineering, environment protection and safety regulations;
O3: for independent life-long learning and professional development.

stakeholders (employers, alumni, etc.). The achievement of programme objectives is an important accreditation criterion as considered by the accrediting organisations, including ENAEE members. Each objective:

- addresses one or more needs of the stakeholders;
- must be understandable by the stakeholders being served;
- must be consistent with the mission of the institution and be shared by each faculty member participating in programme delivery;
- should be limited to a small number of statements;
- should stress the uniqueness of the programme;
- should be achievable;
- must be supported by at least one learning outcome;
- should be broader statements than those of the learning outcomes.

5.4 Programme learning outcomes
To achieve the programme objectives a programme developer must split them into learning outcomes, create a curriculum with detailed descriptions of modules and disciplines including learning outcomes that support all the objectives.

While programme objectives are broad statements that describe the uniqueness of the specialist training and give "a portrait of a graduate" for potential stakeholders, learning outcomes are narrower statements that describe what students are expected to know and be able to do by the time of graduation. These are the skills, knowledge, and behaviors that enable graduates to achieve the programme objectives. They are acquired by students as they matriculate through the programme.

The programme / module learning outcomes describe knowledge, skills, and behaviors that students must demonstrate upon completion of their studies. It is worth noting that learning outcomes should be acquired by all the students by the time of graduation; while programme objectives are achieved only by the graduates within the few years after graduation (and even then not all the objectives are achieved by all the graduates!). The programme outcomes must satisfy the requirements given below:

- are formulated in terms of knowledge, skills and behavior acquired by the graduates upon completion of the programme;
- should be stated such that a students can demonstrate their achievement upon completion of the programme and before graduation;
- must be a unit of knowledge or skill that supports at least one educational objective;
- must be concise and clear to potential stakeholders: students, faculty members, employers and external reviewers;
- must be observable and measurable;
- collectively, the achievement of all the learning outcomes of compulsory modules must lead to achievement of programme learning outcomes.

The programme learning outcomes are formulated by programme developers based on the programme learning objectives and stakeholders' requirements for professional and personal graduate attributes. The achievement of learning outcomes ensures mastering

Example 3
PROGRAMME LEARNING OUTCOMES

The programme graduates are able:

PROFESSIONAL SKILLS
P1: to use in-depth knowledge of natural sciences, mathematics and engineering in TPP and NPP design;
P2: to identify and solve problems of engineering analysis related to TPP and NPP equipment and machinery development using the system analysis;
P3: to apply computer and information technologies in the design of TPP and NPP and the development of thermal and mechanical equipment;
P4: to conduct theoretical and experimental research of thermodynamic, heat and mass transfer processes in thermal and power equipment, and interpret, present and give practical recommendations for results implementation;
P5: to develop mathematical models of engineering processes, calculate strength properties of complex systems using modern tools and design databases for TPP and NPP;
P6: to use scientific knowledge and creativity, analyse, synthesise and critically evaluate data;

PERSONAL SKILLS
P7: to demonstrate knowledge of a foreign language at the level which allows effective communication with the international engineering community, handle documentation and present and defend outcomes of innovative engineering activity;
P8: to function effectively as an individual and as a member and leader of a team that may be composed of different disciplines and levels, take responsibility for the results and follow the corporate culture of organisation;
P9: to demonstrate in-depth knowledge of social, ethical, cultural and sustainable development issues of innovative engineering activity;
P10: to engage in independent learning and continuous professional development.

Example 4
PROGRAMME OBJECTIVES MAPPED TO LEARNING OUTCOMES

Learning outcomes	Programme objectives		
	O1	O2	O3
P1	+	+	
P2	+	+	+
P3	+	+	
P4	+	+	+
P5	+	+	+
P6	+	+	+
P7		+	+
P8			+
P9			+
P10			+

the programme (in other words, successfully studying and completing all the compulsory modules). Thus, as it was noted above, each objective has to be supported by at least one learning outcome.

The programme learning outcomes are split into module learning outcomes. The learning outcomes of a single module are detailed requirements with regard to knowledge, skills and competences and possibly also attitudes that students must demonstrate upon completion of a module / course. They are formulated by programme developers together with the faculty members responsible for module / discipline development and must ensure the achievement of programme learning outcomes.

The programme learning outcomes are formulated by programme developers based on the programme learning objectives and stakeholders' requirements for professional and personal graduate attributes. The achievement of learning outcomes ensures mastering the programme (in other words, successfully studying and completing all the compulsory modules). Thus, as it was noted above, each objective has to be supported by at least one learning outcome.

The programme learning outcomes are split into module learning outcomes. The learning outcomes of a single module are detailed requirements with regard to knowledge, skills and competences and possibly also attitudes that students must demonstrate upon completion of a module / course. They are formulated by programme developers together with the faculty members responsible for module / discipline development and must ensure the achievement of programme learning outcomes.

5.5 Modules and Credit Allocation

While it started as a credit transfer system, the ECTS has developed also into a credit accumulation system. The ECTS credits can be used to describe the contribution a module or unit makes to a study programme. The official transcripts of records issued throughout Europe make use of the ECTS for specifying and giving recognition for student learning activities. Credits are awarded to a student if he/she has completed a module or unit and has been successfully assessed. Thus, being a measure of the student workload needed to achieve of an intended learning outcome, ECTS credits now also serve as a tool for curriculum design.

The next steps in engineering curriculum design refer to the internal (right-hand) loop of the ABET Two Loop Diagram (Figure 5.1.) and in particular, to the planning of the programme structure and content. The methodology described in this book makes use of the ECTS credit system as a tool for the measurement of programme learning outcomes. Taking into account that an ECTS credit is the student workload required to achieve an intended goal in actual learning time, a direct relationship can be established between learning outcomes and their credit value and then define a student workload associated with a programme module.

To assign a credit to a learning outcome, a programme developer must take into consideration the volume and depth of knowledge and skills required to achieve the outcome as well as the contribution and importance of this outcome in the educational programme.

Programme learning outcomes are achieved while studying on the programme or upon the successful completion of some of its modules. A module can include one or several basic disciplines or electives, internship, projects, research work, final qualification work (master thesis). It should be noted that some learning outcomes, like transferable skills, are taught and assessed entirely within modules designed to satisfy the requirements of other learning outcomes. In these cases the ECTS credits for the transferable skills are assigned to the module where the learning outcomes are assessed.

The learning outcomes of a single module describe in detail knowledge and skills that must be achieved by the students and serve as a basis for the development of a module/discipline syllabus. Below is a list of guidelines for writing learning outcomes for modules:

- learning outcomes for single modules must relate to the overall outcomes of the programme;
- learning outcomes for single modules must be measurable and describe knowledge and skills that are to be achieved within the time and resources available;
- learning outcomes must be written in such a way that they are capable of being assessed and for this purpose the use of direct assessment tools or techniques (written surveys and examinations, oral presentations, project work, exams) is required;
- in writing learning outcomes for single modules one should take into consideration what in-depth knowledge and skills have been acquired on the basis of previous education.

Example 5
Allocation of credits to learning outcomes

FES	Professional skills						Personal / transferable skills			
ECTS credits	95						25			
EUR-ACE	Knowledge and understanding	Engineering analysis		Engineering design	Investigations	Engineering practice	Transferable skills			
ECTS credits	24	21		15	16	19	25			
PLOs	P1	P2	P6	P5	P4	P3	P7	P8	P9	P10
ECTS credits	24	17	4	15	16	19	8	5	6	6

Example 6
ALLOCATION OF CREDITS TO LEARNING OUTCOMES AND PROGRAMME MODULES

Module	Credits	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Philosophical and Methodological Problems of Science and Technology	3	1					1			1	
Computer Design of Industrial Equipment	6			4	1	1					
Research Practice	17	*2*	*2*	*3*	*5*			*1*	*1*	*1*	*2*

5.6 Assessment of learning outcomes and programme objectives

In accordance with the EUR-ACE Framework Standards[84] an institution should provide evidence of the "...existence of a regulated, systematic and periodic process for re-examining the needs, objectives and outcomes, educational process, resources and partnerships and management system". Other accreditation agencies have similar requirements in place, for example in ABET[85] Criterion 2 it is stated: "There must be a documented, systematically utilised, and effective process, involving programme constituencies (stakeholders), for the periodic review of the programme educational objectives that ensures they remain consistent with the institutional mission, the programme's constituents' needs and these criteria."

84) The EUR-ACE Framework Standards. Available from: http://www.enaee.eu/wp-content/uploads/2012/01/EUR-ACE_Framework-Standards_2008-11-0511.pdf

85) ABET, Criteria for Accrediting Engineering Programmes, Effective for Reviews During the 2013-2014

Dr. Gerardo del Cerro in his book "Measurement Performance in Engineering Education"[86] underlines the importance of focussing on assessment. He considers that the purpose of the assessment programme is to assure that the educational process is fulfilling its promise to students, which is to engage them in a stimulating, experiential learning process that prepares them fully to take their place in the job market and to develop successful professional careers. The focus of the assessment programme is on student learning and how the programme can help the student to learn more effectively. Although assessment may centre on classroom activities, it can be implemented at course, department or institute wide levels. It reaches its full potential when it is fully institutionalised around a set of clearly defined institutional, programme and course objectives and outcomes. When assessment serves the goal of institutional strategic planning, it becomes an effective continuous quality improvement tool that contributes to the achievement of the institutional vision and mission.

To manage this process, it is invaluable for departments or curriculum committees to establish a manageable framework for the continuous assessment and development of a programme by establishing a strategic planning process based on the following questions[87]:

1. Why? (What are your specific goals and objectives for curriculum assessment and improvement?)

2. Who? (Who will you involve? Who are the target stakeholders?)

3. When? (What are your timelines?)

4. How? (What assessment method is most appropriate?)

5. What? (What data will you collect to help inform?)

After specific objectives are defined, the following stakeholders could be engaged in evaluation processes:

- Students (current and graduating)
- Alumni
- Faculty
- Staff and administration
- Employers and industry representatives
- Professional Associations (certification and accrediting agencies)
- Providers of similar programmes from other institutions

A sample of an assessment plan for programme objectives and learning outcomes is illustrated in the table below (Example 7). Such a plan could be implemented within the department responsible for the delivery of a programme and supervised by the programme coordinator or working group consisting of faculty members who have suitable experience and motivation in assessment.

The data obtained from the surveys are to be used in the evaluation of the achievement of the learning outcomes and continuous programme improvement. If the results of the surveys show that the needs of the stakeholders are not satisfied, the department or programme developer should make a decision to modify either the programme objectives or the programme or module learning outcomes. If one or several of the programme objectives are not achieved, the department or programme developer should substantially modify either the curriculum or the programme objectives.

5.6.1 Assessment of programme objectives

As was discussed in previous sections, programme objectives are usually achieved by the graduates within 3-5 years after graduation and therefore the assessment of the objectives should take place after they have left the institution. In accordance with the table (Example 7) presented in Section 5.6 the main stakeholders who can act as information sources when assessing

86) Gerardo del Cerro. Measurement Performance in Engineering Education. Cooper Union, 2002. pp.13-14

87) Natasha Kenny, Serge Desmarais. A Guide to Developing and Assessing Learning Outcomes at the University of Guelph. Available from: http://www.bccat.ca/bccat_org/assets/File/A%20Guide%20to%20Learning%20Outcomes(1).pdf

Example 7
ASSESSMENT PLAN FOR PROGRAMME OBJECTIVES AND LEARNING OUTCOMES

Assessment Level	Activities	Purpose	Periodicity	Responsibility
Programme objective	Employers Survey	To gather feedback from employers on the quality of the graduates performance and on the relevance and importance of the programme objectives	annually	Faculty / Working group, Job Placement Office, Office for Social Surveys
	Alumni Survey	To gather feedback from alumni on their employment status and career	annually	Faculty / Working group, Job Placement Office, Office for Social Surveys
	Meeting of Working group on assessment of programme objectives	Evaluation of feedback obtained from employers, alumni and other sources. Elaboration of proposals for improvement of the programme objectives.	annually	Working group / Programme Coordinator
	Department meeting on the assessment of programme objectives	Review and approval of the new programme objectives	once in 3-5 years	Faculty
Programme learning outcomes	Graduating Students Survey	To gather feedback from graduating students on their achievement of the learning outcomes and the quality of the education they received.	annually	Faculty, Job Placement Office, Office for Social Surveys
	Internship Supervisors Survey	To gather feedback from supervisors on student performance and their achievement of the learning outcomes	annually	Working group / Programme Coordinator
	Faculty Survey, including members of State Attestation Commission	To gather feedback from faculty on students' achievement of the learning outcomes	annually	Working group / Programme Coordinator
	Meeting of Working group on assessment of learning outcomes	Evaluation of feedback obtained from graduating students, internship supervisors, faculty and other sources. Elaboration of proposals for improvement of the programme learning outcomes.	annually	Working group / Programme Coordinator
	Department meeting on assessment of Learning outcomes	Review and approval of the new programme leaning outcomes	once in 1-3 years	Faculty
Module learning outcomes	Students Survey	To gather feedback on the achievement by students of the module learning outcomes (within all or selected modules or courses)	each semester	Course instructors
	Meeting of Working group on assessment of modules (courses) learning outcomes	Evaluation of feedback got from students and other sources. Review and approval of the new module learning outcomes with course instructors	annually	Working group / Programme Coordinator

Example 8
TARGET INDICATORS FOR ASSESSMENT OF PROGRAMME OBJECTIVE

Code	Programme Objectives	Target indicators	
		Alumni Survey	Employers Servey
O 1	Research and problem solving in the development and optimisation of techniques and machinery for TPP and NPP using computer-aided technologies	% of graduates who pursue a professional career in their degree area % of graduates who carry out research % of graduates who perform tasks listed in the objective % of graduates who got further degrees % of graduates dealing with computer design technologies	% of employers satisfied with the quality of the graduates performance % of employers requesting graduates

programme objectives are employers and graduates (alumni). A sample of the evaluation of a programme objective is given in Example 8.

5.6.2 Assessment of programme learning outcomes

There are many ways to collect evidence of student learning. To simplify the options, somewhat, assessment efforts are categorised as direct and indirect measures. Direct measures are probably more familiar to teaching faculty. A direct measure is based on a sample of actual student work, including reports, exams, demonstrations, performances, and completed works. The strength of direct measurement is that faculty members are capturing a sample of what students can do, which can be very strong evidence of student learning. A possible weakness of direct measurement is that not everything can be demonstrated in a direct way, such as values, perceptions, feelings, and attitudes.

Because each method has its limitations, an ideal assessment program would combine direct and indirect measures from a variety of sources. This triangulation of assessment methods can provide converging evidence of student learning [88].

Dr. Gloria Rogers, who has been working with colleges and universities for over 20 years in the areas of programme assessment of student learning and institutional effectiveness, proposes for implementation following pool of direct and indirect methods [89]:

Direct

- Standardised exams
- Locally developed exams
- Portfolios
- Simulations
- Performance Appraisal
- External examiner
- Oral exams
- Behavioral observations

Indirect

- Written surveys and questionnaires
- Exit and other interviews
- Archival record
- Focus groups

One of the comprehensive approaches to learning outcomes assessment, which is described in many sources, [90, 91, 92] is *curriculum mapping*. Curriculum mapping is an assessment method, which is used to determine where, when, and how learning outcomes are taught and assessed within a degree programme. It provides an effective strategy for articulating, aligning and integrating learning outcomes across a sequence of

88) Available from: http://www.anokaramsey.edu/en/about/Information/Assessment/Measures.aspx
89) Rogers, G., Choosing Assessment Methods. ABET 2010 Webinar Series. Available from: http://www.abet.org/uploadedFiles/Events/Webinars/Choosing_Assessment_Methods.pdf
90) Bath, D. Smith, C., Stein, S. and Swann, R. 2004. Beyond mapping and embedding graduate attributes: bring together quality assurance and action learning to create a validated and living curriculum. Higher Education Research and Development 23(3): 313-328.
91) Uchiyama, K.P. and Radin, J.L. 2009. Curriculum mapping in higher education: a vehicle for collaboration. Innovative Higher Education 33: 271-280.
92) Kenny, N., Desmarais, S., A Guide to Developing and Assessing Learning Outcomes at the University of Guelph. Available from: http://www.bccat.ca/bccat_org/assets/File/A%20Guide%20to%20Learning%20Outcomes(1).pdf

Example 9
ASSESSMENT PLAN FOR A PROGRAMME LEARNING OUTCOME

Programme Learning Outcome:
P7: Demonstrate knowledge of a foreign language at the level which allows effective communication with the international engineering community, handle documentation, present and defend outcomes of innovative engineering activity (8 ECTS)

Key modules/ courses that contribute to achievement of P7	Modules learning outcomes (M) that contribute to achievement of P7	Responsible for assessment of module learning outcomes	Periodicity / started / last assessment year	Responsible for data analysis and evaluation of achievement of learning outcome
M 1. Б2 Foreign Language	**M1 (P7):** to have knowledge and understanding of (i) the communication role of a foreign language in the field of professional development, (ii) notations and abbreviations of international business culture, (iii) main tendencies in inter-cultural professional communication; **M2 (P7):** to be able to translate authentic texts in the field of thermal and nuclear power plants from the foreign language into the Russian language; **M4 (P7):** to be able to use the foreign language for situations requiring professional communication and to use the foreign literature.	Course Instructor	annually / 2011 / 2013	Working group/ Programme Coordinator
M 3.1 Research Work	**M7 (P7):** to be able to use foreign literature in conducting research	Research Supervisor	each semester / 2011 / 2013	Working group/ Programme Coordinator
M 3.3 Research Practice	**M5 (P7):** to be able to use foreign language/ literature for professional activities	Research Practice Supervisor	annually / 2012 / 2012	Working group/ Programme Coordinator
M 4 Master Thesis	**M8 (P7) (3 ECTS):** to be able to communicate effectively; to have knowledge of professional terminology and skills of using literature and presenting information	Research Supervisor, State attestation commission	annually / 2013 / 2013	Working group/ Programme Coordinator

Example 10
ASSESSMENT OF A MODULE LEARNING OUTCOME

Module M1.Б2 Foreign Language
M2: to be able to translate authentic texts in the field of thermal and nuclear power plants from the foreign language into the Russian language

Assessment Criteria	Types of Learning Activity	Formative Assessment	Summative Assessment
Correctness of terminology usage Usage of wide professional vocabulary Correctness of sentences structure Speed of translation work	Independent work of student on translation of authentic texts	Individual assignment	Exam
	In-class work of students with authentic texts	Test	

courses, and explicitly identifying to students, instructors, administrators and external stakeholders how student learning outcomes are delivered within a degree programme.

A sample of mapping programme and modules outcomes and assessment planning within a curriculum is given below (Example 9).

The value of curriculum mapping is demonstrated when instructors collaborate to review data collected from the questionnaires in order to identify strengths, gaps, redundancies and inconsistencies in the curriculum. Based upon the aggregate data related to the intended and delivered learning outcomes, instructors are able to discuss the strengths and weaknesses and establish specific recommendations for improvement. They can evaluate the range and frequency of instructional and assessment methods, and examine how the depth and complexity of student learning experiences varies across the degree programme [93, 94].

5.6.3 Assessment of module learning outcomes

In accordance with the Glossary of Terms Relevant to Higher Education (Engineering) [95], assessment with regards to students, is the total range of written, oral and practical tests, as well as projects and portfolios, which are used to decide on their progress in the Course Unit or Module. These measures may are used by the students to assess their own progress (formative assessment) or by the University to judge whether the course unit or module has been completed satisfactorily against the learning outcomes of the unit or module (summative assessment).

Nowadays there are many assessment techniques for modules or courses that a teacher could use after defining the intended module learning outcomes. In the book "Teaching Engineering" [96] Peter Goodhew provided a helpful list of them:

- Closed-book examination;
- Open-book examination;
- On-line test, involving different options;
- Oral presentation with or without questions;
- Oral examination on a predetermined topic;
- Oral examination on open topics;
- Written report (with or without a pro-forma);
- Designs or manufactured artefacts;
- Poster or e-poster;
- Assignment involving numerical or essay questions;
- A portfolio of work, or an e-portfolio;
- A wiki.

The table *Example 10* presents formative and summative assessment ways of a module learning outcome. To create a culture of success, where all learners believe they can achieve the module learning outcomes, teachers need to [97]:

1) make sure that learners are clear about:
   - what they are meant to be doing
   - how it will be assessed
   - what they are doing well
   - what is wrong and what needs to be done to put it right
2) avoid reference to ability and competition and comparison with others.

The assessment practitioner [98] must have some of the skills of the statistician and a good deal of the vision of the leader. Well versed in social science research methods, the assessor must be able to frequently and effectively discuss the validity of the process in one-on-one situations with faculty and the administration.

More information on activities and outcomes of the ECDEAST project is available in the Appendix 1 of the book and the project web-site *ecdeast.tpu.ru*

93) Uchiyama, K.P. and Radin, J.L. 2009. Curriculum mapping in higher education: a vehicle for collaboration. Innovative Higher Education 33: 271-280.
94) Kenny, N., Desmarais, S. A Guide to Developing and Assessing Learning Outcomes at the University of Guelph. Available from: http://www.bccat.ca/bccat_org/assets/File/A%20Guide%20to%20Learning%20Outcomes(1).pdf
95) Heitmann, G., Bricola, V. Glossary of Terms Relevant to Higher Education (Engineering). Available from: http://www.unifi.it/tree/dl/oc/a6.pdf
96) Goodhew, P. Teaching Engineering. Available from: http://core.materials.ac.uk/repository/teaching-engineering/teaching_engineering_goodhew.pdf
97) Black, P and Wiliam, D., 1999, Assessment for learning: beyond the black box. London: Kings College London.
98) Gerardo del Cerro, 2002, Measurement of Performance in Engineering Education

An example of the curriculum developed in accordance with the Methodology for engineering programme design aligned with accreditation standards presented in the Chapter 5 is given in the Appendix 2. The Appendix contains descriptions of the curriculum and syllabi of several modules of the master degree programme "Computer Technologies for Design of Thermal and Nuclear Power Plants" that were developed by Tomsk Polytechnic University within the ECDEAST project (2010-2013).

Appendices 3 and 4 provide a glossary of terms and definitions of the various acronyms used in the book.

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Appendix 1 – ECDEAST project

The idea of using professional accreditation standards as a basis for curriculum design was implemented within the ECDEAST project (Engineering Curricula Design aligned with EQF and EUR-ACE Standards). In 2010 a consortium of Russian and European Institutions received the financial support of the European Commission for the realisation of the project within the TEMPUS programme. TEMPUS is the European Union's Programme which supports the modernisation of higher education in the countries of Eastern Europe, Central Asia, the Western Balkans and the Mediterranean region, mainly through university cooperation projects. It also aims to promote voluntary convergence of partner country higher education systems with EU developments in the field of higher education. In addition to institutional cooperation TEMPUS also promotes a "people to people" approach.

The alignment of EQF & EUR-ACE Standards with Russian educational standards requirements to the structure of relevant programmes and appropriate graduates' competences was a challenging task for Russian universities and the project partners as well. To be competitive in the educational market, programmes should meet the requirements of the professional community. In engineering, the requirements for graduates' attributes are formulated by both national and international professional organisations dealing with accreditation of engineering programmes and with recognition of professional qualifications. The European Qualifications Framework (EQF) acts as a translation device to make national qualifications more readable across Europe, promoting the mobility of workers and learners between countries and facilitating their lifelong learning. The EUR-ACE Framework standards define programme outcomes for engineering degree programmes. The programme outcomes describe in general terms the capabilities required of graduates from accredited First Cycle (Bachelor) and Second Cycle (Master) engineering programmes as an entry route to the profession. As framework standards of a European system for the accreditation of engineering programs, the EUR-ACE Standards are widely applicable to the variety of the engineering educational models and traditions in Europe and are broadly accepted by authorised national accreditation bodies.

OBJECTIVE

The objective of the ECDEAST project[100] is to ensure that Russian Universities have advanced curricula for programmes which are in line with new developments in a number of chosen engineering areas and are in accordance with the Bologna Process and European standards for the quality of engineering education (EUR-ACE Standards).

The main practical objective of the project is to design new master engineering curricula for Russian Universities based on the experience of the European partners and the EUR-ACE requirements for graduate competences. It is an urgent topic for the Russian Ministry of Education and Science together with leading Russian Universities to develop master programmes in engineering within areas of specialisation in accordance with the 3rd generation of national and European quality standards. After the completion of the project the Russian partner universities are expected to apply for the EUR-ACE Label with the newly implemented programmes. A successful external evaluation will result in the enhanced mobility of graduates and students.

PARTNERS

The official project coordinator was Hochschule Wismar (Germany). The project consortium consisted of the following partners:

- TPU – Tomsk Polytechnic University (Russia)
- BMSTU – Bauman Moscow State Technical University (Russia)
- SPbSPU – Saint-Petersburg State Polytechnical University (Russia)
- HSW – Hochschule Wismar (Germany)
- KTU – Kaunas University of Technology (Lithuania)
- LBUS – Lucian Blaga University of Sibiu (Romania)
- SEFI – Société Européenne pour la Formation d'Ingénieurs
- ENAEE – European Network for Accreditation of Engineering Education.

TPU, BMSTU and SPbSPU are top-ranking engineering higher education institutions in Russia and each has an excellent tradition in engineering education. These three

100) The ECDEAST project web-site. http://ecdeast.tpu.ru

universities were awarded the status of a national research university and were granted the authority to develop their own educational standards and programmes. They are actively involved in cooperation with international organisations, funding agencies and programme developers. TPU engineering programmes have been successfully evaluated by international bodies (ABET (USA) and CEAB (Canada)) and were among the first programmes in Russia to be awarded the EUR-ACE Label.
HSW, KTU and LBUS shared their experience in curricula design in accordance with Bologna principles and European quality standards within the project. Each university provided the project with its experts in a specific discipline area and in the evaluation of the quality of engineering programs.
ENAEE provided the project with experts in the evaluation of the quality of the engineering programmes and was responsible for the organisation of the evaluation of the programmes developed against the EUR-ACE Standards.
SEFI acted as a consultant for the coordinating team and served as a relay as far as dissemination of the project work and outcomes are concerned.

ACTIVITIES AND PROJECT OUTPUTS

The duration of the project was three years. The activities that were arranged and the outputs that were reached are as follows:

Guidelines on engineering programme design

The discussion of the requirements for learning outcomes and curriculum structure started at the Workshop on European and National Standards Alignment that was held at Kaunas University of Technology in 2011. The Partners agreed on the structure of master engineering curricula and graduates' attributes taking into account EQF, EUR-ACE and Federal Education Standards of Russia (FES). The Guidelines on engineering curriculum design, which were based on the alignment of Russian and European requirements for engineering graduates' competences, were developed as methodological recommendations for the academic staff of the partner universities.
The Guidelines describe a methodology for engineering curriculum design and the main steps of the methodology were the definition of the programme objectives and learning outcomes and credit allocation for programme and module learning outcomes in accordance with the FES and EUR-ACE Framework Standards requirements and the assessment of the achievement of the learning outcomes. The Guidelines are available through the project website in Russian and in English.

Training of faculty of TPU, BMSTU and SPbSPU for curriculum design

Faculty training workshops were organised at each of the Russian partner universities and these workshops included lectures, discussions, case studies, and practical exercises on curricula design. Attention was also paid to active methods of student-oriented learning (team work, problem-based learning). The experience of the European partners in these topics was shared with the participants and was of great benefit in helping achieve the project objective. Materials on the methodology were published and distributed among the faculty involved in the project and are posted on the project website.

Faculty mobility

Extensive faculty exchanges were organised in order to share the experience of the Russian faculty with the EU partners for the development and updating of new modules and courses, teaching materials, and methods for the assessment of the achievement of programme learning outcomes. Faculty mobility was organised in two rounds. The first round was aimed at sharing experience and traditions in curriculum design and general issues of programme and module structure. For the second round key faculty members were selected for face-to-face meetings and discussions on specific modules, teaching materials and the facilities required.

Updated syllabi and teaching materials

The updated syllabi and teaching materials for courses and modules with ECTS credits mapped to learning outcomes were developed by September 2012. The most up-to-date textbooks for the areas of programme specialisation were selected with the advice of the European partners and purchased for TPU, BMSTU and SPbSPU. State-of-the-art powerful software packages for engineering design were also purchased from leading European companies in order to extend the opportunities for advanced master studies.

New curricula and three master programmes
Discussion and approval of the new master programmes was held at the end of the second year of the project during the Conference "International Cooperation in Engineering Education" at SPbSPU at which there was broad participation of all the partners, Russian engineering universities, professional community (Russian and European), and representatives of the Ministry of Education and Science of the Russian Federation.
The following master curricula were developed in close cooperation of the partner universities from Russia and the EU (which worked in pairs):

- Master programme in Computer Technologies for Design of Thermal and Nuclear Power Plants (TPU and HSW);
- Master programme in Cryogenic Engineering and Technology (BMSTU and KTU);
- Master programme in Intellectual Systems and Technologies (SPbSPU and LBUS).

Following the development of the curricula, the Russian Universities (TPU, BMSTU and SPbSPU) started these new programmes in the autumn of 2012, when the first classes of students (10 students in TPU, 5 students in SPbSPU, and 8 students in BMSTU) were enrolled. The newly developed teaching materials and methodologies were applied, and the recently purchased up-to-date software and textbooks were used in corresponding modules.

Evaluation of Programmes against EUR-ACE Standards
Evaluations of the new programmes at the Russian partner universities were carried out by review teams with a balance of international accreditation expertise and experience of Russian education system. Each team was composed of three international experts, with considerable experience of international accreditation, two Russian professors and two Russian students. The international experts were affiliated to either ENAEE or SEFI. The Russian professors and students on each team were nominated by the other two participating universities, and were able to translate and interpret as necessary for the international members. The student members in each team had the important role of meeting the students on the individual programmes to obtain evidence of their perception of the programmes.
Prior to the visits, the departments delivering the programmes were asked to provide a Self-Assessment Report in English, that included background information about the department and the university, the structure of the Programme, details of the modules, comparison with international and national standards, and information about Programme delivery.
The evaluation visits lasted two days and were organised in a similar way to an accreditation visit and included evaluating the programme methodological documents and meetings with faculty, students, graduates and employers.

The evaluation teams reported on the following positive aspects of the programmes:

- Specification of the programme objectives and learning outcomes.
- Programme documentation including module descriptors, credit allocation and module learning outcomes.
- Industrial support for the programmes including input into programme design, teaching and project work.
- Positive comments from students about the programme and teaching.
- Programmes supported by research activities.
- Content and Level of the programmes appears to be consistent with EUR- ACE.

Possible Improvements which were proposed:

- Wording of the programme learning outcomes could be improved by emphasising competences instead of knowledge.
- Module descriptors should include more information about assessment, and how the learning outcomes are achieved.
- The formal University methods of top down quality assurance should be supplemented by feedback from students using departmental questionnaires.

As a formal requirement for the accreditation of a programme is that there are graduates from the programme and since there were no graduates available within the duration of the project, the result of evaluation by the ENAEE was considered as a preliminarily evaluation of the compliance of the programme to EUR-ACE Framework Standards and will be used for the programme improvement.

CONCLUSION

The programmes developed within the project met both the requirements of the third generation national standards of RF and the EUR-ACE Standards for engineering programmes. The development and implementation of master programmes in engineering by leading Russian engineering schools is an important step for the Bologna process in Russia, where the introduction of a 3 cycle degree system is progressing rather slowly. The experience gained in the project by the universities will be distributed through the Educational and Methodological Association of Engineering Institutions of Russia, which is an entity of BMSTU and is responsible for framework standards of engineering study programmes and their dissemination among most of the technical universities of Russia.

After the first graduations from the new programmes developed, the Russian universities are expected to apply for formal accreditation against the EUR-ACE Standards. The recognition of the programme quality through the EUR-ACE Label will contribute to spreading project outcomes through its positive impact on governmental structures and professional engineering organisations. The project outcomes and the best practices developed will be disseminated among the Russian engineering schools and the engineering community.

Appendix 2 – Case study: a Master Curriculum in Electrical Engineering

OVERVIEW

The Master Degree Programme "Computer Technologies for Design of Thermal and Nuclear Power Plants" has been developed at Tomsk Polytechnic University (Institute of Power Engineering, Department of Nuclear and Thermal Power Plants) within the TEMPUS project "ECDEAST: Engineering Curricula Design aligned with EQF and EUR-ACE Standards" (N°511121-TEMPUS-1-2010-1-DE-TEMPUS-JPCR).

CONCEPTION

The programme "Computer Technologies for Design of Thermal and Nuclear Power Plants" is one of the programmes within the field of study 140100 "Heat and Power Engineering" of Tomsk Polytechnic University. It focusses on advanced studies in natural and engineering sciences and computer and information technologies. The graduates gain experience in usage of modern software and hardware tools for design equipment of power energetics and for the operation of Thermal and Nuclear Power Plants (TPP and NPP). The graduates are prepared for research, simulation of strength properties and technological processes of heat transfer, development and implementation of new technologies of conversion of natural energy into electricity.

The acquisition of managerial and economic competences is incorporated in the study process to ensure careers for prospective graduates in national power energy industry and research/design institutions. The graduates are employed at "Atomenergoproekt", "Teploelektroproekt", SibCOTES, All-Russian Thermal Engineering Institute, Russian Research and Design-Engineering Institute of Nuclear Power Machine Building and other institutions.

PROGRAMME OBJECTIVES

The programme objectives have been developed in close cooperation with the programme stakeholders based on qualification profile, types and tasks of professional activity that programme graduates must be able to achieve / solve. Use of the relevant data ensures the stakeholders' needs are taken into account when defining the programme objectives. The team of programme developers considered the requirements of potential employers as priorities. The program objectives were widely discussed both in group of developers, and at the TPU departments responsible for the programme delivery and were approved by the TPU Academic Council.

TPU constantly keeps in contact with representatives of a labour market and employers to ensure their continuing involvement in the programme design and delivery, study process, development of teaching materials, and in programme evaluation. The university stipulates the active participation of students in the programme development, updating, monitoring, and evaluation.

The programme objectives are consistent with the Federal Education Standards of Russia in Heat and Power Engineering and with the mission of TPU.

PROGRAMME LEARNING OUTCOMES

The programme learning outcomes have been developed to ensure achievement of the programme objectives. They correspond to the requirements of the Federal Education Standards (FES) of Russia in Heat and Power Engineering and of the Association for Engineering Education of Russia (AEER) accreditation criteria for engineering programmes (criterion 5).

The programme learning outcomes are systematically submitted to self-evaluation and external evaluation by peers. The Institute of Power Engineering of TPU actively involves stakeholders in the development, updating, monitoring, and evaluation of the programme and modules. At least once every two or three years, the intended learning outcomes are analysed and updated based on:

- recommendations of employers and labour market representatives,
- students and staff questionnaire surveys run by TPU departments,
- results of independent studies,
- contributions from the State Attestation Board on master theses analysis,
- workspaces and labs upgrading,
- programme resources and faculty development, etc.

PROGRAMME STRUCTURE

The notional duration of the programme is two years (full-time study mode) and the programme syllabus carries 120 ECTS credits.

Institution:	National Research Tomsk Polytechnic University (TPU)
Programme:	Computer Technologies for Design of Thermal and Nuclear Power Plants
Field of study:	140100 – Heat and Power Engineering
Degree awarded:	Master of Science
Department:	Institute of Power Engineering Department of Nuclear and Thermal Power Plants
Coordinator:	Dr. Alexander Matveev, Associate Professor, Head of the department E-mail: matveev@tpu.ru
Address:	30, Lenin ave., Tomsk, 634050, Russia
Notional duration:	2 years
Workload:	120 ECTS credits
Classes start:	Fall semester
Mode of study:	Full-time
Language of instruction:	Russian
Date of approval:	May 17, 2012

Code	The programme prepares graduates for
O1	Research and problem solving in development and optimisation of techniques and machinery for TPP and NPP using computer-aided technologies
O2	Engineering design of TPP and NPP machinery and equipment taking into account the requirements and standards of process engineering, environment protection and safety regulations
O3	Independent life-long learning and professional development

Code	Learning outcomes
	The programme graduates are able to 1. Professional skills:
P1	Use of in-depth knowledge of natural sciences, mathematics and engineering in TPP and NPP design
P2	identify and solve problems of engineering analysis related to TPP and NPP equipment and machinery development using the system analysis
P3	apply computer and information technologies in the design of TPP and NPP and the development of thermal and mechanical equipment
P4	conduct theoretical and experimental research of thermodynamic, heat and mass transfer processes in thermal and power equipment and interpret, present and give practical recommendations for results implementation
P5	develop mathematical models of engineering processes, calculate strength properties of complex systems using modern tools and design databases for TPP and NPP
P6	use scientific knowledge and creativity, analyse, synthesise and critically evaluate data
	2. Personal skills:
P7	demonstrate knowledge of foreign language at the level which allows effective communication with the international engineering community, handle documentation, present and defend outcomes of innovative engineering activity
P8	function effectively as an individual and as a member and leader of a team that may be composed of different disciplines and levels, take responsibility for the results and follow the corporate culture of organisation
P9	demonstrate in-depth knowledge of social, ethical, cultural and sustainable development issues of innovative engineering activity
P10	engage in independent learning and continuous professional development

Programme objectives mapped to learning outcomes			
Learning outcomes	Programme objectives		
	O1	O2	O3
P1	+	+	
P2	+	+	+
P3	+	+	
P4	+	+	+
P5	+	+	+
P6	+	+	+
P7		+	+
P8			+
P9			+
P10			+

Code	Cycle /Module/Discipline	ECTS credits
M1	*General scientific cycle*	14
M1.Б	*Compulsory*	11
M1.Б1	*Philosophical and Methodological Problems of Science and Technology*	3
M1.Б2	*Foreign Language*	4 (2/2)
M1.Б3	*Economy and Production Control*	2
M1.Б4	*Mathematical Modeling*	2
M1.B	*Electives*	3
M1.B1.2	*Data-Driven Design*	3
M2	*Professional cycle*	45
M2.Б	*Compulsory*	12
M2.Б1	*Modern Challenges of Thermal Power Engineering and Thermal Technologies*	3
M2.Б2	*Problems of Energy and Resource Saving in Heat Power Engineering and Heat Technology*	3
M2.Б3	*Ecological Safety*	3
M2.Б4	*Principles of Effective Process Management in Heat Power Engineering and Heat Technology*	3
M2.B	*Electives*	33
M2.B1.1	*Computer Design of Industrial Equipment*	6
M2.B2.3	*Computing in Applied Problem Solving*	4
M2.B3.2	*Simulation of Complex Systems*	4
M2.B.5	*Programme Profile "Computer Technologies for Design of Thermal and Nuclear Power Plants"*	
M2.B.5.1	*TPP and NPP Heat Exchangers and Compressors*	4
M2.B.5.2	*Technological Systems and of TPP and NPP*	4
M2.B.5.3	*Reliability and Operation Modes of TPP*	4
M2.B.5.4	*Design of Thermal Power Units and Subsystems*	4
M2.B.5.5	*Technology of TPP and NPP Design*	3
M3	*Research and Internships*	37
M3.1	*Research*	16 (4/6/6)
M3.2.2	*Internship*	4 (2/2)
M3.3	*Research Practice*	17
M4	*Master Thesis*	24

Allocation of credits to learning outcomes and programme modules

Module	Credits	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Philosophical and Methodological Problems of Science and Technology	3	1					1			1	
Foreign Language	4							3	1		
Economy and Production Control	2	1	1								
Mathematical Modelling	2		1			1					
Data-Driven Design	3	1				2					
Modern Challenges of Thermal Power Engineering and Thermal Technologies	3	1			1						1
Energy and Resource Saving in Heat Power Engineering and Heat Technology	3	1	1	1							
Ecological Safety	3	2			1						
Principles of Effective Process Management in Heat Power Engineering, Heat Engineering and Heat Technology	3	1				2					
Computer Design of Industrial Equipment	6			4	1	1					
Computing in Applied Problem Solving	4	1		2		1					
Simulation of Complex Systems	4	2	1			1					
TPP and NPP Heat Exchangers and Compressors	4	1	2			1					
Technological Systems and of TPP and NPP	4	2	1			1					
Reliability and Operation Modes of TPP	4	2	2								
Design of Thermal Power Units and Subsystems	4	1	2	1							
Technology of TPP and NPP Design	3	2	1								
Research	16	1	2	2	5	2		1	1	1	1
Internship	4	2		1					1		
Research Practice	17	2	2	3	5			1	1	1	2
Master Thesis	24		1	5	3	3	3	3	1	3	2

Allocation of credits to learning outcomes

FES*	Professional skills						Personal / transferable skills			
ECTS credits	95						25			
EUR-ACE	Knowledge and understanding	Engineering analysis		Engineering design	Investiga-tions	Engineering practice	Transferable skills			
ECTS credits	24	21		15	16	19	25			
PLOs	P1	P2	P6	P5	P4	P3	P7	P8	P9	P10
ECTS credits	24	17	4	15	16	19	8	5	6	6

*FES – Federal Educational Standards of the RF

ADMISSION REQUIREMENTS

To be admitted into the Master Degree Programme "Computer Technologies for Design of Thermal and Nuclear Power Plants" applicants have to meet the following admission requirements:

- to have a Bachelor degree in Heat and Power Engineering or an equivalent one,
- to pass the entrance exam.

Background requirements:

- to have knowledge of the fundamentals of natural sciences and mathematics;
- to have a basic knowledge of engineering design;
- to be able to apply information technologies in solving technical problems;
- to be able to work with specialised equipment;
- to understand, analyse and correct the engineering specifications for technological processes;
- to be able to read professional literature in Russian and in foreign languages (English or German).

EXAMPLES OF MODULE DESCRIPTION

Below few examples of module description are given. Each module learning outcome values one ECTS credit if another not indicated. Related programme learning outcome is shown in parentheses.

Example 1:
DATA-DRIVEN DESIGN

Department:	*Nuclear and Thermal Power Plants*
Code:	*M1.B 1.2*
Level:	*5 (MSc)*
Credits:	*3 ECTS*
Pre-requisites:	*M2.Б1, M2.Б2*
Developers:	*Leonid A. Belyaev, Alexander S. Matveev*
Lecturers:	*Leonid A. Belyaev*

Learning outcomes:

M1 (P1): to have knowledge and full understanding of system engineering principles, modern information 6D design systems for upgrading, optimisation and alignment of Thermal and Nuclear Power Plants projects; knowledge and understanding of the Project 6D information model for Nuclear Power Plant Unit Design (information about engineering solutions and calculations, 3D nuclear unit design, configurations, delivery lead time, resources, terms and technologies of construction), methods of comprehensive information project management; information infrastructure, integrated financial and economical unit model at all stages of its life (construction, operation, maintenance, decommissioning).

M2 (P5): to be able to simulate business processes to calculate integrated economy of construction, operation and nuclear unit maintenance; to analyse management decisions concerning nuclear unit construction performed in 6D.

M3 (P5): to be able to prepare engineering documentation for nuclear unit (3D), scheduling and planning during design and construction of a nuclear unit (4D), configuration, supply and delivery lead time necessary for a nuclear unit construction (5D), financial and other resources, equipment necessary for a nuclear unit design and construction (6D).

Brief Description:

Purposes of data-driven design. Optimization building of heat power plant and nuclear power plant. Optimisation control of engineering activity under designing, purchases, delivers, building. Possibilities of building's duration reduction, financial expenses and safety extension, building's mobility.

Types of learning activity

Lectures:	*16/32 hrs. (class/self)*
Laboratory work:	*16/48 hrs. (class/self)*
Class hours:	*32 hrs.*
Self-learning:	*80 hrs.*
Total:	*112 hrs.*
Assessment:	*Exam*

Principles of systems engineering and technology of integrated control by life cycle of power units. Activity planning under designing and building of heat power plant and nuclear power plant. Designing processes, stages, tools. Using of 6D-technology.
Communication model of 6B design of power units (information about engineering solutions and calculations, about 3D-design of power unit, about about configuration, materials' and facilities' term supply, about resources, terms and building's technology). Creation of information infrastructure, providing for using of information model under control of designing processes and power units' building.
Ecological monitoring under heat power plant and nuclear power plant building. Heat power plant is as anthropogenic part of landscape, exerting influence upon ecosystem. State ecological assessment. Canvassing. Safety principles of heat power plant and nuclear power plant under the choosing the area and construction site. Selection criterions. Control of landscape modification under heat power plant's and nuclear power plant's building, influence of power plants upon substance flows in natural complexes, migration's and emissions of radionuclides fallout features.
Problems of Nuclear Plants decommissioning and areas de-contamination and re-cultivation. Modern managing principles of 6D projects (goal-oriented approach and Kaizen (continuous improvement)). Critical plan issues. Cost reduction techniques and minimising construction time by means of 6D technologies. Installation process visualisation, assignment of day, week and month plans to contractors. Pre-installation equipment layout. Zonal (ad-hoc) installation during construction stage. Machine workshop installation route. Storage costs reduction. Project limitations during design, reduction of construction contractors. Automation of installation processes.

Textbooks:

1. ISO/IEC 15288: 2005 (2008). Processes of systems life cycles. System Engineering. Information technology
2. Advanced Light Water Reactor Utility Requirements Document, URD, Prepared For Electric Power Research Institute Palo Alto, California.
3. «Cost Management», Department of Energy USA (DOE). Managing administrative issues, budget and assessment.
4. IAEA-TECDOC-1335, Configuration management in nuclear power plants, VIENNA, 2003.
5. IAEA-TECDOC-1651, Information Technology for Nuclear Power Plant Configuration Management, Vienna, 2010.
6. Safety Reports Series No. 65, Application of Configuration Management in Nuclear Power Plants, IAEA, Vienna, 2010.
7. "Enhanced nuclear technologies: Recommendations for information transfer concerning new Nuclear Plants", EPRI, Palo-Alto, California: 2009, 1019221.
8. ISO/IEC 42010:2007 Systems and software engineering – Recommended practice for architectural description of software-intensive systems
9. Elizabeth Hull, Ken Jackson, Jeremy Dick "Requirements Engineering" 2nd Edition
10. ISO IEC 29148 «Requirements Management».
11. PDTR 24748:2007 Systems and software engineering Life cycle management, Guide for life cycle management.
12. ISO/IEC TR 24774:2007 Software and systems engineering – Life cycle management – Guidelines for process description
13. ISO/IEC TR 19760:2003 Systems engineering – A guide for the application of ISO/IEC 15288 (System life cycle processes).
14. The Method Framework for Engineering System Architectures (MFESA). Software Engineering Institute Carnegie Mellon University Pittsburgh, PA 15213, Donald Firesmith 5 March 2009.
15. V.V. Yemelyanenko, A.P. Zhukavin, V.V. Imenin, A.Ye. Kroshilin, V.Ye. Kroshilin, A.O. Kovalevich, V.N. Maidanik, A.A. Prosvirin, Ye.F. Seleznev, R.G. Sychev, I.V. Fedorov, R.L. Fuks. "Experience of complex mathematical modeling for the analysis of nonsteady NPP operation modes", 3rd Edition, 2005.

Example 2

ENERGY AND RESOURCE SAVING IN HEAT POWER ENGINEERING AND HEAT TECHNOLOGY

Department:	*Nuclear and Thermal Power Plants*
Code:	*M2.B 2*
Level:	*5 (MSc)*
Credits:	*3 ECTS*
Pre-requisites:	*M2.Б1*
Developers:	*Valeriy V. Litvak, Alexandra M. Antonova, Alexander S. Matveev*
Lecturers:	*Valeriy V. Litvak*

Learning outcomes:
M1 (P1): to have knowledge of electrical and heat power production process, regulations of thermal and mechanical equipment, machinery, thermal grids, buildings and facilities
M2 (P2): to be able to check the operability and energy efficiency of basic thermal and mechanical equipment; to develop fuel and energy balance sheets.
M3 (P3): to be able to develop diagrams of power units, selecting their parameters, features of pipeline network, typical means of energy efficiency increase; to work with industrial and education software

Brief Description:
Main trends of energy policy of the Russian Federation; place of energy efficiency in Russia's Energy Strategy up to 2030; basic terms and definitions.
Legal and regulatory basis of energy-saving. Legislation about energy saving. The Federal Law of the RF No. 261. Industrial and territorial rules, norms, standards and regulations.
Basics of contractual relations between consumers and power-supplying organisations. Specifications for connection of consumers' power units. Conditions and modes of power consumption for electrical and heat power. State Technical Supervision Authority for power plants. Legal and regulatory basis for energy saving at the federal, regional and municipal levels.
Fuel and Energy balance. Preparing a fuel and energy balance sheet. Analytic balance and synthetic balance. Energy balance sheet for a power plant, power station and region. Method of energy balance.

Types of learning activity	
Lectures:	*8/32 hrs. (class/self)*
Laboratory work:	*24/48 hrs. (class/self)*
Class hours:	*32 hrs.*
Self-learning:	*80 hrs.*
Total:	*112 hrs.*
Assessment:	*Exam*

Energy saving potential
Standardisation of energy resources consumption. Prediction of fuel and energy consumption.
Measurement of electric power, heat power, gas, solid fuels, petroleum products, other energy resources. Metrology and measurement errors.
Inspection of effective power plants and grids. Methods and program of energy inspection. Analysis of operation modes of heat engineering equipment. Heat input for heating. Heat balance. Instruments for energy inspection. Energy passport of a plant, enterprise.
Program of costs control and energy saving. Organisation, technical, technological and investment actions on energy saving. Selection of priority measures. Calculations of specific consumption of fuel and energy, fuel reserves and losses in electrical and heat grids.
Basis of relationships between power producers and consumers. Reformation of power industry of Russia. Generating, network, sales and maintenance companies. Monopoly and competition in power industry. Competitive efficiency of power production. Wholesale and consumer power markets.
Technical and economic analysis of energy saving projects. Economic efficiency performance. Cost of project, internal rate of return, profitability index and payback period. Projects of organisational, processing and investment improvement of power enterprise. Investing in energy efficiency. Energy saving stimulation.
Main trends of electrical and heat power production efficiency increasing. Gas and steam turbine complexes. Joint production of electrical and heat power. Energy saving in auxiliary systems. Energy saving in heat systems. Industrial boiler, pump systems and units. Compressor facility. Power supply and electricity use in lighting, processing systems (welding, galvanics). Mechanical treatment of materials. Construction technologies and materials.
Energy consumption management. Technical and economic planning of energy saving measures. Markets and tariffs for energy resources.

Textbooks:

1. Litvak V.V. Energy saving in heat engineering industry. Tomsk, Izd-vo STT, 2011, 184 p. (Litvak V.V. Energosberezhenie v teploenergetike. – Tomsk, Izd-vo STT, 2011, 184 p.)

2. Litvak V.V. Basics of Regional Energy Saving. – Tomsk, Izd. NTL, 2002, 300 p. (Litvak V.V. Osnovy regionalnogo energosberezheniya. – Tomsk, Izd. NTL, 2002, 300 p.)

3. Varnavskiy B.P., Kolesnikov A.I., Fedorov M.N. Energy audit of industrial and utility enterprises. Textbook, – Moscow, Izd. GEN, 1999, 214 p. (Varnavskiy B.P., Kolesnikov A.I., Fedorov M.N. Energoaudit promyshlennykh i kommunalnykh predpriyatij. Uchebnoe posobie, – Moskva, Izd. GEN, 1999, 214 p.)

4. Handbook for Energy Saving Experts. Issue 1, Legal basis –Krasnoyarsk, Izd. KrasGEN, 2000, 290 p. (Spravochnik dlya ekspertov po energosberezheniyu. Vyp. 1, Normativnaya baza – Krasnoyarsk, Izd. KrasGEN, 2000, 290 p.)

5. Klimova G.N., Litvak V.V., Markman G.Z., Kharlov N.N. Energy saving and electrical power quality. – Tomsk, Izd. TPU, 2006, 168 p. (Klimova G.N., Litvak V.V., Markman G.Z., Kharlov N.N. Energosberezhenie i kachestvo elektricheskoj energii. Tomsk, Izd. TPU, 2006, 168 p.)

Example 3

MODULE MASTER THESIS

Department:	*Nuclear and Thermal Power Plants*
Code:	*M4*
Level:	*5 (master studies)*
Credits:	*24 ECTS*
Pre-requisites:	*M1.Б, M1.B, M2.B, M2.B 5.1-5, M3*
Author:	*Alexandra M. Antonova, Alexander S. Matveev*

Learning outcomes:
M1 (P6, 3 ECTS): to be able to analyse the current state of nuclear power and traditional thermal power equipment and to evaluate its cost efficiency and safety;
M2 (P2): to be able to solve engineering tasks, to integrate knowledge from different fields of study, to make decisions in complex engineering tasks involving high degree of uncertainty and lack of information;
M3 (P3, 5 ECTS): to be able to use applied software and information resources for TPP and NPP design, to maintain and use equipment in accordance with technical standards, norms and regulations;
M4 (P5, 3 ECTS): to have skills in modelling and designing TPP and NPP processes and objects, to use and work out technical documentation;
M5 (P9, 3 ECTS): to have understanding of social, ecological, ethic, economic impact of TPP and NPP, to have awareness in accident forecasting and sustainable development issues;
M6 (P10, 2 ECTS): to be able to acquire new knowledge and to be engaged in independent life-long learning in thermal power engineering;
M7 (P4, 3 ECTS): to be able to choose appropriate research methods, standard and specific software packages for conducting experiments, interpreting the data and drawing conclusions;
M8 (P7, 3 ECTS): to be able to communicate effectively; to have knowledge of professional terminology and skills of using literature and presenting information;
M9 (P8): to be able to work individually and as a member and/or leader of a team and to be responsible for outcomes.

Types of learning activity	
Self-learning:	*540 hrs.*
Total:	*540 hrs.*
Assessment:	*Public Defense*

Brief Description:
The Master Thesis is the basic means of graduate's assessment. The paper is the result of an independent and logically sound study, which is based on solving a specific design problem and fosters the understanding, experience, knowledge and skills necessary for engineering design.
Topics for theses in engineering design include modernisation, reverse engineering, enhancement of safety standards in analogues, prototypes of the Russian and foreign TPP and NPP power units as well as innovative projects. The projects cover wide range of issues concerned with social, ecological, economical aspects and limitations as well as problems of safe operation. While designing potentially hazardous components of TPP and NPP equipment and systems the greatest focus is given to their safety during the entire life of the object, i.e. failure prediction, assessment of safety systems efficiency and radiation level.
The main part of the thesis is performed in the following sequence: analysis of innovations, design problem setting, search for innovative options, engineering calculations, equipment layout, process design, organisational design, ergonomic design, technical and economic evaluation of engineering solutions, prediction of the effect from the implementation of a given solution, project evaluation and analysis.
The thesis is presented as a manuscript with corresponding illustrations and references. The requirements in relation to the content, volume and structure of the Master's Thesis are set by the current Statement on the Final Engineering Certification of TPU graduates and the Federal State Educational Standard for "Thermal Power Engineering".
The thesis is defended by the graduate during the meeting of the State Board for Certification headed by the leading representative of the industry. Members of the Board are selected from a number of potential employers and prominent academics of the University.

Textbooks:

1. Regulations of Thermal Electric Stations Design, SP TES-2007. – Moscow, 2007.
2. STO (Standards of Technical Operation) 70238424.27.100.009-2008. THERMAL ELECTRIC STATIONS. Conditions of Construction. Norms and Requirements. – Moscow, 2009.
3. Fundamentals of Modern Power Engineering / Edited by Ye. V. Ametistov. – Moscow: MEI Publishers, 2007 – 368 p.
4. Thermal Power Engineering Journal (Teploenergetika).
5. Gas Turbine Technologies Journal (Gazotutbinniye tekhnologii).
6. Electric Power Stations Journal (Elektricheskiye stantsii).
7. Thermal and Nuclear Power Plants. Handbook / Edited by A.M. Klimenko, V.M. Zorin. – Moscow: MEI Publishers, 2003 – 648 p.
8. Tsanev S.V., Gas Turbine and Steam-Gas Units of Thermal Power Plants: Textbook / S.V. Tsanev, V.D. Burov, A.N. Remezov. – Moscow: MEI Publishers, 2002. – 580 p, illustrated.
9. Tevlin S.A. Nuclear Power Plants with WWER-1000 Reactors, 2002.
10. Sterman L.S., Lavygin V.M., Tishin S.G. Thermal and Nuclear Power Plants. 2004.

Appendix 3 – Glossary

This Glossary includes terms focussed on higher education and the design and accreditation of study programmes in engineering. It is well known that English words being translated into other languages often have different meanings in different national contexts. We hope that this glossary will help in explaining some words used. Most of terms are adopted from the TREE project publication[101].

Ability (see also *Capability*)
• *Ability, Capability, Capacity*, and *potential* all mean "power to do something".
• *Ability* often implies skill (mathematical ability). *Capability* implies the possession of the required qualities, (the capability of a good engineer to design energy-efficient solutions). *Capacity* suggests the power to receive or absorb (a capacity for learning languages). *Potential* applies to an inherent but untried power (a person with leadership potential).

Accreditation
• *Accreditation* may refer to study programmes and/or Institutions and is sometimes used as a synonym for recognition of prior and experiential learning.
• *Accreditation body*
An independent body that develops educational standards, criteria and procedures and conducts expert visits and peer reviews to assess whether or not those criteria are met.
• *Accreditation of programmes* (see also *Quality Assurance*)
The process by which a qualification, a course or a programme comes to be accepted by an external body as of a satisfactory quality and standard. Accreditation involves a periodic audit against published standards of the engineering education provided by a particular course or programme. It is essentially a peer review process, undertaken by appropriately qualified and independent panels.
• *Accreditation of institutions*
Accreditation is a formal, published statement endorsing the quality of an educational institution, based on external assessment.

Assessment
It is an evaluation process that may apply to programmes, institutions or students.
• *With regards to students,* it is the total range of written, oral and practical tests, as well as projects and portfolios, used to decide on their progress in the Course Unit or Module. These measures may be mainly used by the students to assess their own progress (formative assessment) or by the University to judge whether the course unit or module has been completed satisfactorily against the learning outcomes of the unit or module (summative assessment).
• *With regards to institutions and programmes*, it is the process of systematic gathering, quantifying and using information to judge the effectiveness and adequacy of a higher education institution or a programme. It implies evaluation of core activities. It is a necessary basis for a formal accreditation decision.

Attitude
The way a person regards something or tends to behave towards it, often in an evaluative way. Someone's attitude to something is the way they think and feel about it, especially when this shows in the way they behave.

Attribute(s)
- Specific skills to demonstrate competences.
- A quality or feature that someone or something has.

Capability (see *Ability*)

Certificate (see also *Diploma*)
A document stating that a student has earned a qualification from an educational institution, at a particular level. It may refer to any qualification or award, but in some countries it characterises specific awards or titles.

Competence
Proven ability to use *knowledge, skills* and personal, social and/or methodological *abilities*, in work or study situations and in professional and/or personal development. In the European Qualifications Framework for

101) Günter Heitmann, Valeria Bricola. Glossary of Terms Relevant to Higher Education (Engineering). Available from: http://www.unifi.it/tree/dl/oc/a6.pdf

lifelong learning, competence is described in terms of responsibility and autonomy.

Corequisites (see also *Prerequisites*)
Any conditions or specific courses that must be fulfilled simultaneously (or prior) with another programme or part of a programme.

Course
It may refer to a complete study programme or to a single component (such as *Unit* or *Module*) of a study programme.

Credit (see also *ECTS*)
The "currency" used to measure student *workload* in terms of the *notional learning time* required to achieve specified *learning outcomes*. To each course unit a certain number of credits are assigned. A credit system facilitates the measurement and comparison of learning outcomes achieved in the context of different qualifications, programmes of study and learning environments.

Credit accumulation
In a credit accumulation system *learning outcomes* totalling a specified number of credits must be achieved in order to successfully complete a term, an academic year or a full *study programme*. Credits are awarded and accumulated if the achievement of the required *learning outcomes* is proved by *assessment*.

Credit transfer
The acceptance of credits obtained for a certain purpose, as credits towards another purpose or in another institution.

Curriculum (see also *Study Programme*)
A comprehensive description of a *study programme*. It includes learning *objectives* or intended *outcomes*, contents and assessments procedures.

Degree (see also *Credit accumulation system*)
Qualification awarded to an individual by a recognised higher education institution after the successful completion of a *study programme*.

Degree Programme (see under *Study Programme*)

Diploma (see also *Certificate*)
A *qualification* from an educational institution, at a particular level. It may refer to any qualification or award, but in some countries it characterises specific awards or titles (e.g. Dipl.-Ing., Ingénieur Diplômé, etc.).

Diploma Supplement
It is an annex to the official *qualification* document awarded by the *higher education institution*. It is designed to provide more detailed information on the studies completed according to an agreed format (drawn up by the European Commission, the Council of Europe and UNESCO/CEPES) which is internationally recognised. It provides a description of the nature, level, context, content and status of the studies that were pursued and successfully completed by the holder of the qualification. It aims at improving the international transparency and the *academic/professional recognition* of *qualifications*.

Discipline (also might be referred to as Field of study, Branch of study, *Subject*)
A *particular* area of study, especially a subject of study in a college or university (formal use).

Dissertation
A long, formal piece of writing on a particular subject, especially for a university degree.

ECTS (see also *Credit*)
Acronym for European Credit Transfer System, originally developed by the European Commission in order to increase the transparency of educational systems and facilitate the mobility of students across Europe through credit transfer from one higher education institution to another. It is based on the general assumption that the global workload of an academic year of study is equal to 60 ECTS credits.

ECTS Grading System
Whereas ECTS credits are allocated to successful students only, ECTS grades are awarded to all students. Those who have passed are rated into five sub-groups: the best 10%, receiving the additional grade "A" next to the national grade, the next 25% a "B", the following 30% a "C", the next 25% a "D" and the final 10% a "E"-grade respectively

Education (see also *Training*)
The act, process or art of imparting *knowledge*, understanding, *skills* and *attitudes* normally given by formal education providers like schools, colleges, universities, or other educational institutes. Education may be general or related to specific disciplines (e.g. Engineering education).

Higher Education
All types of study *programmes* at the post-secondary level which are recognised by the competent authorities as belonging to its higher education system.

Higher Education Institution
An establishment providing higher education.
Higher Education Programme (see *Study Programme*)

Employability
It is a set of achievements – *skills*, understandings and personal *attributes* – that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy.

Engineer (see also *Recognition*)
A person qualified by education, training and/or experience to practice the art and science of engineering. The qualifications leading to the title of "engineer", "professional engineer", etc., vary considerably from country to country.

Engineering graduate
A person who has successfully completed a degree programme in a recognised engineering discipline.

European Higher Education Area (EHEA)
Its establishment is the overarching aim of the Bologna Process, based on a common reference structure. The comparability of European higher education degrees world-wide is facilitated by the development of a common framework of qualifications, as well as by coherent quality assurance and accreditation/certification mechanisms and by increased information efforts.

European Qualifications Framework (EQF) (see also *Framework for Qualifications*)
It is an overarching framework which aims to make the relationships between European national (and/or sectoral) educational frameworks of qualifications and the qualifications they contain transparent. At present, two European qualifications frameworks exist. One focuses on Higher Education and has been initiated as part of the Bologna process (*Framework for Qualifications of the European Higher Education Area*), the other focuses on the whole span of education and has been initiated by the European Commission (*European Qualifications Framework for Lifelong Learning*).

Field of study
The main subject area of a *study programme* (e.g. Engineering).

Framework for Qualifications of the European Higher Education Area (see also *European Qualifications Framework*)
It defines four levels of qualifications based on the Bologna process: a sub-degree level within the first cycle, the first cycle degree, the second cycle degree and the third cycle degree.

Framework for Qualifications of Lifelong Learning (see also *European Qualifications Framework*)
It defines eight levels of qualifications, based on common descriptors (that is, *knowledge*, *skills* and *competences*) and the corresponding *levels* of *learning outcomes* achieved.

Grade (see also *ECTS Grading System*)
An evaluation in the form of a letter or number given to a student after an examination, test, paper or project, at the completion of a course unit in order to indicate the level of proficiency demonstrated by that student. The Grade is normally based on letters, while in some countries it may be based on numbers.

Knowledge
The outcome of the assimilation of information through learning. *Knowledge* is the body of facts, principles, theories and practices that is related to a field of study, work or everyday life. In the *European Qualifications Framework*, knowledge is described as theoretical and/or factual.

Laboratory
In the educational context, it refers to a practical experimental class where the students are active and supervised by a staff member and/or assistants.

Learning
The process whereby individuals acquire *knowledge*, *skills* and *attitudes* through experience, reflection, study, education and/or instruction.

Learning agreement
Document originally required for the mobility of Erasmus students. It is agreed between the three parties involved (home Institute, hosting Institute and student) and specifies the task assigned to the student for his/her study period abroad. It contains the list of *course units* or *modules* which the student plans to take. For each *course unit/module* the title, the code number and the *ECTS credits* are indicated. In some countries the term refers to the agreement signed between a student and the higher education institution setting out each party's expectations and responsibilities.

Lifelong Learning
All learning activities undertaken throughout life, with the aim of improving *knowledge*, *skills* and *competences*.

Learning Outcomes
Statements of what a learner knows, understands and is able to do *on completion of a learning process*. They usually are defined in terms of *knowledge*, *skills* and/or *competences*. For assessment purposes they may be specified by learning outcomes indicators. The learning outcomes are associated with a study programme (programme learning outcomes) or with a module (module learning outcomes) depending on the time when they are expected to be achieved by students and when assessment is performed.

Level
A threshold standard of achievement within a hierarchy of levels, e.g. within a qualifications framework.

Level descriptors (see also *Descriptors*)
Specifications of generic standards or intended *learning outcomes* with regard to a certain level in a qualifications framework or a multi-tier educational system.

Module
A coherent part of a *study programme* with specific *learning outcomes* and a pre-determined number of credits. In some countries it is identified with a course *unit*, in others with a group of course *units*.

N**otional Learning Time**
The number of hours the designer of the course unit assumes an average student will take to achieve specified *learning outcomes* and gain *credits*.

Prerequisites (see also *Corequisites*)
Any prior conditions or specific courses that must be fulfilled before access to another programme or part of a programme.

Profession
An activity, access to which, the practice of which, or one of the modes of pursuit is subject, directly or indirectly, to legislative, regulatory or administrative provisions concerning possession of specific *higher education* (and possibly *training*) requirements.

Profile
Set of aims and attributes which illustrate the specific character of *a qualification, study programme or higher education institution.*

Programme (Learning) Objectives
The specific *knowledge*, *skills* and/or *competences* which graduates of a *study programme* are expected to possess after some time after graduation. Some of objectives are expected to be achieved by all graduates and others just by some of the graduates.

Qualification
A generic term that usually refers to an award granted for the successful completion of a *study programme*. It is the formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved predetermined learning outcomes to given standards.

National Qualifications Framework
An instrument for the classification of *qualifications* according to a set of criteria for specified *levels* of learning achieved. It aims to integrate and coordinate national qualifications sub-systems and improve the transparency, access, progression and quality of qualifications in relation to the labour market and civil society.

Recognition
The provision by which a body or institution (the recogniser) considers another body or institution (the recognised) appropriate or competent for a certain purpose.
• *Academic Recognition*
A formal acknowledgement, by a competent authority or a *higher education institution*, of the academic *qualifications* as indication of the capabilities obtained in a *study programme* or part of it. It may refer to an individual or be included in a recognition agreement between education institutions or authorities. Usually this is sought as a basis for access to further studies (cumulative recognition) or as a recognition allowing some exemptions in a programme offered by the host institution (recognition by substitution, such as in ECTS).
• *Competent Recognition Authority*
A body officially charged with making binding decisions on the recognition of qualifications.

Professional Recognition
It can be distinguished between De facto Professional Recognition and De jure
• *Professional Recognition* (see below).
• *De facto Professional Recognition*
It refers to situations where the profession is not regulated. In that case, after the completion of a *study programme*, students are recognised as engineers on the basis of their academic degree.
• *De jure Professional Recognition*
A formal acknowledgement by a competent authority of the *professional qualifications* and/or *capabilities* of individual applicants to practice their profession at a specified level of responsibility. It refers to the right to practice and the professional status accorded to a holder of a qualification.

Quality Assurance
The structure and/or the processes by which an institution maintains the quality of its provision by planned and systematic actions.
It is an umbrella term for several instruments which are concerned with the monitoring and development of quality. These instruments include evaluation, accreditation, benchmarking and quality management tools.

Skills
The *ability* to apply knowledge and to use know-how to complete tasks and solve problems. In the *European Qualifications Framework*, skills are described as cognitive (use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments).
• *Transferable skills*
Skills which can be used in different work and learning environments; in other words, which can be transferred from one situation to the next (e.g. communication skills, report writing, etc.).

Specialty (see also *Branch* and *Field of Study*)
A specified area or part of a branch or a field of study. E.g. Electromagnetic Waves is a *specialty* of the field Electrical Engineering.

Study Programme
A course of study recognised by the competent authority of a State as belonging to its *higher education system*, and the completion of which provides the student with a higher education *qualification*. It has a set of *learning outcomes* and is composed of compulsory and optional *course units* or *modules* which lead to the achievement of a pre-determined set of *learning outcomes*.

Subject
A taught *course*, sometimes used instead of *course unit*.

Syllabus (see also *Curriculum*)
List of topics (content) of a *course unit*. In the USA it is also used for the content of a Study

Term
A part of an academic year (usually a third)

Training (see also *Education*)
Systematic instruction and programmes of activities and learning for the purpose of acquiring *skills* for particular jobs.

Transcript
The official record or breakdown of a student's progress and achievements. Many modular credit based education systems employ detailed transcripts that show the *grades* for the course *units* undertaken.

Understanding
The *capacity* for rational thought or inference or discrimination.

University
An autonomous *higher education institution* – traditionally comprising different disciplines and executing research activities - which offers education at degree level. Courses may be taken at bachelor, master or doctorate level (first, second, third cycle).

Workload
A quantitative measure in real hours of all learning activities, which may feasibly be required for the achievement of the *learning outcomes* (e.g. lectures, seminars, practical work, private study, information retrieval, research, examinations). The student workload of a full-time *study programme* in Europe based on 60 ECTS credits yearly is supposed to consist on average of 1500 to 1800 hours workload per year.

Appendix 4 – List of Acronyms

ABET: was incorporated as Accreditation Board for Engineering and Technology* (USA)

*) In 2005, ABET formally changed its name to ABET and no longer uses the title "Accreditation Board for Engineering and Technology"

AEER: Association for Engineering Education of Russia

ARACIS: Agenția Română de Asigurare a Calității în Învățământul Superior, Romanian Agency for Quality Assurance in Higher Education (Romania)

ASCE: American Society of Civil Engineers

ASEE: American Society of Engineering Education

ASIIN: Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik, Accreditation Agency for Study Programs in Engineering, Informatics, Natural Sciences and Mathematics (Germany)

BMSTU: Bauman Moscow State Technical University (Russia)

CDIO: Conceive, Design, Implement and Operate (Worldwide Initiative)

CEAB: Canadian Engineering Accreditation Board (Canada)

CHEA: Council of Higher Education Accreditation (USA)

CTI: Commission des Titres d'Ingénieurs (France)

E4: Enhancing Engineering Education in Europe (Thematic Network)

EAFS: EUR-ACE Framework Standards

EC-UK: Engineering Council - United Kingdom

ECDEAST: Engineering Curricula Design aligned with EQF and EUR-ACE Standards (TEMPUS Project)

ECTS: European Credit Transfer and Accumulation System

EFMD: The Management Development Network (former name European Foundation for Management Development)

EHEA: European Higher Education Area

ENAEE: European Network for the Accreditation of Engineering Education

ENQA: European Network of Quality Assurance

EQANIE: European Quality Assurance Network for Informatics Education

EQF – EHEA: European Qualifications Framework for the European Higher Education Area

EQF-LLL: European Qualifications Framework for Lifelong Learning

EQUIS: EFMD Quality Improvement System

ESG: European Standards and Guidelines for Quality Assurance in Higher Education

EUA: European University Association

EUCEET: European Civil Engineering Education and Training (Thematic Network and Association)

EUGENE: EUropean and Global ENgineering Education (Academic Network)

EUR-ACE – EUR-ACE®: is the European quality label for engineering degree; EURopean Accredited Engineer

FCD: First Cycle Degree

FEANI: Fédération Européenne d'Associations Nationales d'Ingénieurs, European Federation of National Engineering Associations

FES: Federal Educational Standards (Russian Federation)

HEI: Higher Education Institution

HSW: Hochschule Wismar (Germany)

ICT: Information and Communication Technology

IEA: International Engineering Alliance

IPD: Initial Professional Development

ISO: International Organization for Standardization

KAUT: Komisja Akredytacyjna Uczelni Technicznych, Accreditation Commission for Engineering Programmes (Poland)

KTH: Kungliga Tekniska Högskolan (Royal Institute of Technology, Sweden)

KTU: Kauno technologijos universitetas (Kaunas University of Technology, Lithuania)

LBUS: Lucian Blaga University of Sibiu (Romania)

LiU: Linköping University (Sweden)

LO: Learning Outcome(s)

LTSN: Learning and Teaching Support Network (UK)

MIT: Massachusetts Institute of Technology (USA)

MLO: Module Learning Outcome(s)

MOOC: Massive Open On-line Course(s)

MÜDEK: Association for Evaluation and Accreditation of Engineering Programs (Turkey)

NPP: Nuclear Power Plant

NQF: National Qualifications Framework

OAQ: Organe d´accréditation et d´assurance qualité des hautes écoles suisses (Swiss Center of Accreditation and Quality Assurance in Higher Education, Switzerland)

OBTL: Outcome Based Teaching and Learning

ODL: Open and Distance Learning

OE: Ordem dos Engenheiros (Portugal)

PBL: Problem Based Learning

PE: Professional Engineer

PEO: Programme Educational Objective(s)

PLO: Programme Learning Outcome(s)

QAA: Quality Assurance Agency for Higher Education (UK)

QF-EHEA: Framework for Qualifications of the European Higher Education Area

QUACING: Agenzia per la Certificazione di Qualità e l'Accreditamento EUR-ACE dei Corsi di Studio in Ingegneria (Italy)

SCD: Second Cycle Degree

SEFI: Société Européenne pour la Formation des Ingénieurs, European Society for Engineering Education

SME: Small and Medium size Enterprises

SPbSPU: Saint-Petersburg State Polytechnical University (Russia)

SSC: Subject Specific Criteria

STEM: Science, Technology, Engineering or Mathematics

TPP: Thermal Power Plant

TPU: Tomsk Polytechnic University (Russia)

TQM: Total Quality Management

UK-SPEC: United Kingdom Standards for Professional Engineering Competence

VET: Vocational Education and Training

WA: Washington Accord

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