GUIDELINES on Engineering Curriculum Design
Aligned with EQF and EUR-ACE Standards

Tomsk, 2013

The Guidelines discuss requirements to learning outcomes at master level used within Bologna process (e.g. in A Framework for Qualifications for the European Higher Education Area and European Qualification Framework), criteria for accreditation of engineering programmes (at master level), and include comparison of the Russian Federal Educational Standards (FES) requirements and EUR-ACE Framework Standards. The second part of the Guidelines describes a methodology for engineering curriculum design and its main steps: defining of programme objectives and learning outcomes and credit allocation for programme/module learning outcomes in accordance with the FES and EUR-ACE Framework standards requirements, assessment of learning outcomes achievement. The examples are given to illustrate methodological recommendations.

The Guidelines are developed within the TEMPUS Project N°511121-TEMPUS-1-2010-1-DE-TEMPUS-JPCR “Engineering Curriculum design aligned with EQF and EUR-ACE Standards” (ECDEAST). The Guidelines are recommended for development of master programmes in engineering and technology.
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The guidelines are developed within the TEMPUS project N°511121-TEMPUS-1-2010-1-DE-TEMPUS-JPCR Engineering Curricula Design aligned with EQF and EUR-ACE Standards. The project is carried out by the consortium of three Russian universities (Tomsk Polytechnic University, Baumann Moscow State Technical University and Saint Petersburg State Polytechnical University) and three European universities (Hochschule Wismar (Germany), Kaunas University of Technology (Lithuania), Lucian Blaga University of Sibiu (Romania)) in cooperation with the Société Européenne pour la Formation d'Ingénieurs (SEFI) and the European Network for Accreditation of Engineering Education (ENAEE). The project objective is to ensure that Russian universities have advanced curricula for programmes in line with new developments in the chosen engineering areas, the Bologna Process (EQF) and European standards for quality assurance of engineering education (EUR-ACE Framework standards).

The project objectives are:

- To develop a methodology for engineering curriculum design based on the alignment of EQF & EUR-ACE Standards with Federal educational standards requirements to structure of programmes and graduates' competencies;
- To train the Russian universities' faculty to develop engineering curricula according to EUR-ACE requirements with using of ECTS;
- To develop/update and implement three master engineering programmes and course modules materials at TPU, BMSTU and SPbSPU in accordance with the EUR-ACE requirements using the ECTS and Dublin Descriptors;
- To prepare the new programmes for accreditation with awarding of the EUR-ACE label.

The Guidelines are the result of alignment of the requirements of European quality assurance systems of higher education (Dublin descriptors, EQF, EUR-ACE Standards) and Federal Educational Standards for Higher Education of the Russian Federation (FES), studies and analysis of experience of the European partners in use of ECTS and the outcomes-based approach to engineering curriculum design for SCD programmes. The Guidelines were reviewed and updated with consideration of the comments and recommendations given by the experts as well as the faculty members during approbation of the methodology in development, implementation and external evaluation of new programmes in Russian HEIs.
The Guidelines contain description of requirements to learning outcomes at master level within Bologna process (e.g. in A Framework for Qualifications for the European Higher Education Area and European Qualification Framework), criteria for accreditation of engineering programmes (at master level) and also comparison of the Russian Federal Educational Standard requirements and EUR-ACE Framework Standards. The second part of the Guidelines describes a methodology for engineering curriculum design and its main steps: planning of programme objectives and learning outcomes and credit allocation for programme/module learning outcomes in accordance with the FES and EUR-ACE Framework standards requirements. The examples are given to illustrate methodological recommendations.

The first version of the Guidelines has been published in spring of 2011 while preparing the faculty training workshops. The current (second and final) version is a revised and extended publication of the Guidelines which includes curriculum, programme educational objectives, programme learning outcomes, and other examples corresponding to those of one study programme developed within the project. Besides of these illustrative materials and editorials it includes also the table of Acronyms and the Glossary of terms related to curriculum design and accreditation of engineering programmes.

Finalizing the Foreword the authors would like to thank those who contributed to the project and without whose advices and discussions with whom we could ever succeed in achievement of project objectives. We are thankful to Profs. Urbano Dominguez Garrido (University of Valladolid), Erik de Graaff (Aalborg University), Iacint Manoliu (Technical University of Civil Engineering of Bucharest), Giuliano Augusti (ENAEE) and Pranas Žiliukas (Kaunas University of Technology) for their fruitful involvement to the project at its different stages and contribution to the topics of the Guidelines. The special thanks to faculties of all three Russian universities to whom these Guidelines were addressed to, who were asked to work with them, and who were first their testers and critics.
INTRODUCTION

Outcomes-based approach to development and implementation of master programmes within two-tier system is a topical issue for both Russian and European universities. Creation of the European higher education area (as the main output of the Bologna process) and common European quality assurance system are the responses for the challenges of the globalization of the economics and internalization and commercialization of higher education. Engineering profession is influenced by the economic, industrial, political and other trends of the modern world development and thus, it is in need of highly-qualified specialists adequate to the requirements of the modern economy. The priorities for the Russian education are improvement of quality and global competitiveness of engineering education, ensuring the correspondence of national programmes in engineering and technology to the international quality assurance standards in engineering education. Correspondence with the international quality assurance standards will certainly contribute to integration of the Russian Federation into international community and to promotion of the Russian system of higher education abroad as well as foster the mobility of students and graduates of engineering programmes. Thus, the experience of the European universities in development and implementation of master programmes is highly important for Russian universities.

Within creation of the European quality assurance system, in particular, in engineering education, the Russian HEIs have to review and renew their programmes in accordance with the international quality assurance standards. The introduction of the third generation of the FES provides Russian HEIs with new opportunities for programme development (mainly master programmes that are being widely introduced in Russia) corresponding to the requirements of both national and European standards.

International recognition of quality of engineering education is implemented through the system of international agreements based on the principle of substantial equivalence in requirements of the national accreditation systems (e.g. ENAEE in Europe). The EUR-ACE Standards define the requirements for the engineering graduates’ competencies for the FCD and SCD programmes. Successful programme accreditation with awarding the EUR-ACE Label means that programme corresponds to the common European quality assurance standards.

The Guidelines contain description of requirements of national and international quality assurance standards in engineering and technology (in particular, the
requirements for graduates’ attributes / programme learning outcomes): comparison of the Russian FES and EUR-ACE Framework Standards requirements and methodology of engineering curriculum design (for SCD programmes) developed by the ECDEAST project partners are presented in the first and second chapters respectively. The methodology proposed in these Guidelines is based on the experience of European countries in implementation of the two-tier system (Bachelor-Master) in engineering education, “European” requirements to SCD graduates’ competencies (Dublin descriptors, EQF, EUR-ACE Standards) and Russian Federal Educational Standards. The examples of programme conception, objectives, learning outcomes and credit allocation for learning outcomes and modules are given to illustrate methodological recommendations.
CHAPTER 1. OUTCOMES-BASED APPROACH AND REQUIREMENTS FOR ENGINEERING PROGRAMMES ACCREDITATION

1.1 Outcomes-based approach in higher education

Traditionally achievements and quality in higher education have been evidenced by in-put and out-put data with regard to students, graduates, staff, facilities, funding, research and services and by referring to tradition, status, reputation, and ranking of universities. 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, accreditation of programmes was based on checking long lists of in-put data with regard to various criteria and requirements.

The performance- and outcomes-based approaches increasingly have influenced the debate and actions on reform and quality assurance in higher education within the global trends of expansion, diversification, internationalization and commercialization of higher education since 1990. The reasons and driving forces shaped the discussions and developments:

- On the system and institutional level of higher education it was mainly the request for efficiency and accountability of spending public funds which shifted the focus to the outcomes achieved. In addition, increasing tuition fees in many countries raised the interests of students in outcomes of their studies and in the promised and received “value for money”. New public governance and institutional management push the orientation on outcomes and respective performance indicators as well.

- On the programme level the public interests in assuring certain quality of education, in the comparability and in the international recognition of degrees, qualifications and achieved competences foster the orientation toward outcomes. This is reflected in the shift from in-put to outcomes in qualifications frameworks, state directives and regulations, subject benchmarks and accreditation standards. They all refer to competencies or abilities which graduates should have achieved at certain degree levels in generic and subject specific terms.

- On the level of teaching and learning – corresponding to new paradigm and to new requirements in quality assurance and improvement – curriculum development, provision of learning arrangements and student assessment are now undergoing significant changes caused by the orientation toward required or intended learning outcomes.
Even independent from the described changes and demands at system, institution and programme level, the outcomes-based teaching and learning (OBTL) can be a strong tool for quality enhancement, in particular when embedded in an approach of “constructive alignment”\(^1\). This concept constitutes a process whereby the stated aims and objectives of a university and certain programmes with correspondingly specified learning outcomes are aligned with the appropriate content teaching and provision of learning arrangements and an adequate assessment of the outcomes achieved. Comparing achieved learning outcomes with the intended ones closes the feedback loop and may result in measures of change and quality enhancement and, thus, brings off a process of continuous quality assurance.

Outcomes based approaches in higher education are meanwhile a common feature on a global scale. A strong driving force for the implementation of outcomes-based higher education in Europe is the so-called the Bologna Process. Europe has started a coordinated activity to establish a common European Higher Education Area (EHEA) by the Bologna Declaration (1999) in order to increase transparency, mobility and mutual recognition and enhance quality and competiveness. The Bologna Process aims to arrive at this target by 10 different action lines and measures, in particular, 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.

The implementation of an additional degree level after 3 to 4 years of study seemed to be the most demanding challenge 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 kind of master degree with a strong research profile. However, in 2011 the majority of the meanwhile 47 signatory countries of the Bologna Process changed their system to a three cycle structure, sometimes enlarged by a sub-degree level within the first cycle after two years of study. Referring to the agreed Bologna structure the European countries forced their universities and other HEIs to a different extent to introduce a first cycle degree (FCD) level. Some countries immediately shifted to this new structure (e.g. Italy), others for some time continued to provide the old system in parallel to the new one (e.g. Germany). But still a number of European countries in engineering education continue to offer their traditional (e.g. France, Sweden) or newly introduced (UK) integrated

\(^1\) Biggs, J. and Tang, C., 2007, Teaching for Quality Learning at University
programmes, often accompanied by very specialized 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 for the labor market and guarantee employability. Globally this first degree after usually 4 years of study is the regular entrance qualification into engineering practice, sometimes connected with additional requirements concerning practical experiences and an exam in order to become a registered or licensed “Professional Engineer” (PE).

Many of the traditional European research universities with long 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.

A recent survey of the European University Association (EUA) on the implementation of master degree programmes demonstrates that various types of offers have been developed and implemented in the context of the Bologna process. It states:

“Master-level provision takes three principal forms. First, 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 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.”

But even within the mentioned three forms the diversity is high and the readability of these degrees beyond the national context is still low even if master level programmes internationally are the most “marketised” ones and contribute increasingly to the expansion of transnational mobility. One reason is that HEIs based on their autonomy 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 Bologna Qualifications Framework descriptors are very generic:

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

But despite the common structure the diversity in Europe increased.
Already in 2003 at the Bologna Follow-up Conference at Berlin it 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 Qualification 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 respective agreements have been achieved resulting 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)”. If not already in existence, the signatory countries of the Bologna Process were addressed to develop and implement national and institutional quality assurance systems and in particular a National Qualifications Framework according to 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

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3 Dito, p. 13
4 Qualifications Frameworks in the EHEA. Available at: http://www.ehea.info/article-details.aspx?ArticleId=65
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.”

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:

- Knowledge and understanding
- Applying knowledge and understanding
- Making judgments
- Communication skills
- Learning skills.

The accordingly defined outcomes are generic and do not address different disciplines, qualification profiles or types of higher education institutions. They therefore need to be complemented and specified by sectoral or subject-related frameworks dealing with different disciplines or professions and serving different purposes. As will be outlined later this has meanwhile taken place 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.

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 or competencies. An additional advantage is that learning outcomes for the five dimensions are defined for different degree levels. Consequently, European sectoral frameworks and related accreditation standards like EUR-ACE specify learning outcomes for the first as well as for the second cycle degrees and even the doctorate. It differs from the approach of the Washington Accord (WA) and its accreditation standards for engineering programmes. In the WA expected learning

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6 Adam, Stephen, 2008, Learning outcomes, current developments in Europe
8 The Washington Accord (WA) is a network of meanwhile national Accreditation Agencies for engineering programmes aiming at mutual recognition of their accreditation decisions. Russia through AEER is currently a member of WA. Together with other Networks and accords the WA forms the International Engineering Alliance (IEA)
outcomes are phrased as “graduate attributes” to be achieved by the first degree, usually a bachelor degree after 4 years of study.

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 following the compulsory education on primary and secondary level.⁹

The EQF-LLL uses the three 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. The EQF applies to all types of education, training and qualifications, from school education to academic, professional and vocational. Like the Bologna Framework for higher education qualifications, this approach shifts the focus from the traditional system that emphasizes 'learning inputs', such as the length of a learning experience, or 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. Only very few countries have done this already, mainly those where NQFs already exist. Taking already existing NQFs with more than 8 levels into account it is not required to adapt these frameworks to the 8 levels of the EQF as long as an appropriate and convincing relation between different levels can be exposed. In some countries a controversial debate between different stakeholders arouse 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 prefer a comprehensive 8 level framework with learning outcomes phrased as competencies.

⁹ European Communities, 2008, European Qualifications Framework for Lifelong Learning (EQF)
This case illustrates the fact that on 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 (CTI) to accredit Grandes Ecoles and their programmes leading to the degree and title of “Ingenieur diplome”, in the Bologna structure recognized as second cycle degree. Germany for the purpose of programme accreditation and curriculum development decided that on the second cycle 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 UK, besides offering 3 years bachelor and 1 to 2 years master programmes provides 4 years integrated programmes directly leading to a “Master of Engineering” (MEng) degree, required as entry qualification into practice and the phase of Initial Professional Development and targeted 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 HEIs, in particular research intensive Universities, based on their autonomy have the interest and right to go beyond 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 advertisement 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 exists with a special mission and a specific range of learning outcomes they are committed to.

1.2 Learning outcomes in European Qualification Frameworks

As mentioned 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 there is a progression from one level to the next with regard to the level of achievement in each dimension. In practice this does not mean that the
holder of a qualification on a higher level has achieved all knowledge, skills and competences of a previous level. However, looking at master level outcomes it should be realized that they usually extend outcomes partly 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 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 formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements;

– can communicate their conclusions, and the knowledge and rationale underpinning these, 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.”

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

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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 noticed that the EQF-LLL already at the bachelor level 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 of 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.”

1.3 National requirements to engineering programme accreditation

Transnational agreed standards like the EUR-ACE ones specified later in these guidelines or the graduate attributes of the Washington Accord usually function only as a reference for national formats and try to ensure substantial equivalence and facilitate mutual recognition for academic and professional purposes. These national formats are results of different traditions and therefore the focus may be different. Nevertheless, accreditation decisions increasingly are based on the proof of achieved outcomes. Briefly three European and the USA examples in the field of engineering education shall be explained.

1.3.1 France

In France in 1934, the French law that created CTI (Commission des Titres d'Ingénieur – Engineering Degree Commission) set up the first, or at least one of the

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first, evaluation and accreditation structures in France and Europe. The 1934 law, which was confirmed in June 2000 in the French Education Code, calls for the external evaluation and accreditation of French engineering schools to be done by CTI. On their request, CTI can also perform the evaluation and accreditation of establishments abroad that grant foreign engineering degrees.

Originally the CTI evaluation is a kind of mandatory institutional accreditation for engineering schools. Accredited HEIs are authorized to award the “Diplôme d’ingénieur” at the end of a usually 5 years course of study. Graduates have the right to use the title of “ingénieur diplômé”. In Bologna terms this is recognized as a second cycle degree, equivalent to a master degree. Meanwhile the focus of the external evaluation by CTI shifted more and more 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 make their own initiatives and innovations: in particular, the Engineering Schools should define their duties and responsibilities themselves, as well as the skills they want to see in the engineers they train. CTI has also brought these guidelines into phase with those given in documents by national, European and international higher education evaluation organisations, in particular, those concerning engineers.”

As a result of the freedom to decide on their specific programmes and respective learning outcomes quite a variety of profiles exists. In general and independent from the engineering disciplines 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 speciality,
- 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."\(^\text{14}\)

In addition, the programmes should provide possibilities for students to have practical experience by at least 28 weeks of internship, all or part of it can be abroad. School collaboration with its stakeholders, primarily applicants, engineering students and the professional world, is required. The main aim of this collaboration is to bring graduate engineers' profiles up to date according to the graduates' professional skills and capacities. In addition to evaluating the capacities, the school has an approach to evaluating engineering students' skills, in cooperation with companies.\(^\text{15}\) CTI also checks that the school has a quality assurance and management system in place evaluating the achievement of intended or required outcomes and supporting continuous improvement.

1.3.2 United Kingdom (UK)

In the UK programme accreditation in engineering is executed by Professional Institutions and therefore embedded in a concept of professional competence achievement based on three elements or phases: education and training in an accredited engineering programme, initial professional development in appropriate engineering practice, finally a professional review leading to registration in one of the Institutions. The membership after this formation process is connected with the right to carry the professional title of either “Chartered Engineer” (CEng) or “Incorporated Engineer” (IEng). Not all of the graduates from engineering programmes apply for


\(^{15}\) Dito, p. 20
these professional titles and undergo the required formation process but instead go for regular employment.

There are no state directives or regulations for engineering programmes. Apart from restrictions caused by funding rules the Universities enjoy a traditionally high degree of autonomy with regard to programme profiles and delivery. As 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 UK-SPEC standards of the Engineering Council UK\(^{16}\) the voluntary accreditation of programmes by the professional Institutions sets the standards for programme development and curriculum design.

Until recently the entry requirement on the route to a “Chartered Engineer” was a Bachelor Honours degree in engineering (BEng Hns.) after 3 to 4 years of study. The United Kingdom Standards for Professional Engineering Competence (UK-SPEC) – developed in 2003 – require a Master of Engineering degree (MEng), normally acquired after an integrated course of study in engineering of 4 years duration. Alternatively an Accredited Bachelor Honours Degree plus an appropriate Master degree or further learning to Master level is accepted. Accordingly the standards have been extended to master level requirements and are based on learning outcomes.

Irrespective of Bachelor or Master level certain General Learning Outcomes should be achieved categorized in 4 dimensions:

- Knowledge and understanding
- Intellectual Abilities
- Practical skills
- General transferable skills
  - In addition a range of 5 Specific Learning Outcomes in engineering has to be achieved, 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

\(^{16}\) Engineering Council (EC) UK an association functioning besides other commitments as a kind of umbrella organization for the Professional Engineering Institutions
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 mentioned Specific Learning Outcomes it requires:

Underpinning science and mathematics, etc.

- A comprehensive understanding of the scientific principles of own specialization and related disciplines;
- An awareness of developing technologies related to 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 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

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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 fulfill 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 stated learning outcomes have to be specified with regard to the various engineering disciplines. This is done by the respective Professional Institutions through their evaluators in the accreditation panels and in many cases supported by respective guidelines or handbooks. Programme providers have the possibility to go beyond these required outcomes or define additional outcomes they aim to achieve. During the accreditation process they have to make evident that at least the required learning outcomes are to be achieved. Typically the educational institution will make a submission in advance of the accreditation panel visit 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

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18 e.g.: Institution of Engineering and Technology, 2006, IET Handbook for Learning Outcomes for BEng and MEng Degree Programmes
Entry to the programme and how cohort entry extremes will be supported.

1.3.3 Germany

With the shift to the three cycle Bologna structure and the implementation of Bachelor and master degree programmes, Germany cancelled all discipline-related and often very detailed input-oriented requirements and recommendations for programmes. In addition, in most of the federal states, the governmental approval of 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 authorized by the Accreditation Council (Akkreditierungsrat) for Higher Education, 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 only very few qualitative requirements besides some generic qualification objectives and profile descriptions. 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 to the German Qualification Framework for Higher Education – adopted in 2005 – are expected. The increase of autonomy of HEIs should contribute to more flexibility in responding to new demands and to the increase of quality. External programme accreditation is aiming to assure academic as well as professional quality and therefore involves stakeholders like employers, unions, professional organizations and students in addition to academia, but no representatives from ministries or government. 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 programme development of the HEIs. They refer to the EQF requirements in the dimensions of knowledge, skills and competences. Master level outcomes are perceived as an extension of those already addressed at bachelor level. As general learning outcomes covering all ASIIN-related disciplines, the following additional specialist competences master graduates should have achieved. They should have
- deepened the specialist and interdisciplinary knowledge they acquired during their first degree programme conferring a professional qualification, and/or broadened this knowledge through further methodological and analytical approaches;
- gained the ability to formulate solutions to complex problems and tasks in a scientific context or for use in industry or society, and to critically analyse and further refine these solutions.

Complex problems and tasks of this type exhibit the following characteristics:

a) their solution requires an analytical approach based on underlying principles,
b) they involve a broad range of sometimes conflicting factors, as well as different groups who are either affected by or have an interest in them,
c) they require different potential solutions to be weighed up,
d) they are uncommon in the relevant scientific or technical context, and fall outside predefined standards and paradigm solutions;
- acquired the skill of recognizing future problems, technologies and scientific developments due to the depth and breadth of the competences they have mastered, and of subsequently including them in their work;
- mastered the ability to work independently and scientifically, and to organise, carry out and lead more complex projects;
- acquired scientific, technical and social competences (capacity for abstract thought, systematic analytical thinking, team and communication skills, international and intercultural experience, etc.), and are thus especially capable of assuming leadership responsibilities."

With regard to the different engineering disciplines and specializations additional subject related learning outcomes have been specified by ASIIN and offered as reference, some of which dealing with the German distinction between two types of master level profiles: the “practice-oriented” and the “research oriented”. This is a distinction which is neither addressed in the French or UK learning outcomes nor in the transnational sectoral frameworks like EUR-ACE or the Washington Accord. It refers mainly to the interests of the traditional German research intensive Technical Universities, less to the demands of industry and the labour market.

1.3.4 USA and the Washington Accord

ABET, the American Board of Engineering and Technology, recognized accreditor for college and university programmes in applied science, computing, engineering, and technology, was the first agency to pilot and later implement an outcomes based approach to programme accreditation. In their Criteria 2000 for engineering programmes they defined 9 criteria with criterion 3 dealing with programme outcomes. 11 generic learning outcomes for all engineering disciplines are specified. In its most recent version it is phrased as follows:

“The program must have documented student outcomes that prepare graduates to attain the program educational objectives.

Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze 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
(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.”

The quoted list of learning outcomes applies to the Bachelor degree after normally 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 programs must develop, publish, and periodically review, educational objectives and program outcomes. The criteria for master’s level programs are fulfillment of the baccalaureate level general criteria, fulfillment of program criteria appropriate to the masters level specialization area, and one academic year of study beyond the baccalaureate level. The program must demonstrate that graduates have an ability to apply masters level knowledge in a specialized area of engineering related to the program area.”

The same holds for the list of “graduate attributes” of the Washington Accord. They also address the first degree level and the bachelor as the entry qualification into practice and/or professional development and professional competence achievement. Only 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 concept is primarily devoted to a specialization in a certain subject area. But additional outcomes are required. Extending the ABET list of 11 outcomes ASCE defined 22 learning outcomes to be achieved. Even more interesting is the approach to specify the level of achievement which each one of the listed outcomes should reach during study, initial professional practice and later continuing professional development.

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

Independent from the range of required or intended learning outcomes it is necessary for curriculum and module design as well as for outcome 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 as will be illustrated in the following paragraph dealing with the EUR-ACE standards.

1.4 EUR-ACE Framework Standards

The EUR-ACE Framework Standards have been developed by the European Network for Accreditation of Engineering Education (ENAAE) as an agreed and

21 ABET, Dito, p. 5
22 ASCE, 2008, Body of Knowledge, 2nd. edition
recognised standard within Europe for engineering education that provides a route into the engineering profession. The principal objective of ENAEE is to provide a de-centralized Europe-wide system of accreditation of engineering programmes using the EUR-ACE Label, and thereby promote the objectives of the Bologna process of quality, transparency, recognition and mobility.

Accreditation of engineering programmes has been practiced for many years, under different names, in a number of European countries. ENAEE has been established as a non-profit organisation to develop, implement and promote the EUR-ACE Framework Standards as a means of recognising and co-ordinating existing national standards and practices, and has had support from several European Commission projects. Further information about the structure and organisation of ENAEE and the development of the EUR-ACE Framework Standards is available on the ENAEE website.23

The following sections describe the specification of what the EUR-ACE Framework Standards are intended to achieve, the standards for engineering education that have been developed to meet this specification, a brief outline of how the standards are implemented, and finally a summary of ENAEE future strategy.

1.4.1 Specification for EUR-ACE Framework Standards

The EUR-ACE Framework Standards are designed to be applied to agencies that accredit engineering programmes, and not directly to engineering programmes. They are concerned with the accreditation of the academic standard of engineering programmes only, and not with the accreditation of universities or other institutions of higher education (HEIs). The Standards, together with the procedures for their implementation, are intended to be widely applicable and inclusive, in order to reflect the diversity of engineering degree programmes that provide the education necessary for entry to the engineering profession. The Standards have been developed to be fully consistent with the requirements of the Bologna process, including the Dublin Descriptors, which are intended to apply to all degree programmes in the European Higher Education Area (EHEA), and with the Standards and Guidelines for Quality Assurance in Higher Education (ESG) published by the European Association for Quality Assurance in Higher Education (ENQA).

The academic standard in EUR-ACE Standards is expressed as Programme Outcomes that describe in general terms the capabilities required of graduates from accredited First and Second Cycle programmes, or from programmes that are designed to progress directly to a degree at the level of Second Cycle (conventionally termed integrated programmes). The Programme Outcomes will need to be interpreted by agencies, and other users, to reflect their individual traditions and the specific requirements of different branches, cycles and profiles.

The use of Programme Outcomes in EUR-ACE Standards has important advantages:

- it respects the different teaching traditions and methods within Europe;
- it can accommodate future developments in teaching methods and practice;
- it encourages the sharing of good practice;
- it can accommodate developments in new and existing engineering technologies.

Consequently HEIs retain the freedom to design programmes with an individual emphasis and character, including new and innovative programmes, and to prescribe conditions for entry to each programme.

In EUR-ACE Framework Standards the term engineering graduate is used to describe someone who successfully completes an accredited engineering programme. The term engineer is avoided because it has widely different interpretations within Europe, including regulatory meanings in some countries. It is the responsibility of the relevant authority within each country to decide if a qualification, accredited or not, is sufficient for engineering registration or qualification in that country, or if further education, training or experience are necessary.

The processes for accrediting programmes of engineering education should contain four basic elements:

- an assessment of the content of the programme;
- an assessment of the level of the programme;
- an assessment of the infrastructure and resources to deliver the programme;
- a procedure for evaluating and deciding on the above three elements.

Therefore a framework such as EUR-ACE Framework Standards that is intended to assess the standards and the effectiveness of accreditation agencies should have statements about the standards to be achieved in each of these four elements. The requirements specified in EUR-ACE Standards for each of these four elements are outlined briefly in the following sections.
1.4.2 Content

Content comprises the engineering topics that are included in the requirements of an accrediting agency. They are expressed in EUR-ACE STANDARDS in general terms as Programme Outcomes so that they can be interpreted for different branches of engineering. 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 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;
- a 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 judgement 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 modelling, 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.

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

1.4.3 Level

Level is the depth of knowledge and understanding that underlies all the requirements in EUR-ACE Framework Standards. In the descriptive paragraphs under the headings Engineering Analysis, Engineering Design and Investigations the Programme Outcomes are required to be ‘consistent with their [the students’] level of knowledge and understanding’. The level required at Second Cycle is specified in one of the Programme Outcomes under the heading of Knowledge and Understanding, and requires graduates of accredited programmes to have:

‘a critical awareness of the forefront of their branch’.

This short statement defines the Level in EUR-ACE Standards, and is consistent with the Dublin Descriptors. However, although it states that the EUR-ACE standards have some link to the forefront of the subject, it is not immediately evident how to interpret this requirement.

What criteria should an agency use in order to determine if a programme is at the Forefront? Such criteria are necessary to enable HEIs to provide the relevant evidence for accreditation, and also to ensure consistency in decision making by the accrediting agency. The following activities are capable of providing the necessary evidence, and agencies will require the HEI to identify the aspects of the programme claimed to be at the Forefront.

- Project work in the final year of the programme that is directly related to the research programme of the university. The research need not be directly scientific or engineering research, but could be a closely associated activity, eg developing instrumentation.
- Project work in the final year on an industrial topic, and which could be carried out in industry depending on the particular teaching arrangements. Such activity would
need to be monitored to ensure that it was concerned with using relevant ideas and concepts informed by the Forefront in new products, designs, systems, processes, etc.

- A specified number of taught credits in the final year of the programme that are at the Forefront. The credits need not be concentrated into specific modules, but could be distributed throughout the teaching programme in the final year.

It will also be necessary for the HEI to show that its assessment methods are able to demonstrate that the graduates have achieved the specified outputs. It clearly would be unacceptable if the connection to the Forefront was simply a verbal or anecdotal account of recent developments. Of course the form of the connection to the Forefront will reflect the design of each teaching programme and the characteristics of the particular discipline, but it would need to be assessed as relevant and proportionate by the panel of accreditors.

Who is to decide if the Forefront requirement has been satisfied? The prime responsibility is that of the panel of accreditors who assess the programme; they are experts in that discipline and have detailed information about the programme. Their evaluation of the programme, and their discussion with the course providers is, in part, a debate about the location of the Forefront in that branch of engineering. Of course opinions will differ about its location, but in most accreditation processes the panel of accreditors make a recommendation to a committee that makes the final decision. This two stage process of recommendation and decision is important in assisting consistency of decision making about the level of an accredited programme, and in increasing participation in the debate on the location of the Forefront.

1.4.4 Infrastructure and Resources

If a programme is to be accredited it is not sufficient for the content and level alone to be specified, it is also necessary that the infrastructure, including staffing and resources, is adequate to ensure that the programme can be properly taught. Therefore EUR-ACE Standards specifies requirements for the infrastructure that the accrediting agency should incorporate into its assessment procedures. These requirements are detailed in Section 2 of EUR-ACE Standards under five headings:

- Needs, objectives and outcomes;
- Educational process;
- Resources and partnerships;
- Assessment of the educational process;
Management system.

The infrastructure and resource requirements specified in EUR-ACE Standards follow very closely those for accrediting agencies developed by ENQA and published as ESG.

1.4.5 Accreditation Procedures

EUR-ACE Standards also outline the procedures that an accreditation agency would be expected to use in making assessments. The EUR-ACE requirements follow closely the internationally accepted practice, and specifically the format detailed in ESG. In particular the EUR-ACE requirements expect that an accreditation agency would have documented information about the following aspects of its accreditation procedures:

- documentation to be provided by HEIs;
- composition of accreditation panel;
- duration of the accreditation visit;
- structure of the accreditation visit;
- verification and validation of the report by the accreditation agency/commission;
- decision on the accreditation;
- publication of results;
- procedures for appeals.

Full details of the ENAEE procedures for evaluating accreditation agencies are published on the ENAEE web site.

1.4.6 Implementation of the EUR-ACE Framework Standards

EUR-ACE Standards are administered by ENAEE which is a non-profit association open to all organisations with an interest in the standards of engineering education. Agencies with standards and procedures that have been assessed as consistent with those specified in EUR-ACE Standards are authorised to award the EUR-ACE Label to programmes that the agency has accredited. A certificate confirming the award of the EUR-ACE label is presented to the HEI teaching the accredited programme. The EUR-ACE label therefore adds value to existing accreditation processes, and provides information about the quality of the programme to various stakeholders:

- Employers are assured that the programme meets an agreed international standard;
- HEIs can promote labeled programmes as preparation for professional status;
Students are guaranteed that programmes are internationally recognised. Professional Engineering Organisations can be satisfied about the educational standards of graduates from such programmes.

At present nine agencies are authorised to award EUR-ACE Labels and over 500 labels have been awarded to FC and SC programmes:

- ASIIN (Germany);
- CTI (France);
- Engineering Council (UK);
- Engineers Ireland;
- OE (Portugal);
- AEER (Russia);
- MÛDEK (Turkey);
- ARACIS (Romania);
- QUACING (Italy).

Since 12 February 2013, the following have candidate status:

- OAQ (Switzerland);
- KAUT (Poland).

The procedure for evaluating and deciding on applications is the responsibility of the EUR-ACE Label Committee which is an ENAEE committee with representatives of all agencies authorised to award the EUR-ACE Label. The authorisation process followed by the EUR-ACE Label Committee is detailed on the ENAEE website.

1.4.7 Future Developments

The major purpose of EUR-ACE Standards is to provide an agreed standard within Europe of the education necessary for entry to the engineering profession, and thereby promote the mobility of engineers. To achieve this purpose it is essential for ENAEE to be an inclusive organisation with a wide membership, and to support this aim ENAEE has recently carried out an internal review of its standards and procedures to ensure that they are consistent with the requirements of other international frameworks. Furthermore ENAEE is developing a strategy to promote the merits and advantages of the EUR-ACE label in adding value to existing accreditation processes.

The standards established in EUR-ACE Framework Standards could have wider application than within the EHEA, and so ENAEE has begun informal discussions with the International Engineering Alliance (IEA) on the comparability (and possible
equivalence) of the standards used by each organisation. As a first step, work is in progress to establish a common glossary of the words and the definitions that are used with specific meanings in the two frameworks.

It is possible to conclude that ENAEE is a stable and firmly established organisation, and that the benefits of the EUR-ACE Framework are being increasingly recognised.

1.5 Federal Educational Standards of the RF

The third generation of state educational standards – Federal Educational Standard for Higher Education of the Russian Federation (FES RF) has come into force since 2011-2012 academic years. All the Russian HEIs have to renew their programmes in accordance with the new standards. The requirements of FES RF for academic programmes are obligatory for the HEIs to get a national accreditation.

The Research Centre for the Problems of Quality in Specialists’ Training identified basic distinguishing features of FES and educational programmes implemented on their basis. The authors consider that these features reflect the relation of FES with trends in global higher education and give “international dimension” to Russian educational standards and programmes.

These distinguishing features are the following:

- Transition to two-tier structure (Bachelor - Master) of higher education corresponding with A Framework for Qualifications for the European Higher Education Area,
- Transition to credit systems complying with ECTS to evaluate the workload of modules and programmes,
- Expansion of social responsibility of Russian higher education in general and its institutions for personal and interpersonal students skills, ensuring their ability to professional and social activity upon completion of educational programme,
- Interdisciplinary and transdisciplinary approach to design and implementation of educational programmes,

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Ensuring consistency with traditions of Russian higher education to provide students with fundamental disciplinary knowledge and high level of their professional thinking,

Tendency to balance cognitive learning with acquiring practical skills in communications, problem and critical thinking; strengthening of creative approach to the educational process,

Using of module principle in design and implementation of educational programmes,

Focusing on students achievement by applying adequate assessment tools and technologies,

Increasing level of students freedom when choosing individual educational paths,

Expansion of universities’ autonomy and academic freedom in design and implementation of educational programmes, particularly in defining their content and using educational technologies alongside with the increasing HEI responsibility for the quality of education. FES give the universities right to structure their educational programmes taking into consideration institution mission, traditions, aims, and stakeholders’ demands,

Development of efficient social dialogue between HEIs and industry as a prerequisite for designing of successful educational programmes,

Increasing of staff and students’ responsibility for efficiency of educational process.

Identified FES features such as multi-tier system, interdisciplinarity, collaboration with industry, will contribute to efficient development of competencies of engineering graduates.

The new FES differs from the previous standards first of all by usage of the outcomes-based approach and the two-tier system (introduction of Bachelor-Master programmes for majority of specialities/disciplines in higher education). The third generation of the Standards incorporates changes in nature of master programmes in Russia. Master programmes have become 2-year study programmes that provide graduates with in-depth competencies in the relevant field of study. They are now separated from the Bachelor ones (it is worth mentioning that Master studies were considered to last 6 years including 4 years of Bachelor studies according to previous legislation).
The new FES differentiate master study programmes between research- and practical-oriented profiles to prepare graduates for different types of professional activities, especially in engineering. Thus, master studies are not considered anymore as a preparatory step to PhD studies. Master programmes are acknowledged to be programmes reflecting university’s scientific traditions and academic policy. New standards allow developing interdisciplinary master programmes integrating knowledge from a number of co-fields of study. This is of special importance for innovations in engineering education that is required to grow-up “new generation of engineers” being able to create and deal with advanced technologies and knowledge.

The FES include the following sections:

1. Range of application
2. Acronyms
3. Description of the field of study.
4. Description of the professional activity
5. Requirements for programme learning outcomes (graduate’s competencies)
6. Requirements for programme structure
7. Requirements for programme implementation
8. Requirements for quality assurance procedures.

The first three sections include descriptive information about the particular programme. The HEIs are granted with their right to define the profile of programmes within the specified discipline / speciality.

The section 4 includes fields, objects, types and tasks of professional activity that master programmes graduates must be able to achieve / solve. The FES does not refer to “programme educational objectives” but specifies the descriptions of graduates professional activity can serve as a basis for formulation of requirements for programme learning outcomes.

The section 5 of the Standards describes the requirements for graduates' attributes. These requirements are given in terms of “competences”. The FES refer to “competence” as an integrated term used for knowledge, skills, attitude and experience. It is obvious that the FES and EQF use different definitions for “competences”. In the FES they are classified in 2 groups: professional and personal (transferable) skills. Professional skills (competences) are structured on 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. It’s noteworthy that FES classify some learning outcomes that are used to be personal (leadership or problem solving) as professional skills for substantially all SCD.

The section 6 contains requirements for programme curriculum (the workload of the study cycles and modules, expected learning outcomes for these modules). The FES define two main cycles for master programmes:

- M.1. Scientific cycle (with disciplines like methodology of research, history and philosophy of science, intelligence systems, optimization methods, etc.);
- M.2. Professional cycle (with disciplines like computation systems, technology for software development, current issues of informatics and computer science, etc.);

and two sections:

- M.3. Internship and research work;

The workload of the cycles and sections may vary depending on the speciality.

The section 7 contains the requirements for programme implementation:

- list of the obligatory programme documentation;
- requirement for use of different educational technologies / methods of teaching;
- requirements for programme curriculum (availability of electives, laboratories, internships and research works; maximum workload per week, maximum contact hours per week, duration of vacation within the academic year);
- faculty requirements;
- requirements for information resources and library;
- general requirements for programme financing;
- minimum requirements for equipment.

The section 8 is devoted to quality assurance procedures including participation of employers in external programme evaluation. This section also contains the requirements for the final state attestation.

The FES requirements for graduate’s competencies are obligatory for HEIs in developing new programmes. The universities have the right to introduce new / additional competencies with consideration of the programme profile.
The HEIs that have the right to develop their own educational standards can define the profiles for FCD programmes or implement programmes without profiles. Within one speciality a HEI can implement any number of master programmes that satisfy the FES requirements.

1.6 Compatibility of the FES and EUR-ACE Framework Standards

The main advantage and innovation of the third generation of educational standards is shifting from inputs oriented to an outcomes oriented paradigm. Together with Bologna impacts (three-tiers, credits, etc) it makes the Russian higher education getting part of the European Higher Education Area. It provides the Russian universities with the opportunity to eliminate the barriers for graduates’ academic and professional mobility; to give universities and students more academic freedom in programme design and implementation and to open the door to recognition of the programmes’ quality through the international accreditation. The way to an integration to EHEA lies through the using of common (agreed) set of requirements to learning outcomes.

The EUR-ACE Framework Standards specify the student learning outcomes in generic terms so that they can be interpreted for different branches of engineering. The Ministry of higher education and science of Russian Federation has elaborated and approved FES on about 170 branches of SCD programmes, more than 50% of them are related to engineering and technology. FES requirements to learning outcomes for graduates of different engineering programmes take many forms and are sometimes broad or narrow in their terms. Total number of FES requirements for SCD learning outcomes varies from 14 to 70. For example FES set 51 professional and 9 personal skills for master programme on Electrical Engineering. At the same time FES for master programme on Informatics contain list of 7 professional and 7 personal skills.

FES and other documents in Russian higher education use the term “competences” to describe the complex of skills, knowledge and attitudes that students have to demonstrate at the end of educational programme. In European standards this complex (or “mixture”) of students’ abilities is usually termed as ”learning (programme) outcomes”. Below we assume a common sense to be used while comparing these standards.
Brief comparison of approaches adopted by the Washington Accord signatories, European countries and FES for requirements to engineering programmes (that are important for programme design) are given below:

**Common features:**

1. Different terms and definitions are used; even the Ministry of Education and Science of RF used various definitions/terms in standards and regulations.
2. FES have no definition for “programme educational objectives” and thus do not define the mechanisms for their achievement.
3. The professional skills (competencies) must include engineering design, engineering analysis, engineering practice and investigations.
4. The level of graduate’s competencies (both professional and personal) is defined by the programme developer and the level of the programme.
5. Both FES and EUR-ACE STstandards prescribe an educational programme to have sufficient and adequate resources (infrastructure, staff, finance, etc.) to accomplish the programme outcomes. FES are even more detailed with this respect requiring universities to ensure 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, as an essential part of learning environment.

**Differences:**

1. Different terms and definitions are used; of the Ministry of Education and Science of RF used various definitions/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 do not provide clear recommendations to describe differences in the levels of bachelor and master competencies. However, EUR-ACE Framework Standards contain general requirements to graduates of engineering programmes, thus describing 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 include requirements for structure and content of engineering programmes (including the credit 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 likely rudiments of the previous generation of educational standards.

5. Standards for some specialities often contain too detailed list of knowledge, skills and competencies.

As a conclusion, it should be stated that there is no contradiction in Russian and European approaches and standards in general, not taking into consideration different structure of the standards and usage of some terms/definitions:

- FES defines fields of study and objects of graduate’s professional activity that are equivalents of programme educational objectives.
- Graduate’s competencies (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 last development of engineering profession and experience 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 minimum set of requirements for academic programme: the HEIs have the right to supplement and broaden the requirements for graduate’s competencies while developing their programmes, thus fostering the Standard requirements.
CHAPTER 2. METHODOLOGY OF ENGINEERING CURRICULUM DESIGN

The methodology of engineering curriculum design described in this chapter is developed with consideration and implementation of an outcomes-based approach, ECTS credit system, requirements of national and international accreditation criteria and other recent development in higher education. The European universities have been updating their curricula since 1999 that was initiated by the Bologna process. Considerable progress is made in implementing three-tier degree structure of higher education, ECTS, student-centered learning, and outcomes-based approach as well. A number of papers and books devoted to these topics have been published.\(^{25,26,27,28,29}\) The topics of programme design have been also elaborated in detail by the TUNING Group. This group published a guide\(^{30}\) with instructions on how to describe the competences and learning outcomes of the degree profile in a consistent way, together with helpful examples. It discusses also taxonomies used to outline the learning outcomes and includes a formative template for presenting programme outputs. However the terminology and definitions used by the TUNING Group sometimes significantly differ from usually accepted ones in engineering education and profession.

A main emphasis of the methodology presented in this Chapter is put on direct and strong links to graduate attributes defined by accreditation bodies and professional societies (see Chapter 1). The general requirements for engineering programmes' graduates are formulated in the “EUR-ACE Framework Standards for the accreditation of engineering programmes” that is an agreed and recognised standard within Europe for engineering education. As shown in the previous Chapter, the new Federal Educational Standards being introduced in Russia provide the Russian universities with the opportunity to simultaneously meet requirements of national and European quality standards of engineering education.

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In the following sections we describe how engineering courses might be designed, taught, and assessed to equip students with the intended attributes. As far as a set of intended learning outcomes

2.1 Engineering curriculum design and continuous programme improvement

A curriculum design is a constituent part of a lifelong process of programme continuous improvement, as for instance represented by the ABET two loop diagram (Figure 2.1). 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).

![Figure 2.1. ABET Two Loop Diagram](image)

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/overlapping between the loops assures that the outcome assessment is used to verify if the programme objectives are met: the learning outcomes can be modified (as well as the study process) to assure the achievement of programme objectives; a programme objective can also be reviewed/updated, if it cannot be achieved for some reason. It should be noted that the external loop (left) is turned over a little bit slower than the internal one (right): the achievement of programme educational objectives is verified after several graduations; thus the internal loop is turned over several times before the external loop is closed.
The continuous improvement assumes that a curriculum design/redesign to be executed if needed to ensure PEO/PLO achievement.

In accordance with the Figure 2.1, 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 constituencies and creation of the system ensuring the interaction with constituencies and studying of their needs.

**Step 2. Definition of programme educational objectives**

A programme developer must indicate the programme educational objectives based on the needs of the constituencies (main constituency). The programme objectives are to be consistent with the mission of the institution/department to ensure a programme’s market competitiveness and to meet the demands of constituencies.

**Step 3. Definition of measurable programme learning outcomes**

A programme developer formulates measurable *learning outcomes* – knowledge, skills and attitudes that a student acquires during his study for the programme. The programme learning outcomes must correspond with the needs of the constituencies 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. Any module has its own learning outcomes (MLO) which contribute to the achievement of programme learning outcomes (PLO). A module’s syllabus, teaching technologies, and supporting facilities are to be aimed at the achievement of module learning outcomes.

The achievement of any MLO requires a certain student learning activity (or activities) that is defined by the nature of MLO, learning environment, technologies etc. It corresponds to a number of ECTS credits assigned to a certain MLO, expressing the average student workload needed to achieve this MLO. Thus, a programme designer allocates the total amount of (mandatory) programme’s credits among MLO according to their contribution to 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 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 are to 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.

### 2.2 Programme conception

The starting step in programme design is the definition of its conception. This includes definition of the programme constituencies, studying their needs and definition of programme objectives based on the constituencies' needs.

The demand of the constituencies is highly important for each educational programme. A programme developer, taking into consideration the mission and development strategy of a HEI, must clearly understand who are programme constituencies and design programme so as to meet their expectations. The programme constituencies 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 choice of a programme main constituency (constituencies), study of its needs and development of programme concept aimed to satisfy constituency’s needs and expectations, will help to avoid difficulties in programme development, such as: 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: an effective feedback mechanism has to be in place.

The faculty/department designing/delivering the programme must realize itself as a principle responsible body for programme. A programme developer must be aware of modern trends in higher education development (and, in particular, in a discipline) as
well as of the requirements of professional organizations and accreditation agencies with regard to graduates’ attributes to ensure the recognition of the graduates’ competencies. To be competitive an educational programme must

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

A systematic investigation of constituencies’ 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 changing environment. The institution/department responsible for programme delivery must have an on-going system for continuous programme improvement including study of constituencies’ needs, definition of programme objectives and systematic assessment of their achievement. The data collected by surveys of different groups of constituencies (alumni, faculty, employers, etc) must be analyzed and used for continuous programme improvement and updating of programme objectives.

**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 focuses on advanced studies in natural and engineering sciences, computer and information technologies. The graduates gain experience in usage of modern soft- and hardware tools for design equipment of power energetics and for 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 the natural energy into electricity.

The acquisition of managerial and economic competencies is incorporated in the study process to ensure carrier prospective 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.
2.3 Programme educational objectives

Definition of programme objectives is the next step in programme design. The programme objectives are brief description of programme concept in terms of competencies acquired by the students upon 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.

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

The processes of teaching and learning must ensure the achievement of 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 only by some of them.

The evaluation of the achievement of programme objectives is usually done through survey of programme constituencies (employers, alumni, etc). The achievement of programme objectives is an important accreditation criterion as considered by the accrediting organizations, including ENAEE members. Each objective:

- addresses one or more needs of constituencies/stakeholders;
- must be understandable by the constituency 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 by a few 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 that of the learning outcomes.
Example 2. Programme objectives

The programme graduates are prepared:

O1: for research and problem solving in development and optimization 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.

2.4 Programme learning outcomes

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

While programme objectives are broad statements that describe the uniqueness of specialist' training and give “a portrait of a graduate” for potential constituencies, 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 program.

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 are acquired by all the students by the time of graduation; while programme objectives are achieved by the graduates within the few years after graduation (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 upon completion of the program and before graduation;
– must be a unit of knowledge/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 learning outcomes of compulsory modules must lead to achievement of programme learning outcomes.

**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 design of TPP and NPP and 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, 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, analyze, synthesize and critically evaluate data;

**Personal skills**

**P7:** to demonstrate knowledge of foreign language at the level allowing to communicate effectively with the international engineering community, work out documentation, 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 organization;

**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.

The programme learning outcomes are formulated by programme developers based on the programme learning objectives and constituencies’ requirements to professional and personal graduates’ attributes. The achievement of learning outcomes ensures mastering the programme (in other words, successful study of 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 competencies 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.

**Example 4. Programme objectives mapped to learning outcomes**

<table>
<thead>
<tr>
<th>Learning outcomes</th>
<th>Programme objectives</th>
<th>O1</th>
<th>O2</th>
<th>O3</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>P6</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>P8</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>P9</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>P10</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

### 2.5 Modules and Credit Allocation

Started as a credit transfer system the ECTS develops into an accumulation system. The ECTS credits are used (besides of communication between universities/departments) to describe a module/unit contribution to a study programme. The official transcripts of records issued throughout Europe make use of the ECTS for specifying a recognized student learning activities. Credits are awarded to a student if he/she has completed a module/unit and has been successfully assessed. Thus, being a measure of a student workload needed to achieve of an intended learning outcome, ECTS credits serve today as a tool for curriculum design as well.

Next steps in engineering curriculum design refer to the internal (right-hand) loop of the ABET diagram (Figure 2.1.), in particular, to the planning of programme structure.
and content. The methodology described in this paper assumes the use of the ECTS credit system as a tool for measurement of programme learning outcomes. Taking into account that ECTS credit is a student workload required to achieve an intended goal in notional learning time, the authors establish the direct relation 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 it as well as the contribution/importance of this outcome for the educational programme.

Example 5. Allocation of credits to learning outcomes

<table>
<thead>
<tr>
<th>FES</th>
<th>Professional skills</th>
<th>Personal / transferable skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS credits</td>
<td>Knowledge and understanding</td>
<td>100</td>
</tr>
<tr>
<td>EUR-ACE</td>
<td>Engineering analysis</td>
<td>24</td>
</tr>
<tr>
<td>EUR-ACE</td>
<td>Engineering design</td>
<td>21</td>
</tr>
<tr>
<td>EUR-ACE</td>
<td>Investigations</td>
<td>15</td>
</tr>
<tr>
<td>EUR-ACE</td>
<td>Engineering practice</td>
<td>16</td>
</tr>
<tr>
<td>EUR-ACE</td>
<td>Transferable skills</td>
<td>19</td>
</tr>
<tr>
<td>EUR-ACE</td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

Programme learning outcomes are to be achieved while studying for the programme or upon successful completion some of its modules. A module includes one or several basic disciplines or electives, internship, projects, research work, final qualification work (master thesis). It is important to underline that some learning outcomes, like transferable skills, are taught and assessed entirely within a number of modules designed to satisfy the requirements of other learning outcomes; ECTS credits are assigned to the module where a learning outcomes is assessed.

The learning outcomes of a single module describe in details knowledge and skills that contribute to achievement of learning outcomes by the students and serve as a basis for 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 observable and 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; for this purpose the use of direct assessment tools or techniques (written surveys and examinations, oral presentations, project work, exams) is needed;

- in writing *learning outcomes for single modules* one should take into consideration that in-depth knowledge and skills are acquired on the basis of previous education.

**Example 6. Allocation of credits to learning outcomes and programme modules**

<table>
<thead>
<tr>
<th>Module</th>
<th>Credits</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philosophical and Methodological Problems of Science and Technology</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Design of Industrial Equipment</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Practice</td>
<td>17</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
2.6 Assessment of learning outcomes and programme objectives

In accordance with the EUR-ACE Framework Standards\textsuperscript{31} an institution should give evidence of “Existence of a regulated, systematic and periodic process for re-examining needs objectives and outcomes, educational process, resources and partnerships, management system”. Other accreditation agencies have similar requirements in place, for example in ABET\textsuperscript{32} Criterion 2 it is stated: \textit{There must be a documented, systematically utilized, and effective process, involving program constituencies, for the periodic review of these program educational objectives that ensures they remain consistent with the institutional mission, the program’s constituents’ needs, and these criteria.}

Dr. Gerardo del Cerro in his book “Measurement performance in Engineering education”\textsuperscript{33} underlined important focuses of assessment. He considers that the purpose of the assessment programme is to assure that the educational process is fulfilling its promise to students – 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 center on classroom activities, it can be implemented at schoolwide, course or department levels. It reaches its full potential when it is fully institutionalized 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 department/curriculum committees to establish a manageable framework for continuous programme assessment and development by establishing a strategic planning process based on the following questions\textsuperscript{34}:

\textsuperscript{32} ABET, Criteria for Accrediting Engineering Programmes, Effective for Reviews During the 2013-2014
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 following stakeholders could be engaged in evaluation processes:

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

A sample of assessment plan for programme objectives and learning outcomes is illustrated in the table below (Example 7). Such plan could be implemented within the department responsible for a programme delivery and supervised by programme coordinator or working group consisted from faculty members having good experience and motivation in assessment.
### Example 7. Assessment plan for programme objectives and learning outcomes

<table>
<thead>
<tr>
<th>Assessment Level</th>
<th>Activities</th>
<th>Purpose</th>
<th>Periodicity</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programme objective</td>
<td>Employers Survey</td>
<td>To gather feedback from employers on quality of the graduates performance, on relevance and importance of the programme objectives</td>
<td>Annually</td>
<td>Faculty / Working group, Job Placement Office, Office for Social Surveys</td>
</tr>
<tr>
<td></td>
<td>Alumni Survey</td>
<td>To gather feedback from alumni on their employment status and career</td>
<td>Annually</td>
<td>Faculty / Working group, Job Placement Office, Office for Social Surveys</td>
</tr>
<tr>
<td></td>
<td>Meeting of Working group on assessment of programme objectives</td>
<td>Evaluation of feedback got from employers, alumni and other sources. Elaboration of proposals for improvement of the programme objectives.</td>
<td>Annually</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td></td>
<td>Department meeting on assessment of programme objectives</td>
<td>Review and approval of the new programme objectives</td>
<td>Once in 3-5 years</td>
<td>Faculty</td>
</tr>
<tr>
<td>Programme learning outcomes</td>
<td>Graduating Students Survey</td>
<td>To gather feedback from graduating students on their achievement of the learning outcomes and quality of the education got.</td>
<td>Annually</td>
<td>Faculty, Job Placement Office, Office for Social Surveys</td>
</tr>
<tr>
<td></td>
<td>Internship Supervisors Survey</td>
<td>To gather feedback from supervisors on student performance and achievement of the learning outcomes</td>
<td>Annually</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td></td>
<td>Faculty Survey, including members of State Attestation Commission</td>
<td>To gather feedback from faculty on students achievement of the learning outcomes</td>
<td>Annually</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td></td>
<td>Meeting of Working group on assessment of learning outcomes</td>
<td>Evaluation of feedback got from graduating students, internship supervisors, faculty and other sources. Elaboration of proposals for improvement of the programme learning outcomes.</td>
<td>Annually</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td></td>
<td>Department meeting on assessment of Learning outcomes</td>
<td>Review and approval of the new programme leaning outcomes</td>
<td>Once in 1-3 years</td>
<td>Faculty</td>
</tr>
<tr>
<td>Module learning outcomes</td>
<td>Students Survey</td>
<td>To gather feedback on students achievement of the module learning outcomes (within all or selected modules/courses)</td>
<td>Semestral</td>
<td>Course instructors</td>
</tr>
<tr>
<td></td>
<td>Meeting of Working group on assessment of modules (courses) learning outcomes</td>
<td>Evaluation of feedback got from students and other sources. Review and approval of the new module learning outcomes with course instructors</td>
<td>Annually</td>
<td>Working group / Programme Coordinator</td>
</tr>
</tbody>
</table>
The data got through the surveys are to be used for evaluation of achievement of learning outcomes and continuous programme improvement. If surveys’ results show that needs of the constituencies are not satisfied, the department/programme developer should make a decision to modify either programme objectives or programme/module learning outcomes. If one or several programme objectives are not achieved, the department/programme developer should substantially modify either curriculum or programme objectives.

2.6.1 Assessment of programme objectives

As it was discussed in previous sections programme objectives are usually achieved by the graduates within 3-5 years after graduation. Therefore the assessment of the objectives should take place out of institution. In accordance with the above presented table (Example 7) main stakeholders who can act as information sources when assessing programme objectives are employers and graduates. A sample of evaluation of a programme objective is given below.

**Example 8. Target indicators for assessment of programme objective**

<table>
<thead>
<tr>
<th>Code</th>
<th>Programme Objectives</th>
<th>Target indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Alumni Survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employers Survey</td>
</tr>
<tr>
<td>O1</td>
<td>Research and problem solving in development and optimization of techniques and machinery for TPP and NPP using computer-aided technologies</td>
<td>% of graduates who pursue professional career in their degree area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of graduates who carry out research</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of graduates who perform tasks listed in the objective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of graduates who got further degrees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of graduates dealing with computer design technologies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of satisfaction by quality of graduates performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of request for graduates</td>
</tr>
</tbody>
</table>

2.6.2 Assessment of programme learning outcomes

There are many ways to collect evidence of student learning. To simplify the options, somewhat, assessment efforts are categorized 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.35

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 methods36:

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardized exams</td>
<td>Written surveys and questionnaires</td>
</tr>
<tr>
<td>Locally developed exams</td>
<td>Exit and other interviews</td>
</tr>
<tr>
<td>Portfolios</td>
<td>Archival record</td>
</tr>
<tr>
<td>Simulations</td>
<td>Focus groups</td>
</tr>
<tr>
<td>Performance Appraisal</td>
<td></td>
</tr>
<tr>
<td>External examiner</td>
<td></td>
</tr>
<tr>
<td>Oral exams</td>
<td></td>
</tr>
<tr>
<td>Behavioral observations</td>
<td></td>
</tr>
</tbody>
</table>

One of the comprehensive approach to learning outcomes assessment described in many sources37,38,39 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 courses, and explicitly identifying to students, instructors, administrators and external stakeholders how student learning outcomes are delivered within a degree program.

See a sample of mapping programme and modules outcomes and assessment planning within a curriculum in the Example 9.

Example 9. Assessment plan for a programme learning outcome

Programme Learning Outcome:
P7: Demonstrate knowledge of foreign language at the level allowing to communicate effectively with the international engineering community, work out documentation, pre-sent and defend outcomes of innovative engineering activity (8 ECTS)

<table>
<thead>
<tr>
<th>Key modules/courses that contribute to achievement of P7</th>
<th>Modules learning outcomes (M) that contribute to achievement of P7</th>
<th>Responsible for assessment of module learning outcomes</th>
<th>Periodicity / started / last assessment year</th>
<th>Responsible for data analysis and evaluation of achievement of learning outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.62 Foreign Language</td>
<td>M1 (P7): to have knowledge and understanding of foreign language communication role in the field of professional development; notations and abbreviations of international business culture; 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 foreign language for situations modeling professional communication, to use the foreign literature.</td>
<td>Course Instructor</td>
<td>Annually / 2011 / 2013</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td>M3.1 Research Work</td>
<td>M7 (P7): to be able to use foreign literature in conducting research</td>
<td>Research Supervisor</td>
<td>Semestral / 2011 / 2013</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td>M3.3 Research Practice</td>
<td>M5 (P7): to be able to use foreign language/literature for professional activities</td>
<td>Research Practice Supervisor</td>
<td>Annually / 2012 / 2012</td>
<td>Working group / Programme Coordinator</td>
</tr>
<tr>
<td>M4 Master Thesis</td>
<td>M8 (P7) (3 ECTS): to be able to communicate effectively; to have knowledge of professional terminology and skills of using literature and presenting information</td>
<td>Research Supervisor, State attestation commission</td>
<td>Annually / 2013 / 2013</td>
<td>Working group / Programme Coordinator</td>
</tr>
</tbody>
</table>
The value of curriculum mapping is demonstrated when instructors collaborate to review data collected from the questionnaire to identify strengths, gaps, redundancies and inconsistencies in the curriculum. Based upon the aggregate data related to the intended and delivered learning outcomes, instructors discuss strengths 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\textsuperscript{40,41}.

2.6.3 Assessment of module learning outcomes

In Accordance with the Glossary of Terms Relevant to Higher Education \textit{(Engineering)}\textsuperscript{42}, \textit{assessment 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 (\textit{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 (\textit{summative assessment}).

Nowadays there are many assessment techniques for modules or courses that a teacher could use after defining intended module learning outcomes. In the book \textquotedblleft Teaching Engineering\textquotedblright\textsuperscript{43} 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;

\textsuperscript{43} Peter Goodhew. Teaching Engineering. Available from: http://core.materials.ac.uk/repository/teaching-engineering/teaching_engineering_goodhew.pdf
• A portfolio of work, or an e-portfolio;
• A wiki.

In the table below is presented formative and summative assessment ways of a course learning outcomes.

**Example 10. Assessment of a module learning outcome**

Module M1.52 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*

<table>
<thead>
<tr>
<th>Assessment Criteria</th>
<th>Types of Learning Activity</th>
<th>Formative Assessment</th>
<th>Summative Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctness of terminology usage</td>
<td>Independent work of student on translation of authentic texts</td>
<td>Individual assignment</td>
<td></td>
</tr>
<tr>
<td>Usage of wide professional vocabulary</td>
<td>In-class work of students with authentic texts</td>
<td>Test</td>
<td>Exam</td>
</tr>
<tr>
<td>Correctness of sentences structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed of translation work</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To create a culture of success, where all learners believe they can achieve, teachers need to\textsuperscript{44}:

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\textsuperscript{45} 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.

\textsuperscript{44} Black, P and Wiliam, D (1999). Assessment for learning: beyond the black box. London: Kings College London.
2.7 Examples: Curriculum and syllabi

The example of curriculum and syllabi of several modules for the master degree programme “Computer Technologies for Design of Thermal and Nuclear Power Plants” are given below. The master programme is developed by Tomsk Polytechnic University within the ECDEAST project (2010-2013).
# Example 11. Curriculum

Curriculum of Master programme “Computer Technologies for Design of Thermal and Nuclear Power Plants”. Notional duration of study is two years (full-time mode).

<table>
<thead>
<tr>
<th>Code</th>
<th>Cycle / Module / Discipline</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>General cycle</td>
<td>14</td>
</tr>
<tr>
<td>M1.B1</td>
<td>Philosophical and Methodological Problems of Science and Technology</td>
<td>3</td>
</tr>
<tr>
<td>M1.B2</td>
<td>Foreign Language</td>
<td>4 (2/2)</td>
</tr>
<tr>
<td>M1.B3</td>
<td>Economy and Production Control</td>
<td>2</td>
</tr>
<tr>
<td>M1.B4</td>
<td>Mathematical Modeling</td>
<td>2</td>
</tr>
<tr>
<td>M1.B1.2</td>
<td>Data-Driven Design</td>
<td>3</td>
</tr>
<tr>
<td>M2</td>
<td>Professional cycle</td>
<td>45</td>
</tr>
<tr>
<td>M2.B1</td>
<td>Modern Challenges of Thermal Power Engineering and Thermal Technologies</td>
<td>3</td>
</tr>
<tr>
<td>M2.B3</td>
<td>Ecological Safety</td>
<td>3</td>
</tr>
<tr>
<td>M2.B1.1</td>
<td>Computer Design of Industrial Equipment</td>
<td>6</td>
</tr>
<tr>
<td>M2.B2.3</td>
<td>Computing in Applied Problem Solving</td>
<td>4</td>
</tr>
<tr>
<td>M2.B3.2</td>
<td>Simulation of Complex Systems</td>
<td>4</td>
</tr>
<tr>
<td>M2.B.5.1</td>
<td>TPP and NPP Heat Exchangers and Compressors</td>
<td>4</td>
</tr>
<tr>
<td>M2.B.5.2</td>
<td>Technological Systems and of TPP and NPP</td>
<td>4</td>
</tr>
<tr>
<td>M2.B.5.3</td>
<td>Reliability and Operation Modes of TPP</td>
<td>4</td>
</tr>
<tr>
<td>M2.B.5.4</td>
<td>Design of Thermal Power Units and Subsystems</td>
<td>4</td>
</tr>
<tr>
<td>M2.B.5.5</td>
<td>Technology of TPP and NPP Design</td>
<td>3</td>
</tr>
<tr>
<td>M3</td>
<td>Research and Internships</td>
<td>37</td>
</tr>
<tr>
<td>M3.1</td>
<td>Research</td>
<td>16 (4/6/6)</td>
</tr>
<tr>
<td>M3.2.2</td>
<td>Internship</td>
<td>4 (2/2)</td>
</tr>
<tr>
<td>M3.3</td>
<td>Research Practice</td>
<td>17</td>
</tr>
<tr>
<td>M4</td>
<td>Master Thesis</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>120</td>
</tr>
</tbody>
</table>
Example 12. Module Economy and Production Control

Department: Management
Discipline code: M1.63
Level: 5 (master studies)
Credits: 2 ECTS
Prerequisites: no
Authors: Lidia A. Korshunova
Lectors: Lidia A. Korshunova, Alexander S. Matveev

Learning outcomes

M1 (P2): to knowledge of principles and means of business management; basics of production organization and planning; modern tools for management task solution, methods of business-planning and decision making;

M2 (P1): to be able to estimate investments, productive costs, demand on current assets; to plan the work of the equipment, taking into account its' outage; to analyze production and economic activity of heat power plant and nuclear power plant; to evaluate efficiency of measures by improving of heat and power facilities and equipment

Brief Description


Power resources and economy of its' using. Secondary power resources. Fuel and energy balance. Efficiency of power resources' usage.

Power system loads designing. Curves load configuration management of power and heat power's consumers.

Production facilities and capacities in the sphere of power engineering. Investments into power engineering, source of financing and lumping. Key and current assets. Key assets' amortization, key assets' functional depreciation. Power-producing cost value. Charges diversity by products' types. The ways of cost reduction of power and heat energy.


Production capacity planning of power system. Annual power generation planning by power plants of power system. Fuel balance and fuel supply plan of heat power station.

Repair maintenance organization and planning. Labour and salary organization and planning.

**Textbooks**


**Projects**

1. Estimation and analyze of technical and engineering factors of heat power plant and nuclear power plant.
2. Planning of the production program of heat power plant and nuclear power plant.
3. Technical and engineering foundation of research project.
4. Technical and engineering evaluation of the investment project of heat power plant’s and nuclear power plant’s reconstruction.
5. Business plan of innovation project.

**LECTURES** 8 / 8 hrs  
**SEMINARS** 24 / 24 hrs  
**CONTACT HOURS** 32 hrs  
**SELF-STUDY** 64 hrs  
**TOTAL** 96 hrs

**ASSESMENT** Exam
Example 13. Module Computing in Applied Problem Solving

Department: Nuclear and Thermal Power Plants

Discipline code: M2.B2.3
Level: 5 (master studies)
Credits: 4 ECTS
Prerequisites:

Authors: Mikhail A. Sheremet, Alexander S. Matveev
Lectors: Mikhail A. Sheremet

Learning outcomes

M1 (P3): to have knowledge and understanding of principles of using software tools for engineering analysis, including the strength, stability, heat transfer, frequency analysis, the dynamics of mechanisms, fluid dynamics, data and process management; principles of using software systems such as SolidWorks, ANSYS, «Hydraulics» for the design, 3D modeling of components, piping and assembly

M2 (P1): to have knowledge and understanding of principles for design documentation in accordance with the State standard specification

M3 (P3): to be able to use computing systems to solve complex problems in the mechanics of fluids, thermodynamics, heat transfer calculations on the strength, and selection of mechanical equipment to use hydro / gas dynamic and thermal models of the devices to hold stationary and transient thermal analysis

M4 (P5): to be able to computer systems to select variations of priority thermal couplings and calculation of thermal parameters in different operating modes, the selection of thermal and nuclear power equipment

Brief Description

CAD software suite to automate the work on the stages of design and technological preparation of production. Ensures the development of products of any complexity and purpose.

The design of pre-production. 3D designing products (parts and assemblies), takes into account the specifics of production, creates design documentation in accordance with State Technical Standard. Designing communications (pipelines, etc.). Engineering analysis (strength, stability, heat transfer, frequency analysis, the dynamics of the mechanisms of gas / fluid dynamics, etc.). Rapid analysis of manufacturability at the design stage. Preparing data for IETM. Data management and processes during CPR.


SolidWorks Simulation Professional. Calculation of the strength of structures in the elastic zone, statement and solution of contact problems, the calculation of assembly, the determination of the Eigen forms and frequencies of vibrations, the calculation of the stability of structures, fatigue calculations, simulation of fall, the thermal calculations. Optimizing model parameters SolidWorks Motion: an integrated dynamic and kinematic analysis of mechanisms, the definition of velocity, acceleration, and the mutual influence of elements of the system.

SolidWorks Flow Simulation. Modeling the flow of liquids and gases, the management of computational mesh, using various physical models of liquids and gases, a comprehensive thermal design, hydraulic / gas dynamic and thermal models of technical equipment, both
stationary and transient analysis, the calculation of rotating objects, export results to SolidWorks Simulation.


The "Hydraulics". The use when designing and reconstructing energy facilities for the thermal and hydraulic calculations of pipelines, pumping liquid or gaseous products, as well as gas-liquid mixtures. Calculation of the combined pipeline systems of arbitrary complexity.

Labs

1. Development of products using CAD software package Solidworks.
2. Design of the pipeline in 3D technology
3. Analysis of the strength and stability in the CAD Solidworks.
4. The calculation of heat transfer in Solidworks CAD
5. The calculation of hydrodynamic processes in CAD Solidworks
6. Determination of the Eigen forms and frequencies of vibrations in the CAD system SolidWorks Simulation Professional.
8. Solution of the problem and the heat transfer in a software system ANSYS.
9. Calculation of the combined pipeline system in the "Hydraulics".

Textbooks

10. Shalumov A.S., Vachenko A.S.,Fadeev O., Bagaev D. Introduction to ANSYS: Strength and thermal analysis

LECTURES 8 / 32 hrs
LABS 24 / 48 hrs
CONTACT HOURS 32 hrs
SELF-STUDY 80 hrs
TOTAL 112 hrs
ASSESSMENT Exam

67
**Example 14. Module Master Thesis**

**Master Thesis**

Department: Nuclear and Thermal Power Plants  
Discipline code: M4  
Level: 5 (master studies)  
Credits: 24 ECTS  
Prerequisites: M1.5, M1.6, M2.5, M2.6, M2.5.1-5, M3  
Author: Alexandra M. Antonova, Alexander S. Matveev.

**Learning outcomes**

**M1 (P6, 3 ECTS):** To be able to analyze 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 modeling 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 into 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.

**Brief Description**

Master Thesis is the basic means of graduate’s assessment. The paper is result of an independent logically sound study, which is based on solving the specific design problem and fosters understanding, experience and knowledge and skills necessary for engineering design.

Topics of the thesis in engineering design include modernization, 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.

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, organizational 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. Requirements 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, 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 the number of potential employers and prominent academicians of the University.

**Textbooks**

5. Gas Turbine Technologies Journal (Gazotutbinniye tekhnologii).

**SELF-STUDY** 540 hrs
**TOTAL** 540 hrs

**ASSESSMENT** Public Defense
<table>
<thead>
<tr>
<th>ACRONYMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABET</strong> – Accreditation Board for Engineering and Technology (USA)</td>
</tr>
<tr>
<td><strong>ASCE</strong> – American Society of Civil Engineers</td>
</tr>
<tr>
<td><strong>ASEE</strong> – American Society of Engineering Education</td>
</tr>
<tr>
<td><strong>AEER</strong> — Association for Engineering Education of Russia</td>
</tr>
<tr>
<td><strong>ARACIS</strong> – Romanian Agency for Quality Assurance in Higher Education (Romania)</td>
</tr>
<tr>
<td><strong>ASIIN</strong> – Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik (Germany), Accreditation Agency for Study Programs in Engineering, Informatics, Natural Sciences and Mathematics</td>
</tr>
<tr>
<td><strong>CTI</strong> - Commission des Titres d'Ingénieurs (France)</td>
</tr>
<tr>
<td><strong>EC-UK</strong> – Engineering Council - United Kingdom</td>
</tr>
<tr>
<td><strong>ECTS</strong> – European Credit Transfer System</td>
</tr>
<tr>
<td><strong>EFMD</strong> – European Foundation for Management Development</td>
</tr>
<tr>
<td><strong>EHEA</strong> – European Higher Education Area</td>
</tr>
<tr>
<td><strong>ENQA</strong> - European Network of Quality Assurance</td>
</tr>
<tr>
<td><strong>ENAEE</strong> – European Network for the Accreditation of Engineering Education</td>
</tr>
<tr>
<td><strong>ESG</strong> – European Standards and Guidelines for Quality Assurance in Higher Education</td>
</tr>
<tr>
<td><strong>EUR-ACE</strong> – EUR-ACE® is the European quality label for engineering degree; EUROPean Accredited Engineer</td>
</tr>
<tr>
<td><strong>EQF</strong> – European Qualifications Framework</td>
</tr>
<tr>
<td><strong>EQF-LLL</strong> – European Qualifications Framework for Lifelong Learning</td>
</tr>
<tr>
<td><strong>EQANIE</strong>– European Quality Assurance Network for Informatics Education</td>
</tr>
<tr>
<td><strong>EQUIS</strong> – EFMD Quality Improvement System</td>
</tr>
<tr>
<td><strong>EUA</strong> – European University Association</td>
</tr>
<tr>
<td><strong>FCD</strong> – First Cycle Degree</td>
</tr>
<tr>
<td><strong>FEANI</strong> – Fédération Européenne d'Associations Nationales d'Ingénieurs, European Federation of National Engineering Associations</td>
</tr>
<tr>
<td><strong>FES</strong> – Federal Educational Standards (Russian Federation)</td>
</tr>
<tr>
<td><strong>HEI</strong> – Higher Education Institute</td>
</tr>
<tr>
<td><strong>ICT</strong> – Information and Communication Technology</td>
</tr>
<tr>
<td><strong>IEA</strong> – International Engineering Alliance</td>
</tr>
</tbody>
</table>
KAUT – Komisja Akredytacyjna Uczelni Technicznych, Accreditation Commission for Engineering Programmes (Poland).

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

NPP – Nuclear Power Plant

OAQ – Swiss Center of Accreditation and Quality Assurance in Higher Education (Switzerland)

OE – Ordem dos Engenheiros (Portugal)

SCD – Second Cycle Degree

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)

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

TPU – Tomsk Polytechnic University

TPP – Thermal Power Plant

UK-SPEC – United Kingdom Standards for Professional Engineering Competence

WA – Washington Accord
GLOSSARY

This Glossary includes terms focused on higher education, design and accreditation of study programmes in engineering. It is well known that English words being translated into other languages often have different meaning in national context. We hope that this glossary would help in explaining of the some words used in the Guidelines. The most of terms are adopted from the TREE project publication.

**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 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 amount 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)

Comprehensive description of a study programme. It includes learning objectives or intended outcomes, contents, assessments procedures.

Degree (see also Credit accumulation system)

Qualification awarded to an individual by a recognised higher education institution after 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 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 the 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, project, at the completion of a course unit in order to indicate the level of proficiency demonstrated by that student. 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 educational context, 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 concluded between the three parties involved (home Institute, hosting Institute and student) and specify 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.
**Notional 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, some just by any.

**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/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 that 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.