ECDEAST>
Engineering Curricula Design
alligned with EQF & EUR-ACE Standards

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

European Commission
TEMPUS

[Version 1.0 ENG]

Tomsk, 2011

УДК 378.214.1
ББК Ч481.21

The project is financed with support of the European Union
The content of the publication/material is a subject of responsibility of the author and does not reflect the point of view of the European Union.

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The Guidelines discusses of 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 Standard requirements and EUR-ACE Framework Standards. The second part of the Guidelines describes a methodology for engineering curriculum design, 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 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”. The Guidelines are recommended for development of master programmes in engineering and technology.

**CONTENT**

## FOREWORD

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 are to be reviewed and improved 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 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 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, 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.

## 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 contains 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, those refer abilities (ant their level) of 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 a 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 by 2010 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 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.”[2]

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 already described Bologna Qualifications Framework descriptors are very generic:

[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”[3]

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 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

[3] Dito, p. 13

description of the curriculum (modules, units and qualifications) and level, cycle and qualifications descriptors associated with the 'new style' Bologna qualifications frameworks."[4]

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:[5]

- Knowledge and understanding
- Applying knowledge and understanding
- Making judgements
- 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 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. 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[6] and its accreditation standards for engineering programmes: expected learning outcomes are phrased as "graduate attributes" to be achieved by the first degree, usually a bachelor degree after 4 years of study.

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[4] Adam, Stephen, 2008, Learning outcomes, current developments in Europe

[5] Bologna Working Group on Qualifications Frameworks, 2005,

[6] 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 RAEE is currently applying for membership. Together with 5 other Networks and accords the WA forms the International Engineering Alliance (IE)

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.[7]

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.

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

[7] European Communities, 2008, European Qualifications Framework for Lifelong Learning (EQF)

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. Some examples are given later in paragraph 3.1.

### 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."[8]

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

**"Knowledge:**

– highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research

– critical awareness of knowledge issues in a field and at the interface between different fields

**Skills:**

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

**Competences:**

– manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches

– take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams.

It should be 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

[8] Bologna Working Group on Qualifications Frameworks,2005, A Framework for Qualifications for the European Higher Education Area

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."[9]

## 1.3 National requirements to engineering programme accreditation

Transnational agreed standards like the EUR-ACE ones specified later in this guidelines or the graduate attributes of the Washington Accord[10] usually function only as 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 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

[9] European Parliament Council, April 2008, Recommendation on the establishment of the European Qualifications Framework on lifelong learning
[10] Graduate Attributes and Professional Competencies . Режим доступа: http://washingtonaccord.org/IEA-Grad-Attr-Prof-Competencies-v2.pdf .

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."[11]

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."[12]

In addition, the programmes should provide possibilities for practical experience and competence achievement by at least 28 weeks of internship, all or part of it can be

[11] References and guidelines: Introduction. Commission des Titres d'Ingénieur, 2010. Режим доступа: http://www.cti-commission.fr/IMG/pdf/20100422_References_and_guidelines_2009-2.pdf.
[12] CTI, 2010, References and Guidelines", p. 17

abroad. School collaboration with its stakeholders, primarily applicants, engineering students and the professional world, is required. Main aims: "The school and its surroundings discuss what is needed to bring graduate engineers' profiles up to date according to their needs. The desired engineer profile is defined according to the professional skills and capacities. In addition to evaluating the capacities, the school has an approach to evaluating engineering students' skills, in cooperation with companies."[13] 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 continuing 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 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 UK14 the voluntary accreditation of programmes by the professional Institutions sets the standards for programme development and curriculum design.

Until recently the educational entry requirement on the route to a "Chartered Engineer" was a Bachelor Honours degree in engineering (BEng 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),

[13] Dito, p. 20
[14] Engineering Council (EC) UK an association functioning besides other commitments as a kind of umbrella organization for the Professional Engineering Institutions

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
- Engineering Practice

These outcomes are detailed for the Bachelor Honours level. With regard to the accreditation of Master of Engineering degrees additional outcomes are to be achieved.[15]

"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.**

[15] Engineering Council UK, 2010, UK Standard for Professional Engineering Competence, p. 15ff

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

**Economic, social and environmental context**

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

**Engineering Practice**

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

All 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.[16] Programme providers of course 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
- 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 in-put 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

[16] eg.: Institution of Engineering and Technology, 2006, IET Handbook for Learning Outcomes for BEng and MEng Degree Programmes

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**."[17]

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:

"Engineering programs must demonstrate that their students attain the following outcomes:

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

[17] Requirements and Procedural Principal for the Accreditation. ASIIN, 2010. Режим доступа: http://www.asiin-ev.de/pages/en/asiin-e.-v/programme-accreditation/requirements-and-procedural-principles.php?lang=EN.

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.

Program outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program. Program outcomes must foster attainment of program educational objectives. There must be an assessment and evaluation process that periodically documents and demonstrates the degree to which the program outcomes are attained."[18]

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."[19]

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

[18] ABET, 2010-2011 Criteria for Accrediting Engineering Programmes, стр. 3. Режим доступа: http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2010-11%20EAC%20Criteria%2011-03-09.pdf. p. 3

[19] ABET, dito, p. 5

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.[20] 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

### 1.4.1. Introduction

The EUR-ACE Framework Standards have been developed by the European Network for Accreditation of Engineering Education (ENAEE) as an agreed and 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 EUR-ACE Framework Standards as a means of recognising and co-ordinating existing national standards and practices. It 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.[21]

[20] ASCE, 2008, Body of Knowledge, 2nd. edition
[21] www.enaee.eu

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

### 1.4.2. 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) [2] published by the European Association for Quality Assurance in Higher Education (ENQA).

The academic standard in EUR-ACE Framework 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 particular traditions and the specific requirements of different branches, cycles and profiles.

The use of Programme Outcomes in EAFS 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 Framework Standards for each of these four elements are outlined briefly in the following sections.

### 1.4.3. Content

Content is the list of engineering topics that it would be expected to be included in the requirements of an accrediting agency. They are expressed in the EUR-ACE Framework Standards as Programme Outcomes and in general terms 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.

### 1.4.4. 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 Framework 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 the 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.

### 1.4.5. 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 Framework Standards specifies requirements for the infrastructure that the accrediting agency should incorporate into its assessment procedures. These are detailed in Section 2 of EAFS 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 EAFS follow very closely those for accrediting agencies developed by ENQA and published as ESG.

### 1.4.6. Accreditation Procedures

EAFS also outlines the procedures that it would expect an accreditation agency to use in making assessments. Again the EAFS requirements follow closely the internationally accepted practice, and specifically the format detailed in ESG [2]. In particular the EAFS requirements expect that an accreditation agency would have documented information available about the following aspects of its accreditation procedures:

- documentation to be provided by HEIs;
- composition of accreditation team;
- 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.

### 1.4.7. Implementation of the EUR-ACE Framework Standards

EUR-ACE Framework Standards is administered by ENAEE which is a non-profit organisation 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 Framework 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 labelled 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 seven 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;
- MŰDEK (Turkey);

– OE (Portugal);
– RAEE (Russia).

A further four agencies have applied for authorisation and their applications are being evaluated:

– OAQ (Switzerland);
– ARACIS (Romania):
– SKVC (Lithuania)
– 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.

#### 1.4.8. Future Developments

The major purpose of EUR-ACE Framework 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 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 FES requirements

The third generation of state educational standards – Federal Educational Standard for Higher Education of the Russian Federation (FES RF) comes into force in 2011-2012 academic years, and 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 state HEIs to get a national accreditation. The 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).

Master studies differentiate between research- and practical-oriented profiles and are to prepare graduates for different types of innovative activity, especially in engineering. Thus, master studies are not considered anymore as a preparatory step to PhD studies as it was earlier. The new master programmes become 'author's programmes': they are developed with consideration of traditions of f HEI's research schools, and give HEIs more academic freedom in curriculum design. The FES extend a freedom in developing of interdisciplinary programmes to integrate knowledge of several closely related specialities. Development of interdisciplinary master programmes is essential for innovative engineering education: innovations in engineering and technology are created on interdisciplinary basis.

The main features of the third generation of Standards are use of the *outcomes-based approach* to programme development and use of the ECTS credits to evaluate the workload of programme modules.

The FES include the following sections:

1. Range of application
2. Acronyms
3. Description of the speciality
4. Description of the graduate's professional activity (both for FCD and SCD programmes)
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 their master programmes within the specified discipline / speciality. *Sections 4 and 5* of the Standards describe the professional activity and the requirements for graduates' competencies following the tradition of the Russian higher school. The *section 4* includes fields, objects, types and tasks of professional activity that master programmes graduates must be able to achieve / solve. These descriptions serve as a basis for formulation of requirements for programme learning outcomes that are given in section 5. The requirements for programme learning outcomes are presented as competencies (in the FES a *competence* is an integrated term used for knowledge, skills, attitude and experience).

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;
- M.4. State attestation (including master thesis defence).

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 / study forms;
- requirements for programme curriculum (availability of electives, laboratories, internships and research woks; maximum workload per week, maximum contact hours per week, duration of vacation within the academic year);
- faculty requirements;
- requirements for information resources and library infrastructure;
- 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 feature of the third generation of educational standards is *the outcomes-based approach to curriculum design*. The agreed set of requirements to learning outcomes will facilitate the creation EHEA; will eliminate the barriers for graduates' academic and professional mobility; will give universities and students more academic freedom in programme design and implementation. The outcomes-based approach to curriculum design as well as allocation of ECTS credits to learning outcomes and transition to two-tier system will undoubtedly contribute to integration of Russian system of higher education into European higher education area.

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. All standards take into consideration the needs of programme constituencies/stakeholders; the close cooperation with the stakeholders in planning and evaluation of achievement of learning outcomes should be in place.
2. The requirements for learning outcomes (graduates' competencies) include both professional and personal / transferrable skills and knowledge

3. The professional 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.

**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 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.
4. Standards for some specialties 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.

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

A methodology of engineering curriculum design described in this chapter was developed with consideration of modern trends in higher education development such as use of the outcomes-based approach, use of the ECTS credit system, correspondence with national and international accreditation criteria.

### 2.1 Engineering curriculum design and continuous programme improvement

Engineering curriculum design, a first cycle in a programme continuous improvement, is presented by the ABET two loop diagram (Figure 2.1). It has two loops demonstrating the on-going improvement of study process aimed at achievement of programme educational objectives (PEO) and programme learning outcomes (PLO).

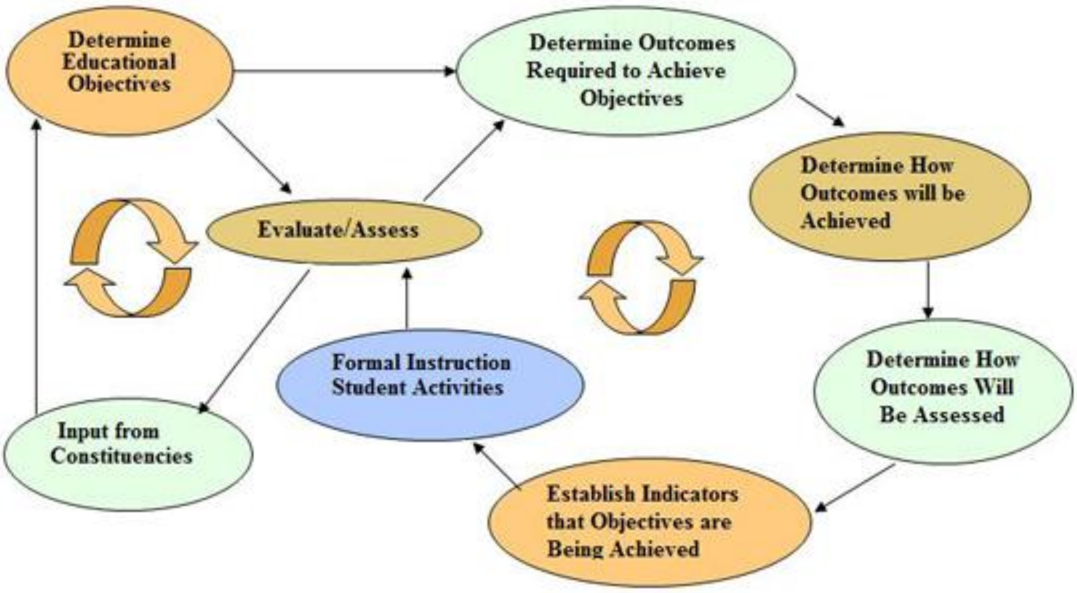


Figure 2.1. ABET Two Loop Diagram

The left loop shows the steps involved in establishing and assessing program objectives; the right loop show how outcomes that support the program'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 is turned over a little bit slower than the internal one: 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.

In accordance with the Figure 2.1. engineering curriculum design includes the following steps:

**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.

**2. Definition of programme educational objectives**

A programme developer must formulate the programme objectives based on the needs of the constituencies (main constituency). The programme objectives must be consistent with the mission of the institution/department to ensure its market competitiveness and demand of constituencies.

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

A programme developer formulates programme *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.

**4. The curriculum design**

A programme developer must plan how the learning outcomes are to be achieved by defining the programme modules that ensure their achievement and by assigning ECTS credits to learning outcomes. Each module has a number of learning outcomes that have their credit value depending on their contribution to achievement of programme outcomes. A teacher responsible for a module must ensure development of its syllabus, teaching technologies, and supporting facilities aiming at achievement of module learning outcomes. Each module must have the assessment methods and tools for achievement of planned learning outcomes. The credits should not be assigned to a module if module does not include assessment of outcomes to be achieved. The notional learning time for a module is defined in accordance with its credit value.

**5. Development of the assessment system for achievement of learning outcomes and programme objectives**

The assessment of achievement of learning outcomes and programme objectives must be done systematically and used for programme continuous improvement. The professional accreditation of a programme by the accrediting agency is an important part of the assessment system of an institution/department.

More detailed description of these steps, including the 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 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' employment, programme financing, programme content, programme evaluation and quality assurance. A programme must be flexible to exist in changing environment: an effective feedback mechanism has to be in place.

The faculty/department delivering the programme must realize itself as a body main responsible body for programme. A programme developer must be aware of modern trends in higher education development (in particular in his field of study) as well as of the requirements of professional organizations and accreditation agencies to graduates' attributes to ensure the recognition of the graduates' competencies.

To be competitive an educational programme must:

– differ significantly from the similar programmes of other HEIs, fully corresponding the needs of its constituencies;

– guarantee the high standards of specialists' training and improve programme continuously.

A systematic survey of constituencies' needs and definition of programme concept and objectives corresponding 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 during survey 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 Master programme "Physics of High Technology in Mechanical Engineering" is aimed at training specialists who will be able to do research in elaboration of new technologies of materials treatment and processing for different branches of mechanical engineering industry. The graduates are prepared to work at the research institutions involved in elaboration of new technologies of materials treatment and processing, e.g. *Institute of Strength Physics and Materials Science of the Siberian Branch of the Russian Academy of Sciences*; industrial plants and companies of the Tomsk Special Economic Zone dealing with development and production of the advanced materials for mechanical engineering, elaboration of the new technological processes for their production; as well as companies using nanomaterials and related products.

The programme focuses on advanced studies in natural and material sciences, usage of new information technologies. The graduates gain experience in usage of the modern research techniques, including new information technologies, and are prepared for development and implementation of the high-tech production of the advanced materials and products for the mechanical engineering industry.

## 2.3. Definition of 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 must 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.

Study process 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.

**<u>Example 2.</u> Programme objectives** *(for SCD programme "Physics of High Technology in Mechanical Engineering")*

The programme graduates are prepared:

O1: for research works at the institutes and companies of material science and mechanical engineering profile of the Tomsk Special Economic Zone;

O2: for research in solving engineering problems in development of new methods for production and processing of new materials;

O3: for engineering activity in development of new materials, modern techniques of materials' and nanotechnologies treatment and processing for mechanical engineering industry;

O4: to run interdisciplinary projects and work in international multidisciplinary team;

O5: to engage in independent life-long learning.

### 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 programme.

The ***programme / module learning outcomes*** describe knowledge, skills, and behaviors that students must demonstrate upon completion of their studies. It is worth noting that learning outcomes 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, behavior and competencies acquired by the graduates upon completion of the programme;

– should be stated such that a students can demonstrate <u>upon completion</u> of the program and <u>before graduation;</u>

– 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, achievement of learning outcomes of compulsory modules must lead to achievement of programme learning outcomes.

**Example 3.** **Programme learning outcomes** *(for SCD programme "Physics of High Technology in Mechanical Engineering")*

The programme graduates should have:

P1: in-depth knowledge materials' characteristics and structure used in mechanical engineering industry;

P2: in-depth knowledge of physics and of usage of plasma, fascicular laser and other modern techniques for new materials treatment and processing in mechanical engineering industry;

P3: the ability to formulate and solve engineering problems in development and treatment of new materials using system analysis and modeling of objects and processes for mechanical engineering industry;

P4: the ability create new and improve the existing technological processes of material treatment ensuring their competitiveness at the global market of mechanical engineering production;

P5: the ability to conduct theoretic and experimental investigations in modern technologies of new materials ' and nanotechnologies treatment and creation;

P6: the ability to implement, operate and maintain the modern tools and equipment for high-tech automated production ensuring their efficiency; to commit to the health, safety and legal issues and responsibilities of engineering practice, to be aware of the impact of engineering solutions in a societal and environmental context;

P7: the ability to integrate knowledge of economics, project management and innovative engineering activity with consideration of legal issues and intellectual property rights protection.

P8: knowledge of foreign language at the level allowing to develop the relevant documentation and present the results of his/her innovative engineering practice;

P9: the ability to function effectively as an individual and as a member and/or leader of multidisciplinary team, to be responsible for the results of the teamwork and to commit to the professional code of ethics;

P10: in-depth knowledge of social, cultural and ethic's context of innovative engineering *practice and* sustainable development issues;

P11: the ability to engage in independent, life-long learning.

The programme learning outcomes are formulated by programme developers based on the 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 to knowledge, skills and behaviors that students must demonstrate upon completion of a module / discipline. 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.

**<u>Example 4.</u> Programme objectives (O) mapped to learning outcomes (P)**

| Learning outcomes | Programme objectives | | | | |
|---|---|---|---|---|---|
| | O1 | O2 | O3 | O4 | O5 |
| P1 | + | + | + | + | |
| P2 | + | + | + | + | |
| P3 | | + | + | + | + |
| P4 | | | + | | + |
| P5 | | + | + | | + |
| P6 | | | + | | |
| P7 | | + | + | + | |
| P8 | | | | + | |
| P9 | | | | + | |
| P10 | + | | | | |
| P11 | + | + | | | + |

## 2.5. Curriculum design

Next steps in engineering curriculum design refer to the internal (right-hand) loop of the ABET diagram (figure 2.1.), in particular, to 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 the programme objectives within the notional learning time, the authors establish the direct relation between learning outcomes and their credit value and then define the notional learning time required to 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.

**<u>Example 5</u>. Allocation of credits to learning outcomes**

| FES | Professional skills | | | | | | Personal / transferable skills | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ECTS credits | 100 | | | | | | 20 | | | | |
| EUR-ACE | Knowledge and understanding | | Engineering analysis | Engineering design | Investigations | Engineering practice | Transferable skills | | | | |
| ECTS credits | 70 | | 8 | 8 | 8 | 6 | 20 | | | | |
| PLOs | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 |
| ECTS credits | | | 8 | 8 | 8 | 6 | 6 | 4 | 4 | 4 | 2 |

Programme learning outcomes are achieved while studying for the programme and successful completion of programme modules and disciplines. A programme developer must design a curriculum including modules and disciplines that contribute to achievement of learning outcomes. Programme modules usually include one or several basic disciples 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; thus 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.**

| Module | Credits | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| INVE511 | 6 | 3 | - | - | 1 | 1 | 1 | - | - | - | - | - |
| | | | | | | | | | | | | |
| PRME501 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - |
| | | | | | | | | | | | | |
| OEMP501 | 4 | 1 | 1 | 1 | - | - | - | 1 | - | - | - | |
| | | | | | | | | | | | | |

### 2.6. Assessing the learning outcomes and programme objectives

Study process must ensure the achievement of learning outcomes by all the students. The programme must have a system ensuring on-going evaluation of the accomplishment of the curricular tasks as well as a feedback mechanism for continuous improvement of the programme. At this stage one should plan how learning outcomes are to be assessed, what assessment tools are to be used and what evidences are required to guarantee the achievement of learning outcomes. Each HEI has a quality assurance system that guarantees the achievement of programme learning outcomes. The system is based on monitoring of student studies for the programme and summative of the achievement of module/discipline learning outcomes. In engineering education it is highly important if the achievement of programme learning outcomes and objectives is evaluated by the professional society (national or international accrediting organizations) through programme accreditation.

The achievement of learning outcomes of particular module must be assessed with a help of the relevant methods and tools ensuring the assessment of students' knowledge and skills. The assessment criteria describe what students / graduates must be able to do to demonstrate the achievement of learning outcomes. The assessment criteria must include the adequate assessment methods and tools. Each module/discipline must have the assessment units, coherent and explicit set of learning outcomes with associated performance and assessment criteria. Performance criteria indicate what concrete actions the student should be able to perform as a result of participation in the programme and state minimum criterion for evaluation. The primary difference between program outcomes and performance criteria is that programme outcomes are intended to provide general information, while performance criteria indicate concrete measurable expectations.

Assessment of achievement of learning outcomes is extremely difficult since the assessment process is related to graduates' professional development survey; employers' survey and analyzing data from different sources out of a HEI. However organization of such surveys is the only way to get the evaluation of achievement of programme objectives and mission of a HEI.

The data get through the surveys of graduates' employability and' professional development 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.

The example of curriculum and syllabi of several modules for the programme *“Physics of High Technology in Mechanical Engineering”* are given below.

**Example 7. Programme** *"Physics of High Technology in Mechanical Engineering"*.

| № | Discipline code | Discipline / Module | Credits | Prerequisites |
|---|---|---|---|---|
| 1. | MASC501 | Current Issues of Mechanical Engineering | 5 | |
| 2. | THER505 | Thermodynamics of irreversible process | 5 | |
| 3. | ENGL501 | Foreign Language | 4 | |
| 4. | MASC520 | Physics and chemistry of nanomaterials | 5 | |
| 5. | METE510 | Special Course of Mechanical Engineering Technology | 5 | |
| 6. | INVE511 | Methodology and experimental investigation Devices in Mechanical Engineering | 6 | |
| 7. | MATH524 | Mathematical Methods of Experimental Data Processing | 5 | |
| 8. | THER513 | Physical Foundations of High-Temperature Technologies in Mechanical Engineering | 5 | |
| 9. | MATH512 | Numerical Calculation Methods in Mechanical Engineering | 6 | |
| 10. | METE533 | Systems Analysis, Simulation and Optimization in Mechanical Engineering | 6 | |
| 11. | PHYS537 | Theory of elasticity | 5 | |
| 12. | INFO515 | Artificial intelligence, Experimental Systems and Knowledge Database in Mechanical Engineering | 6 | |
| 13. | PHYS608 | Tribology | 5 | PHYS537 |
| 14. | TECH609 | Technologies of heterophasis and heterogeneous materials production | 5 | THER505, THER513 |
| 15. | TECH521 | Automated Control of Vacuum Equipment | 5 | |
| 16. | MNGT437 | Project management | 4 | |
| 17. | MNGT452 | Quality management | 4 | |
| 18. | ECON443 | Economics and Administration Problems in Mechanical Engineering | 4 | |
| 19. | LAW414 | Intellectual Property Protection in Engineering Science | 4 | |
| 20. | PROJ501 | Project 1 | 10 | |
| 21. | PROJ502 | Project | 10 | PROJ501 |
| 22. | THES600 | Master thesis | 30 | |

**<u>Example 8</u>. Module** *Methodology and Experimental Investigation Devices in Mechanical Engineering*

**Methodology and Experimental Investigation Devices in Mechanical Engineering**

| | |
|---|---|
| Department: | Physics of High Technology in Mechanical Engineering |
| Discipline code: | INVE511 |
| Level: | 5 (master studies) |
| Credits: | 6 ECTS |
| Prerequisites: | no |
| Author: | Ass. Prof. Korosteleva E.N. |
| Lectors: | Ass. Prof. Korosteleva E.N.<br>Ass. Prof. Fedorov P.S., Ass. Prof. Serov N.N., Lecturer Tutin A. V., Lecturer Mamonov N.M. |

Learning outcomes:

M1: knowledge and understanding of the main principles of research work; basic and special methods and devices for investigations in high-tech mechanical engineering industry;

M2: knowledge and understanding of physical principles of qualitative and quantitative structural analysis of materials, products, methods and tools for analysis of physical and mechanical characteristics of new materials and products;

M3: knowledge and understanding of physical principles of optical geometry, optical, electronic and X-ray microscopy; methods of scientific and engineering analysis of investigation results;

M4: the ability to choose and use the methods and tools for analysis of physical and mechanical characteristics of new materials and products; to plan, run and assess the results of investigations; to formulate engineering problem with consideration of availability of relevant materials and tools; to integrate different investigation methods and techniques for decision of mechanical engineering tasks;

M5: the ability to use optical, electronic and X-ray microscopy for studying of mechanical and physicochemical characteristics of new materials and products for mechanical engineering industry;

M6: the ability to work in multidisciplinary team ensuring effective decision making in studying of characteristics of new materials and products for mechanical engineering industry.

| | |
|---|---|
| LECTURES | 36 / 72 hrs |
| LABS | 36 / 36 hrs |
| SEMINARS | 18 / 36 hrs |
| CONTACT HOURS | 90 hrs |
| SELF-STUDY | 144 hrs |
| TOTAL | 234 hrs |
| ASSESMENT | Exam |

**<u>Example 8</u>. Module** *Economics and Administration Problems in Mechanical Engineering*

**Economics and Administration Problems in Mechanical Engineering**

| | |
|---|---|
| Department: of | Economics |
| Discipline code: | DEMP501 |
| Level: | 5 (master studies) |
| Credits: | 4 ECTS |
| Prerequisites: | |
| Author: | Prof. S. L. Eremina |
| Lectors: | Prof. S. L. Eremina, Ass. Prof. P.S. Sidorov, Ass. Prof. N.N. Sedov, Ass. Prof. A.V. Kutin, Ass. Prof. N.I. Massonov |

Learning outcomes:

M1: knowledge and understanding of new methods for decision of the management tasks and for organisation of different types of activity including business plan and decision making;

M2: the ability to use the new methods of economic analysis, methods of assessment of economic and social efficiency of production; to assess the competitive ratio of mechanical engineering production;

M3: the ability to knowledge in project management for engineering problems taking into account legal issues of innovative activity;

M4: the ability to assess the availability of commercialization of new developments for both national and international markets of mechanical engineering industry.

| | |
|---|---|
| LECTURES | 24 / 48 hrs |
| SEMINAR | 24 / 48 hrs |
| CONTACT HOURS | 48 hrs |
| SELF-STUDY | 96 hrs |
| TOTAL | 144 |
| ASSESMENT | Exam |

**<u>Example 8</u>. Module** *Research Project 1*

**Research Project 1:**

| | |
|---|---|
| Department: | Physics of High Technology in Mechanical Engineering |
| Discipline code: | PRME501 |
| Level: | 5 (master studies) |
| Credits: | 10 ECTS |
| Prerequisites: | no |
| Author: | Ass. Prof. Korosteleva E.N. |
| Lectors: | Prof. Psachie S.G., Prof. Kulkopv, Prof, Mulin, V.A., Ass.Prof. Korosteleva E.N., Ass. Prof. Fedorov P.S., Ass.Prof. Serov N.N. |

Learning outcomes:

M1: knowledge and understanding of physical principles of qualitative and quantitative structural analysis of materials, products, methods and tools for analysis of physical and mechanical characteristics of new materials and products;

M2: the ability to conduct theoretical and experimental investigations in new materials treatment, development of new nanomaterials and nanotechnologies;

M3: the ability to use optical, electronic and X-ray microscopy for studying of mechanical and physicochemical characteristics of new materials and products for mechanical engineering industry;

M4: the ability to develop new and improve the existing technological processes of quality control of material treatment for mechanical engineering industry;

M5: the ability to operate and maintain modern equipment ensuring its high efficiency; to commit to health and safety issues, to be aware of the impact of engineering solutions to environmental context

M6: the ability to solve engineering problems related to development of new materials and technologies of material treatment in mechanical engineering;

M7: the ability to use knowledge of project management, legislation in innovative engineering activity and intellectual property rights protection in scientific research and investigations;

M8: the ability to use knowledge of foreign language for searching new data, studying technical documentation, presentation of research results;

M9: the ability to work efficiently individually and as a member and/or leader of the team; to be responsible for results of the teamwork;

M10: knowledge and understanding of social, ethic and cultural aspects of innovative engineering activity, awareness and competence in sustainable development issues.

| | |
|---|---|
| SELF-STUDY | **360 hrs** |
| TOTAL | **360 hrs** |
| FORM OF CONTROL: | Report |