The Projecting of Qualification Framework for Engineering Domains

Petru Todos* and Stela Țicul**
* Technical University of Moldova, Vice-rector, Chisinau, Republic of Moldova
** Technical University of Moldova, Department of Quality Management, Chisinau, Republic of Moldova

Abstract – **Within this paper we present a model of elaboration of National Qualification Framework and Study Programs for engineers' training on the basis of a competitive approach, European Credit Transfer System (ECTS), and the demands of the new higher educational structure on cycles: Bachelor-Master-Doctorate (B-M-D). This model constitutes the basis of all study programs in engineering domains proposed by the Technical University of Moldova, for example Engineering and Industrial Technologies, Energetics, Electrical Engineering, Technology of Food Products, Materials Technology etc.**

I. Introduction

Higher education in Republic of Moldova is now on a very important stage of great changes. At the end of this academic year, thousands of graduates from the first cycle (Bachelor) will pass to the second cycle (Master). The implementation of the first cycle was accompanied by a series of problems. Despite this, the majority of already existing courses could be modified and adapted to the requirements of the new system, with duration of 3 or 4 years of study for Bachelor program. It is true that this adaptation was often made mechanically, without a profound understanding and an adequate projecting of training programs on the basis of expected competences that students should acquire during this cycle.

Nowadays, there is another situation when faculties/chairs have to elaborate the concept, structure, standards and study plans for each specialty, and to assure the didactical-material base for the new Master programs which should be competitive to the European ones.

Only an adequate defining of competences for the second cycle in strong connection with competences of the first cycle and those defined for the third cycle (Doctorate) can create the premises for obtaining the final results determined by Bologna Process in order to correlate them with the European Higher Educational Area, international recognition, and compatibility of qualifications.

The educational system reorganization on three cycles, on the one hand, and the elaboration of new Curriculum, on the other hand, will assure an optimal and effective relation between those three levels/cycles, and a well performed architecture of study plans.

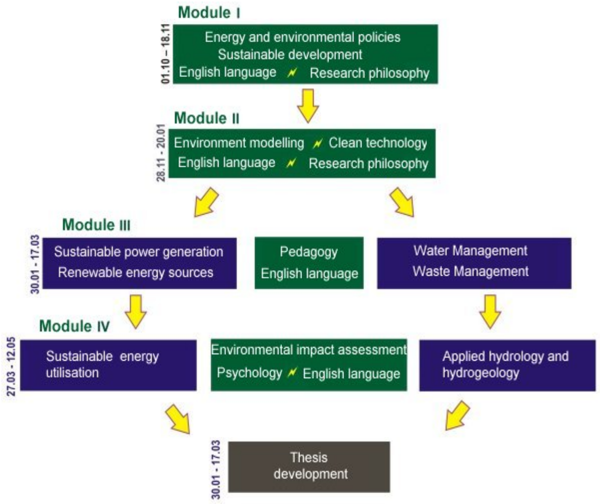
Engineers' training constitutes in these conditions an essential segment of higher educational schools from Republic of Moldova. The future potential of national industry and other economical branches, the possibilities of European and world integration will depend on the degree of engineers' qualification and skills. Thus results the necessity for adjusting engineering training programs, titles and qualifications granted to graduates from our universities to the demands of Bologna process oriented towards the creation of an Educational and Research European Area by the end of 2010. The recognition of our graduates' diploma on the European labor market will greatly depend on the competences acquired by these young men during the educational/training process.

Technical University of Moldova, together with other universities from our country, that offer engineering specialties, was entitled by the Ministry of Education and Youth of Republic of Moldova to define the content of National Qualification Framework (professional standards), that corresponds to the 6, 7, and 8 levels of the European Qualification Framework (ECF), and to study plans for domains of engineering professional training during Bachelor and Master cycles/programs, and was also entitled to develop the curriculum for these two cycles. The content and quality of these documents will assure an adequate compatibility and competitiveness of the engineering education in Republic of Moldova in comparison with that offered by West European universities.

This work presents a useful model of concomitant elaboration of specialists training programs for engineering domains at Bachelor and Master levels.

As a result of National Qualification Framework's elaboration there were made great changes in the curricula of all study programs, and there were also implemented new Master programs, as for example the Master program "Environment and Clean Technologies", with the specialization "Energy and Environment" (www.utm.md/master). The Master Program in Environment and Clean Technologies provides a qualitative education in the Energy and Environment domain, through a sustainable politics and attitude concerning the energy use and production, as well as the environment protection. The realization and implementation of this Master program is elaborated in co-operation with the Royal Institute of Technology, Sweden (KTH), State University of Moldova (SUM), Technische Universitat Berlin, Germany (TUB), Academy of Science of Moldova (ASM) being supported by the Ministry of Environment and Natural Resources and Ministry of Energy.

The structure and the courses provided by this program are presented in the picture below:



II. USED METHODOLOGY AND PRINCIPLES

When projecting the National Framework of Qualifications for engineering domains there were taken into account:

- The reports of Bologna working team [1, 2],
- The directives and documents of EU Commissions [3, 5], and
- Tuning reports [6, 8]

elaborated for different domains in cooperation with specialists from European Higher Educational Area, and especially on the basis of the experience acquired in European Universities like Royal Institute of Technology, Sweden (KTH), State University of Moldova (SUM), Technische Universitat Berlin, Germany (TUB), Academy of Science of Moldova (ASM), University of Gent, Belgium, University Rennes 2, France, University Paris 12, France, Polytechnical Institute of Toulouse, France, Technical University of Iasi, Romania. There was also used the already existing experience and potential of our higher educational school in the domain of planning specialists' training process for national economy, it was taken into account the experience and all the mistakes that had been made during 1998-2005 due to the replacement of the existing period of study of 5 years with 4 years, and due to educational standards on specialties elaborated in the period of 2002-2003.

At the elaboration of Qualification Framework (educational standards) for engineering training domains there should be considered the following principles, reflected as basical elements of Educational Law (provisions regarding the organization of Bachelor and Master Degree studies) and the Plan-cadre, as well as other normative acts:

- *The divisibility and integrity principle*. Higher education is organized in three distinct cycles, B-M-D, but which are linked one to each other, and the results of each cycle represent a starting point (an input) for the following cycle. Thus, for example, when projecting Master programs it should be taken into account the previous stage (there will be imposed some conditions, preliminary requisites for each Master Degree program regarding candidate's training during the first cycle), and the need to train Master Degree students for the third cycle (Doctorate) - these being the preliminary requisites for Doctorate. There will be also used the same program planning mechanisms for all the three cycles;
- *Consecutiveness and continuity principle*. Each following cycle is oriented towards gnosiological competences and professional skills training, leadership skills and scientific research abilities development;
- *Formative continuity principle* – skills development for lifelong study;
- *Flexibility principle* – the creation of continuing modernization possibilities, permanent adaptation to dynamic changes on labor market regarding graduates competences;
- *Modular principle study organization* with multiple possible directions which should be followed during each program.

At the elaboration of National Qualification Framework for engineering domains there were taken into account the provisions of the project of Regulation on Master Degree studies organization, the second cycle that stipulates the following:

1. Master Degree studies are organized in two forms: Professional Master Degree studies, and Academic Master Degree studies;
2. the admission to Academic Master Degree studies is conditioned by some preliminary requisites – fundamental and special courses which will be taken during the first cycle or facultative before the admission to Master Degree studies;
3. individual or team activities become prior;
4. the research or conceptual projecting component becomes the basical subject of Master Degree studies;
5. Master Degree studies are organized on interdisciplinary basis.

III. GENERAL STRUCTURE OF THE MODEL

On the basis of the above mentioned principles, and taking into account the normative recommendations and restrictions, the process of projecting the Qualification Framework for a certain domain, for example Electrical Engineering, is realized by following several basical steps:

- The formation/training of future specialist's competitive model for a certain domain (the determination of generic and specific competences);
- The appreciation of competences included in the model on credit basis;
- The naming of module which will assure the realization of envisaged competences;
- The formation of study directions within the domains/specialties – the assurance of students' internal mobility (between domains and specialties).

IV. Basically Stages and Steps of the Model

Further we present a short description of the steps taken within these stages of Qualification Framework projecting.

A. The competitive model of the specialist is formed by analyzing:

- The standards of occupational classifier on domains;
- The results of employers' questioning;
- The results of staff questioning;
- The results of graduates questioning;
- The national and world experience in the domain.

As a result there are formulated the competences necessary to our graduates for a successful employing on the labor market. We should also make a distinction between professional competences and social competences, generic competences and specialization competences.

Generic competences can be classified into: instrumental, personal and systemic.

Instrumental competences refer to: capacity to analyze and synthesize, organizational and planning capacities, basical general capacities, communication capacities, knowledge regarding working on the computer, information management, capacity to solve different problems, and capacity to make decisions.

Personal (interpersonal) competences refer to: capacity to criticize and self criticize the ability to work in an interdisciplinary team, international relations skills, ability to work with experts from other domains, capacity to perceive the intercultural diversity and multitude, capacity to work in international context, ethic values knowledge.

Systemic competences refer to: aptitude to apply knowledge in practice, capacity to learn, capacity to adapt to new conditions, capacity to generate new ideas, capacity of leadership, capacity to understand the culture and customs of other countries, capacity of project elaboration and management, capacity to take the initiative, responsibility for quality, the wish to obtain success.

Specific competences are separately defined for each domain of professional formation/training or specialty, and aim at student's training for an immediate employment on the labor market. For domains of engineering formation/training, these competences will be centered on the following prior activities of the specialist, graduates of these programs [9]: engineering analyses, engineering projecting, research, and practice in engineering.

Further we present a competitive generalized model of engineer, describing: engineering profession, engineers' functions, and general competences defined for graduates from engineering programs.

Engineer's profession

The basical job of engineers consists of permanent solving of complex problems in an original manner, problems that deal with: conceiving, realization and implementation of systems or services of financing and selling of goods within an organization. Thus, the engineer should have a set of technical, economical, social and humanity knowledge based on a large scientific culture.

The activity of engineer is mostly realized in industry, constructions, public works, agriculture and services. It often mobilizes human potential, technical and financial means in an international context. It obtains an economical and social appreciation (sanction), takes into account human, life and environment protection, and in general the collective wealth. Certainly this is the multidimensional profession students from engineering domain are trained for.

Engineer's functions

The professional certification of engineers is based on the following general qualities obtained during the formation/training cycle:

1. The knowledge and understanding of a variety of fundamental sciences;
2. Aptitudes to mobilize the resources of a technical and scientific domain of specialty;
3. The knowledge of engineering methods and instruments:
   - problem identification and solving (problems that are often unknown and not completely defined);
   - data collection and interpretation;
   - the usage of informational means;
   - the analyzing and conception/conceiving of complex systems;
   - experimenting;
4. The capacity to integrate him-/herself in an organization, to impel and develop it:
   - team spirit;
   - capacity of enrollment and leadership;
   - project management, work supervising;
   - capacity to communicate with specialists and non-specialists;
5. The capacity to take into account the industrial, economical and professional risks:
   - competitiveness and productivity;
   - innovation;
   - intellectual and industrial property;
   - taking into account quality and security procedures;
6. Aptitudes to work in an international context:
   - knowledge of one or more foreign languages;
   - security and economical intelligence;
   - cultural opening;
   - international experience;
7. Taking into account cultural values:
   - knowledge regarding social relations;
   - environment and sustainable development;
   - Ethics.

B. The determination of each competence "contribution" (the second step) to the formation of an upright portrait of the specialist will be realized on the basis of an expert analysis (project team) by presenting the results in percents or decimal fraction. For example:

Competence 1	Competence 2 …	Competence n
20% (0.2)	45% (0.45)	X% (0.001 X)

The importance of competences will of course vary between cycles and domains. For example, for License programs oriented towards specialists' training in the fields of production, exploiting and services, a greater stress will be laid on:

- formation of enterprise spirit;
- environment and sustainable development;
- production, exploiting and maintenance;
- quality, security.

The content of Master Degree programs will be more important to competences and skills training that are linked with:

- analyzing and conceiving of complex systems;
- innovation and research;
- projects and enterprises administration.

Below it is presented a general description of exigencies on cycles of specialists' training/formation for engineering domains which could be useful to the differentiation of the importance of competences [9].

Engineering analysis

Graduates should be able to solve engineering problems that correspond to their level of knowledge and understanding, and which could also require some other knowledge from other domains. The analysis can include: problem identification, taking into account possible methods of solving, the best methods selection, and correct implementation. Graduates should also be capable to use a variety of methods, including mathematic analysis, computer modeling or practical experiments, to recognize the importance of social, health and safety, environmental and commercial constraints.

The graduates from the *first cycle* should demonstrate:

- ability to apply in practice their knowledge and understanding in order to identify, formulate and solve engineering problems using already known, elaborated and established methods;
- ability to apply in practice their knowledge and understanding in order to analyze products, processes and engineering methods;
- ability to select and apply in practice relevant analytical and modeling methods.

The graduates from the *second cycle* should demonstrate:

- Ability to solve unknown problems, which are not completely defined and have competing specifications;
- Ability to formulate and solve problems which arise within their specialization due to the appearing of new domains;
- Ability to use their knowledge and understanding in order to conceptualize engineering models, systems and processes;
- Ability to apply innovative methods in problem solving.

Engineering design

Graduates should be able to realize engineering designs/projects according to their level of knowledge and understanding, working in cooperation with engineers and non-engineers. This could be the design/project of a mechanism, process, method or artifact, and all the specifications can rise from the limit of technical ones, including the knowledge of social, health and safety, environmental and commercial considerations.

The graduates from the *first cycle* should demonstrate:

- Ability to apply their knowledge and understanding to projects elaboration and realization, thus answering to all defined and specified needs;
- Understanding of projecting methods and methodologies, and ability to use them.

The graduates from the *second cycle* should demonstrate:

- Ability to use their knowledge and understanding in the elaboration of solutions for unknown problems, possibly implying other disciplines/domains;
- Creativity in the elaboration of new and original ideas and methods;
- Ability to use the engineering understanding in order to work with the complexity, technical insurance and incomplete information.

Research

Graduates should be able to use adequate methods in order to make research and other detailed investigations of technical problems according to their level of knowledge and understanding. Investigation can imply literature search, experiment projecting and realization, data interpretation and computer simulation. Graduates will have to consult data bases, codes of practice and regulations.

The graduates from the *first cycle* should demonstrate:

- Ability to search adequate literature and to use data bases, as well as other informational sources;
- Ability to project, realize and supervise experiments, to interpret/understand relevant data and make conclusions;
- Ability to work within a laboratory or workshop.

The graduates from the *second cycle* should demonstrate:

- Ability to identify, localize and obtain the necessary data;
- Ability to project and supervise/conduct analytical, modeling and experimental investigations;

- Ability to critically evaluate data and make conclusions;
- Ability to investigate the application of new technologies that appear within their engineering domain.

Engineering practice

Graduates should be able to apply their knowledge and understanding to the development of practical abilities necessary for problems solving, realization of investigations and projecting of engineering mechanisms and processes. These abilities can include the materials knowledge, usage and limitations, computer modeling, engineering processes, equipment work practice in workshops, as well as technical literature and informational sources. They should also recognize the wider, non-technical, implications of engineering practice, as well as ethical, environmental, commercial and industrial implications.

The graduates from the *first cycle* should demonstrate:

- Ability to select and use adequate equipment, instruments and methods;
- Ability to combine theory with practice in order to solve engineering problems;
- Understanding of applicable techniques and methods and their limitations;
- Considering the non-technical implications of engineering practice.

The graduates from the *second cycle* should demonstrate:

- Ability to integrate their knowledge from different domains;
- Comprehensive understanding of applicable techniques and methods and their limitations;
- Knowledge and understanding of non-technical implications of engineering practice.

Transferable abilities

Within this program there should be developed all the abilities necessary for engineering practice which are applied in the entire world, in different domains.

The graduates from the *first cycle* should demonstrate:

- Effective functioning as an individual person and as a member of a team;
- Usage of different methods in order to effectively communicate with the engineering community and society in general;
- Knowledge of problems and legal, health and security responsibilities of the engineering practice, of the impact of engineering solutions on social and environmental context in accordance with professional ethics, responsibilities and norms of engineering practice;
- Knowledge of project management and business practice, as well as the risks and changes management and understanding of their limitations;
- Ability to recognize lifelong learning necessities and ability to realize an independent research.

The graduates from the *second cycle* should demonstrate:

- The accomplishment of all requests regarding the transferable skills possession necessary to all graduates from the first cycle in order to pass to the second one;
- Effective functioning as a leader of a team that could consist of different disciplines and levels;
- Effective work and communication in national and international contexts.

C. The passing from competences to module or study disciplines constitutes the basis of the future study plan.

Step I. Curriculum components are compound.

Step II. The study process is optimized by eliminating all the disciplines/courses that are “unnecessary” and introducing disciplines that are considered necessary for the already mentioned competences, the analysis of obligatoriness and consecutiveness of disciplines study.

Step III. There are underlined the interdisciplinary links. It is determined the “importance” of disciplines within each competence with the help of expert method. For example:

Competence 1 (10% of success)

Discipline 1	Discipline 2	Discipline m
25% Competence 1	10% Competence 1	y% Competence 1

Step IV. It is determined the number of ECTS study points/credits for each competence and discipline of the training program, taking into account that one year of study is equivalent to 60 credits, the total number of credits for the entire first cycle for general domains of study 52, 54, 55, 58 (engineering, technologies of processing, architecture and constructions) is 240 credits, and for Master Degree program – 90 credits. The importance of the course/modulus expressed in credits is determined by pDj= 0,01* X *0,01*Y* (total number of credits).

Step V. It is determined the workload expressed in hours necessary for learning – the passing from credits to hours. It is designed the plot of study plans, taking into account time norms (hours in class – 27-28 per week for the first cycle, and 16-20 hours per week for the second cycle) and all the limitations regarding the number of evaluations during sessions.

Students’ initiation into enterprise’s life and the realization of professional activity is integrated in the program through different types of probation, especially a long probation period within an enterprise, which are also included in the program and integrated in the European Credit Transfer System. The total duration of probation periods can vary according to the domain of formation/training.

D. The determination of study directions represents a very important stage, aimed at satisfying individual demands of students and possible demands of different groups of employers, and also to the creation of specializations and options within the domain. Due to this fact, the number of hours and the content of related disciplines are unified in order to organize study activities as module. It is also accepted the free choice of disciplines in order to establish a variable component of competences.

V. Conclusions

On the basis of the model described above there were elaborated the following National Qualification Frameworks: Engineering and Industrial Technologies, Energetics, Electrical Engineering, Technology of Food Products, Materials Technology etc., applied in Bachelor and Master programs. There were also revised all the study programs for Bachelor cycle. A real example of applying the National Qualification Framework into practice is the implementation of the Master program "Environment and Clean Technologies". Another Master program that is in course of elaboration and implementation beginning with the academic year 2008/2009, based on the National Qualification Framework, is "Engineering and Quality Management". On the basis of this paper and of the National Qualification Frameworks elaborated at our university are the European normative acts and documents and directives that constitute the starting point for our higher educational institutions in order to align to European higher education, and also to comply with the demands of European labor market

References

1. *The framework of qualifications for the European Higher Education Area.* Bologna Working Group on Qualification Framework. /http://www.bologna-Bergen2005.no/
2. EUR-ACE. Framework Standards for the Accreditation of Engineering Programs. 2005.
3. Directive 205/36/EC of 7 September 2005 on the recognition of professional qualifications. Official Journal of the European Union. 30.9.2005.
4. SEC (2005) 957.Commisssion des Communautes Europeenes. Document de travail de la Commission.Vers un Cadre Europeen des Certification Proffessionelles pour la formation tout au long de la vie. Bruxelles. 8.7.2005.
5. *COM (2006) 479 final 2006/0163(COD)).* Mettre en oeuvre le Programme communautaire de Lisbone. Recommandation du Parlement Europeen et du Conseil, йtablissant le cadre europйen des certifications pour l'apprentissage tout au long de la vie. Bruxelles. 5.9.2006.
6. Paul Ryan, National *University of Ireland. Galway. Welcome to the Afternoon Session*. Tuning in Practice. Tuning applied.
7. *Tuning Educational Structures in Europe. Final Report...* Pilot Project- Phase 1. Socrares, 2003. http://europa.eu.int/comm/education/policies/educ/tuning_en.html
8. *Tuning Educational Structures in Europe II.* Universities' contribution to the Bologna Process. Edited by Julia Gonzalez, Robert Wagenaar. 2005, http://europa.eu.int/comm/education/policies/educ/tuning_en.html,
9. Commission des Titres d'ingeneur, France. *References et Orientations*. 2006.
10. www.utm.md/master