Harmonizing Civil Engineering Education

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Abstract *— Uniformity never will be the objective of education, yet some level of compatibility can be useful or even indispensable. Though academic teachers are rather attached to the idea of University autonomy and freedom than to any form of harmonization, some harmonization is necessary to assure readable and comparable professional degrees, as well as comparable criteria of quality assurance, irrespective of Country and University of graduation. At the stage of studies this should facilitate students' exchange. Unequivocal definition of particular professionals' knowledge, skills and attitudes is necessary from the employee's point of view. In the beginning of 21st century the question what should be taught must be put with regard to integration processes, which are observed in global range. This situation constrains new commitments to the sphere of engineering education, which should be broader and more interdisciplinary directed, preserving its depth and high technical quality. In this paper the particular attention will be given to the question what should be taught at Civil Engineering faculties. The answer for this question will be based on elaborations of European project on Studies and Recommendations on Core Curricula for Civil Engineering developed within the Thematic Network EUCEET* and documents of American Society of Civil Engineers (ASCE). The recommendations of the Bologna Declaration convened in June 1999 will be taken into account as well. This recommendations not only create a good basis to build the European Area of Higher Education, but also can be useful in wider, global scope. In USA the Body of Knowledge Committee of the American Society of Civil Engineers defined the Body of Knowledge for Civil Engineering education presenting the recommendations arranged by three themes: 1) what should be taught to and learned by civil engineering students; 2) how should it be taught and learned; and 3) who should teach and learn it. In the present paper the special attention will be given to the first point, which was formulated in terms of outcomes of education. The answer for the question "what should be taught?" can be given not only in terms of outcomes of the educational process but in terms of subjects and their syllabi as well. So this problem is being solved within the Thematic Network EUCEET. The specific project "Studies and Recommendations on Core-Curricula for Civil Engineering" was launched in 2003. So far the list of 25 core subjects was determined, credit points were assigned and frame syllabi determined to the core subjects. The compilation of the Bologna Declaration, ASCE Body of Knowledge Committee recommendations and the results of EUCEET Core-Curricula Studies can create a base to determine the rules of harmonization for Civil Engineering education in the global scale.*

Index Terms *— Civil Engineering education, Bologna Declaration, EUCEET, Outcomes of education, Core-curricula.*

INTRODUCTION

What should be taught and how it should be taught and learned? These questions always should be present in every education activity. Regarding the engineering education currently they should be put in close context with some features of the globalization process as well as with the specific role of an engineer in the present world. The engineering educators should be aware that the dominating influence of the technology on human life in 21st century puts an engineer at the exposed position. Today an engineer cannot remain just a specialist, who knows how to design and build an engine, a building or a bridge. He must know not only how to solve the problem, but must be aware what will be the impact of his solution for future development of the mankind. That is the position of the society leader. Unfortunately it is not at all the honorable position, as it creates serious responsibilities. This situation in turn constrains new commitments to the sphere of engineering education. Briefly speaking present engineering education should be broader and more interdisciplinary, preserving its depth and high technical quality. Thus the reflection what and how should we teach is particularly important now. This results, among others, in defining the profile of a particular professional including knowledge, skills and attitudes, which he/she should receive irrespective to the place of study and graduation. Some accomplishments in the area of civil engineering education will be presented further on.

EUROPEAN DIVERSITY AND BOLOGNA DECLARATION

In contradiction to United States, which is a big country spread over a big continent, Europe consists of a number of countries with their national ambitions pushed into a small continent. The diversity can be beautiful but it can be burdensome as well. In particular it does not facilitate the inter-university cooperation and pan-European employment. Wide survey of the state of European university education carried on in the end of 20th century revealed huge diversity of European educational systems,

* European Civil Engineering Education and Training.

incomparable and sometimes unreadable professional degrees and many other obstacles handicapping inter-university cooperation and pan-European employment. As the result in 1998 the Ministers of Education of 29 European countries convened at the eldest European University in Bologna the Declaration aimed on creating pre-conditions for the European Area of Higher Education. As it could be expected the initial reaction for this Declaration was not so enthusiastic. Many people from the academic milieu considered the Declaration as the document enforced by politicians and functionaries from the European Commission. Nowadays this approach has changed and we deal with so called "Bologna Process". Many new countries signed the Declaration and two subsequent meetings in Prague (2001) and in Berlin (2003) significantly accelerated this process. Many antagonists realized that the success of the education does not depend on the educational system and official regulations but mainly on the engagement of human element: academic teachers with their knowledge and experience and students with their aptitude and motivation. Currently it seems to be widely accepted, that four recommendations of the Bologna Declaration:

- adoption of a system of easily readable and comparable degrees,
- adoption of a system based on two main cycles, undergraduate and graduate,
- establishment of a comparable system of credits,
- developing comparable criteria and methodologies of quality assurance with view to accreditation procedures and criteria,

create the good basis to build the European Area of Higher Education. In my opinion they can be accepted and useful in harmonising the education in much wider, even global scale.

AMERICAN BODY OF KNOWLEDGE

The steps towards harmonizing the education at the university level can be observed in USA as well. In 2001 the American Society of Civil Engineers (ASCE) formed the Body of Knowledge (BOK) Committee and its charge included defining the BOK for Civil Engineering education. The BOK Committee presented its recommendations arranged by three themes:

1) what should be taught to and learned by civil engineering students;
2) how should it be taught and learned;
3) who should teach and learn it.

In the present paper the special attention will be given to the first point.

The *"what"* recommendations are expressed in terms of 15 outcomes. BOK Committee have adopted 12 outcomes of education in the form used by the American Accreditation Board and added 3 additional ones specific for the Civil Engineering. The list of outcomes of the education consists of 15 outcomes arranged in 3 groups:

- scientific and technical competence outcomes,
- professional skills outcomes,
- personal attitude outcomes.

Knowledge, skills and attitudes in the outcomes include 3 levels of competence:

- Recognition – a reasonable level of familiarity with a concept,
- Understanding – a thorough mental grasp of a concept or topic,
- Ability – a capability to perform with competence.

The highest level is appointed to the group of scientific and technical competence outcomes and to two professional ones. Being aware that the engineering education must be broader now we cannot require from every student highest level of competence in new, non-engineering disciplines. For sure the graduates of engineering faculties should have the recognition of public policy and administration fundamentals, but just the recognition seems to be enough. Only very few of our graduates will need more in their professional life and those should learn it in their postgraduate stage of career.

In the *"how"* recommendations BOK Committee mentions the existing courses on undergraduate and graduate level supplemented by some co-curricular and extra-curricular activities like internships, undergraduate para-professional employment, and relevant part-time or full-time para-professional employment prior to earning a BS degree. It is emphasized that the required level of competence in specific outcomes should be achieved during the undergraduate studies. The role of practical experience gained due to above-mentioned co-curricular activities in this study period is very important too. Finally the necessity of life-long-learning and post-BS engineering experience prior to licensure in fulfilling the BOK requirements is emphasized. In this phase comprising all the professional life everybody should endeavor to reach the professional excellence.

CORE CURRICULA BY EUCEET

In 1998 within the SOCRATES scheme the Thematic Network EUCEET was launched. Since 2003 the specific project "Studies and Recommendations on Core-Curricula for Civil Engineering" is being realized and currently it is in the final phase. The recommendations of American BOK Committee expressed in terms of outcomes of the educational process have been adopted in this project with slight changes. Current form of these outcomes proposed by EUCEET together with required levels of competence comprise:

- ***Scientific and technical competence outcomes:***

1. An *ability* to apply knowledge of mathematics, science and civil engineering, including specialized area related to civil engineering;
2. An *ability* to identify, formulate and solve engineering problems;
3. An *ability* to design a system, its' component or process to meet desired needs;
4. An *ability* to design and conduct experiments, as well as analyze and interpret data;
5. An *ability* to understand the techniques, skills, and modern engineering tools necessary for engineering practice;

- ***2. Professional outcomes:***

6. An *ability* to function on multi-disciplinary teams;
7. An *ability* to communicate effectively;
8. An *understanding* of the elements of project, construction, and asset management;
9. An *understanding* of the role of the leader and leadership principles;
10. A *recognition* of business and public policy and administration fundamentals;

- ***Personal attitude outcomes:***

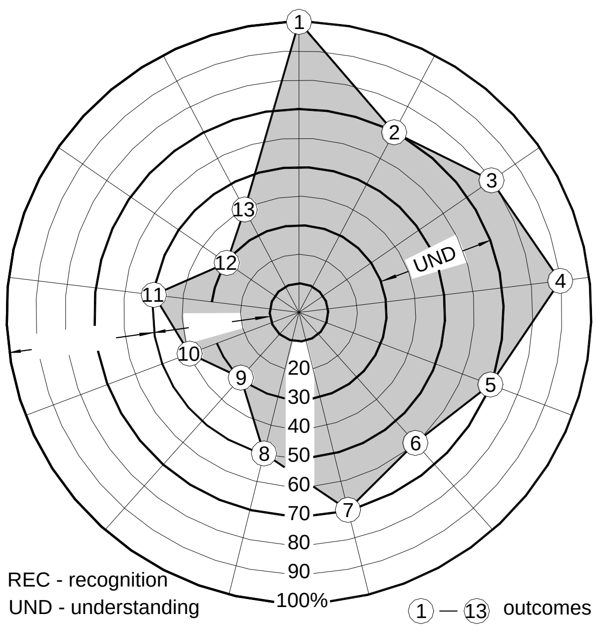
11. An *understanding* of professional and ethical responsibility;
12. An *understanding* of the engineering solutions' impact in a global and societal context (need of broad education and knowledge of contemporary issues);
13. A *recognition* of the need for, and an *ability* to engage in life-long learning.

Knowledge, skills and attitudes in the foregoing outcomes include 3 levels of competence:

- *Recognition* – a reasonable level of familiarity with a concept,
- *Understanding* – a thorough mental grasp of a concept or topic,
- *Ability* – a capability to perform with competence.

The circular diagram of outcomes drawn over the scale of competence is presented in fig. 1.

FIGURE 1
OUTCOMES VERSUS LEVELS OF COMPETENCE



The circled numbers 1-13 indicate outcomes of education. The concentric circles represent levels of competence in percents. Thickened circles separate 3 above determined levels of competence. Obviously the perfect graduate will achieve 100% competence in each of outcomes, but the reality is not so optimistic. The irregular polygon represents the overall competence of a particular graduate and the ratio of its' area to the area of the external circle can be considered as the overall grade of a graduate. This what is represented in fig. 1 seems to fulfill the above-mentioned requirements.

Outcomes of the education determine the general answer for the question "what should be taught", yet this question can be asked in terms of subjects and their syllabi as well. In particular though it is fully acceptable that the graduate should achieve "an ability to apply knowledge of mathematics, science and civil engineering" the question appears what parts of mathematics are most useful for a civil engineer education, what domain of the science and civil engineering should know every graduate of the Civil Engineering faculty. The BOK Committee solves this problem adding some commentaries to every outcome. In EUCEET SP1 project the list of 25 core subjects was determined and credit points for different types of courses were assigned to the core subjects.

The list of core subjects and average credit points calculated on the base of wide inquiry (rounded to 0.5) for two types of courses – 4-year and 5-year – are given in the table 1. The data in the column for the 4-year course can be considered as well as the recommended credit points for the first stage of the two-tiers system recommended by the Bologna Declaration. The average credit points are just the result of calculations rounded to 0.5. Finally the credits will be proposed with some range dependant on the dispersion of data.

TABLE 1
CORE SUBJECTS AND THEIR CREDIT POINTS

No	SUBJECTS	4-years course Credits	5-years course Credits
1	Mathematics and Applied Mathematics	16.0	23.0
2	Applied Chemistry	3.0	3.5
3	Applied Physics	5.5	6.5
4	Computer Science and Computational Methods in C.E.	6.5	8.0
5	Drawing and Descriptive Geometry	4.0	5.0
6	Mechanics	5.5	6.5
7	Mechanics of Materials	7.5	9.5
8	Structural Mechanics	8.5	11.0
9	Fluid Mechanics & Hydraulics	5.5	6.0
10	Engineering Surveying	5.0	5.5
11	Building Materials	5.5	6.5
12	Buildings	4.0	4.5
13	Basis of Structural Design	4.5	4.5
14	Engineering Geology	3.5	4.0
15	Soil Mechanics and Geotechnical Engineering	6.5	9.0
16	Structural Concrete	7.5	9.5
17	Steel Structures	6.0	8.0
18	Timber, Masonry and Composite Structures	3.5	4.5
19	Transportation Infrastructure	4.0	4.5
20	Urban Infrastructure	3.0	3.0
21	Water Structures and Water Management	3.5	4.5
22	Construction Technology & Organization	5.5	7.0
23	Economics and Management	6.0	7.5
24	Environmental Engineering	4.0	4.5
25	Non-technical subjects	6.0	9.0
Core subjects total		**140.0**	**175.0**
Specialization and Elective Subjects including Practical Placement and Final Project		**100.0**	**125.0**
Total		**240.0**	**300.0**

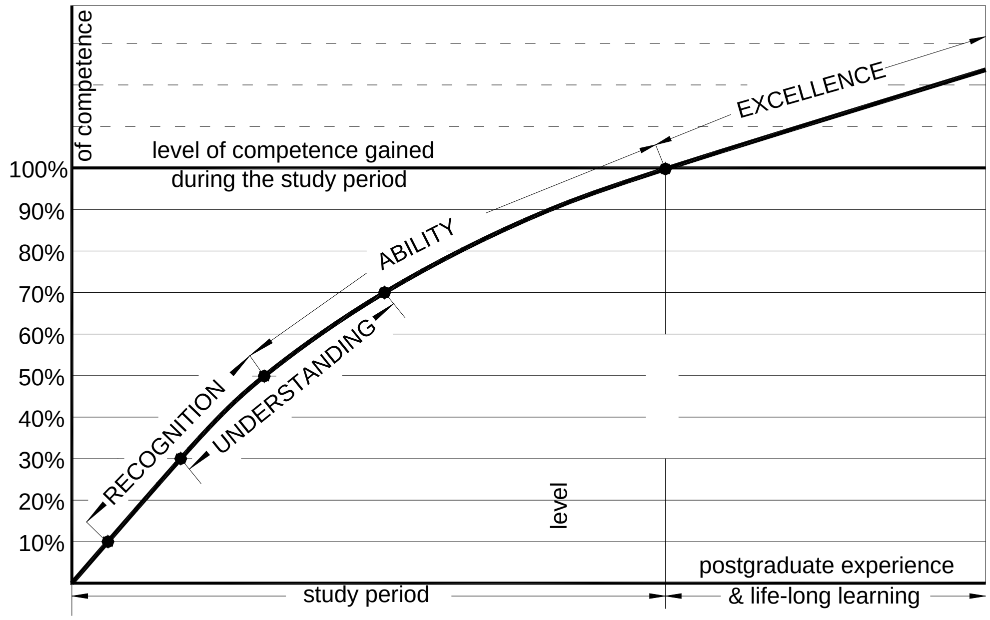
Additionally a brief syllabus for every core subject will be proposed. It will determine the scope of knowledge, which should be known by every student of any civil engineering faculty/department irrespective too her/his specialization and place of study. The sample syllabus for a chosen subject – *Structural Concrete* – is presented in table 2.

The levels of competence defined by the ASCE Body of Knowledge Committee have been adopted here not only for the outcomes of the education but have been extended for the teaching material within every subject as well. However each of 25 subjects is a "core subject", not all knowledge comprised in it must be known to every student on the highest level of competence. In this syllabus total teaching material for a subject will be split in to parts. For each part the required level of competence will be determined. Setting up a particular subject at the list of core subjects means that every student of the Civil Engineering faculty should know some parts of this subject. On the highest level of competence just some parts. Some others are important as well, but maybe the level of understanding or even recognition is sufficient. Considering the general character of the frame syllabus, which is valid for all students, the proposed level of competence should correspond rather with minimal requirements. The deeper and wider knowledge will be taught and higher level of competence will be achieved within the courses in particular specializations. Determining the total level of knowledge, skills or attitudes gained by a graduate during her/his study period as 100% the increasing level of competence can be presented as a diagram (fig. 2). From this diagram we can read that the competence called "recognition" starts on the very beginning of the student's education (10% of knowledge gained), but the highest level of recognition reaches 50% i.e. the level of knowledge where the "ability" starts and understanding reaches quite a reasonable standard. Highest level of understanding (70%) corresponds with approximately 50% of the ability level. The ability starts at the end of recognition and requires quite a reasonable level of understanding. Full understanding can correspond with the higher assessment at the mathematical studies, yet in engineering something more is required: the ability to use the knowledge for creative solving practical problems.

TABLE 2
SAMPLE FRAME SYLLABUS

SUBJECT: STRUCTURAL CONCRETE	7-8 credit points
Course contents	
RC1. The course regards to the design of RC beams, one way slabs and columns, comprising the dimensioning rules under bending, shear and torsion (beams) as well as simultaneous action of bending, and axial force (columns) with regard to ultimate load and serviceability limit states. Concept and idea of concrete reinforcement. Historical background. Material properties - concrete and steel. General characteristic of RC design principles (limit state approach), EC2 and national version. Design of beams (rectangular and T section) with regard to ultimate load limit state under bending, shear and torsion. Single- and multi-span one-way slabs and beams. Design of columns subjected to axial force and bending. Compression: general rules, slenderness and stability. Design with regard to ultimate load limit state for rectangular section. M-N interaction diagrams. Confined columns. Tension: design with regard to ultimate load limit state for rectangular section. Limit states of serviceability - deflection of RC beams, cracking in reinforced concrete.	
RC2. *The course regards to principals of RC elements design. These principals will be presented at simple and popular in constructional practice elements such as floor structures (beam-and-slab, flat slab), stairs, frames, and retaining walls.* Beam-and-slab floors. Two-way slabs: calculation in elastic stadium and by critical load method; reinforcement distribution. Reinforced concrete stairs. Reinforced concrete frame structures. Approximate methods of frame analysis under vertical and horizontal load. Computational methods of frame analysis. Reinforcing rules for frame structures. Reinforced concrete spot footings and strip foundations. Spot footings for pre-cast columns. Retaining walls: calculation and rules of reinforcing.	
RC3*. The course regards to principals of pre-stressed concrete.* Concept of pre-stressing of structural concrete members. Materials and techniques for pre-stressed concrete. High strength concrete and steel for pre-stressing. Pre-tensioning and post-tensioning techniques. Losses of pre-stressing force – short time and long term effects. Basic assumptions for sectional design of flexural pre-stressed members according to ultimate limit state method. Serviceability limit states of pre-stressed members.	
RC4. Brief presentation of advanced reinforced concrete and pre-stressed structures proving the possibilities and advantages of structural concrete.	
Level of competence	Ability in RC1 and RC2, Understanding in RC3, Recognition in RC4.
Skills achieved	Proficiency in calculation of reinforcement and loading capacity of beams, slabs and columns subjected to bending moment, shear and axial force as well as familiarity with reinforcing rules for elements discussed within RC2.

FIGURE 2
DEVELOPMENT OF LEVELS OF COMPETENCE DURING THE STUDY PERIOD AND POSTGRADUATE EXPERIENCE & LIFE-LONG LEARNING



ACKNOWLEDGEMENT

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CONCLUSION

No doubt that the uniformity never will be the objective of the education, yet some level of compatibility can be useful or even indispensable, if we mind the globalization of employment. Knowledge, skills and attitudes of a professional should be comparable irrespective to the place of his graduation. Thus the compilation of the Bologna Declaration and post-Bologna process, ASCE Body of Knowledge Committee recommendations and the results of EUCEET Core-Curricula Studies can be interesting at least to establish the common module and to recognize individual distance from this module. And maybe it is already the time to start the global discussion about the teaching standards in particular professions. Current accomplishments of above mentioned bodies create a good basis to start this work.

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