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Proposal for accreditation procedure to support the development of skills and competencies in globalized engineering world

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Abstract

In this paper we describe the proposal for accreditation of one important subject in engineering, namely Control Systems. The described procedure could be applied in the frame of LLL and also in classical engineering education systems, such as university and college education, in order to harmonize the recognition of engineering degrees in Europe and outside the Europe. We state the necessary outcomes in the subject of Control Systems in engineering at the Bachelor level and the process to test the qualifications. This procedure is based on The European Qualifications Framework for Lifelong Learning (EQF), based on the existing bibliography and on the educational experiences of the authors of this article. The objective of this work is to propose an alternative approach, compared with the classic one (university or college educational systems), to detect and certificate knowledge, skills and competencies, which are necessary for candidates applying for accreditation or certification as Bachelor of Electrical Engineering through LLL-system (Life Long Learning). This proposal has been developed under the work of the ELLEIEC ERASMUS thematic network¹ (Enhancing Lifelong Learning in Electrical and Information Engineering), where the consortium composed of 60 European universities worked together on the ELLEIEC-project.

Introduction

Globalization makes it necessary to cooperate on an international platform, which again requires new sets of engineering competencies and professional skills to enhance technology and innovation as critical foundations to develop knowledge based technical societies and economies. Engineering education has a very important role in this process, because the technology development and changing demands of the labour market require upgrading and renewing of skills and competencies in engineering fields. The Life Long Learning (LLL) procedure should be the platform offering the required qualifications for the demands of companies all over the world in order to support their competitiveness.

Continuous renewing of recent technology knowledge is almost a demand in modern societies nowadays, and many citizens in Europe² have to undertake university education. This is a continuing process for citizens who desire or are obliged by their lifestyle and economy to complete or to renew their knowledge and qualifications, and furthermore want to change the direction of their professional activity. The European Union has, towards that demand, adopted the Life Long Learning (LLL) policy³, under which, the possibility is given to citizens to acquire certified knowledge and professional adequacy which are determined in a detailed and exact way in the European Qualification Framework (EQF) and National Qualification Framework (NQF). This policy has for the time being different levels of application and depth among different countries and is, yet, to be completed. The Life Long Learning (LLL) procedure⁴ is an open system for acquiring knowledge and qualifications, offering services in systematic and flexible manner to the citizens who wish to update their knowledge, skills and competencies, and get an appropriate certificate comparable with university degree. The quality of these services should lead to the level of knowledge and qualifications of the same quality as the classical university education. For this reason, the presence and guarantees of the academic community in the

process of LLL are necessary, also in order to ensure the quality of supplying knowledge, the qualifications and the control of the process with appropriate academic criteria. The derivation of knowledge and the educational process for people wanting to get a certificate of their knowledge and their qualifications within the LLL system usually vary, depending on the country and the involved authorities. This is the reason why it is necessary to develop a certification system which is not only the special procedure for regular university education, but the objective test and certification of candidate's qualifications⁵.

The objective of this work is to propose an alternative approach, compared with the classic one (university or college educational systems), to detect and certificate knowledge, skills and competencies, which are necessary for candidates applying for accreditation or certification as Bachelor of Electrical Engineering through the LLL-system⁶. This is the continuation and completion of the original proposal which has already been developed⁷.

Modern control systems in electrical engineering programs

Linear Control Systems are usually included in Electrical Engineering programs on Bachelor level (Figure 1), but the content of particular courses vary from one country to another, and sometimes from one university to another even in the same country^{8,9}. That is why, EAEEIE (European Association for Education in Electrical and Information Engineering) is a right forum to discuss and agree which subjects should be characterized as certain and significant areas of Control Systems in electrical engineering in order to cover the European and/or international accepted level of professional knowledge on this area at the Bachelor level. The presented proposal for accreditation has been developed within the thematic network and in cooperation with representatives from 60 European universities during ELLEIEC-project, which was supported by EU-FP7 programme. We discussed and agreed on main results for the described accreditation procedure for test of skills, competencies and knowledge with all 60 participants in ELLEIEC-project.

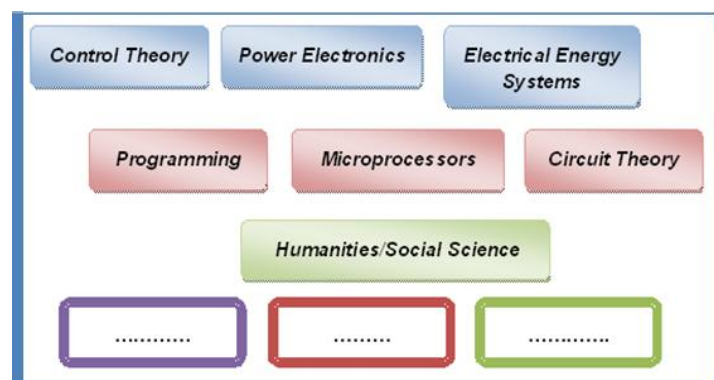


Figure 1. Modules in Electrical Engineering program

In the following we describe the fields of control systems agreed in EAEEIE forum and taken from the contents of a certain book, one of the internationally used books in Control Systems, in order to have a common reference for the overall study content for our work group. This book is “Control Systems Engineering” by Norman S. Nise¹⁰ and the chosen areas of control theory are:

1. Mathematical Modeling in the frequency Domain
2. Mathematical Modeling in the Time Domain

3. Time Response
4. Reduction of Multiple Subsystems
5. Stability
6. Steady-State Errors
7. Root Locus Techniques
8. Design via Root Locus
9. Frequency Response Techniques
10. Design via Frequency Response
11. Design via State Space

However, we would like to emphasize, that the named book should not be considered as a standard literature for accreditation process in control systems. The named subjects in control systems are represented in most of the literature suitable and recommended for electrical engineering on bachelor level. Additionally, cooperation between our universities, discussions with our colleagues in EAEEIE organization and discussions with local industrial companies cooperation support our choice of the named subjects in control systems.

Life Long Learning strategy in European Union

To achieve the accreditation as a Bachelor of Electrical Engineering, according to European norms, the candidate needs to have a certain level of knowledge, skills and competencies in the framework of this science (Electrical Engineering). Electrical Engineering is composed of several scientific fields (and not necessary courses) which constitute a global way to Electrical Engineering science, like Circuit Theory, Control Systems, Electrical Energy Systems, Microprocessors, Circuit Theory, etc. (as shown in Figure 1). These are the basic scientific fields of an expertise. It is common to decompose other areas of expertise in similar way. In accreditation process the entirety of knowledge, skills and competencies, in each of the above decomposed scientific fields, has to be identified objectively. The candidate with the requisite level of knowledge in all scientific fields within electrical engineering science, which means that he or she has the overall knowledge, skills and competencies required of an electrical engineer graduated from university within a certified program, will consequently be able to be approved or certified by authorities with a degree similar to a university degree in electrical engineering. This process could be applied not only in the frame of LLL, but also in the regular study programs in electrical engineering in universities or colleges, because it focuses on the results of the overall learning outcomes¹¹, independently of the procedure (regular lectures, intensive courses, LLL), and independently of the course duration and used learning methods. The important issue is the final result and not the path by which the overall learning outcome has been achieved. Therefore, the proposed methodology enhances the credibility, the transparency and the integrity of this procedure, all of them being absolutely necessary for the success of the LLL policy.

Required engineering competencies and learning objectives

There are several approaches how people can acquire knowledge, skills and competencies. Learning processes have been described several times and with different approaches, for

example with Bloom's revised taxonomy¹¹ and Kolb's experimental learning styles¹³. Based on the above mentioned approaches, the learning cycle is described^{14,15} with the following steps:

1. Get to know facts
2. Learn about context
3. Train procedures for automatic reactions
4. Find rules behind procedures
5. Find strategies for acting

This type of knowledge is called "strategic" and is the basis for creative thinking.

LLL procedure is usually the combination of the different learning processes and leads to professional engineering qualifications, which could be described as Knowledge, Skills and Competencies. The European Qualification Framework (EQF) procedure⁴ is used in general in higher university education as well as in vocational training. Within the EQF frame the following definitions are given:

- **Qualification** means a formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards.
- **Learning outcomes** means statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence.
- **Knowledge** means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of this framework, knowledge is described as theoretical and/or factual.
- **Skill** means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of this framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments).
- **Competence** means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the EQF, competence is described in terms of responsibility and autonomy.

Furthermore, the EQF gives definitions of the 8 different levels in learning outcomes. For level 6, corresponding to the Bachelor level qualifications, these are:

- **Knowledge:** advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.
- **Skills:** advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study.
- **Competence:**
 - manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts
 - take responsibility for managing professional development of individuals and groups.

Our bibliography investigations do not give obvious, clear, or measurable guidelines how to test the above qualifications. For every previously stated definition, we found a lot of hermeneutical

approaches, not only depending on the scientific field under consideration, but also taking different pedagogical and philosophical points of view. The identification and measuring of the qualifications become more difficult with higher levels of education. We also found description made by 4ING¹⁶, the organization of the four councils of schools of engineering, computer science and technology at German research universities, of the named qualifications as follows:

- **Knowledge** related to a field of work or study, means the learnt, retrievable information on facts, the context, to which facts are associated, and the rules interrelating facts to contexts.
- **Skills** means an ability that has been acquired by training and that makes use of the implicit memory, to apply knowledge to *standard* situations, and to use know-how to complete *standard* tasks, and to solve *standard* problems.
- **Competence** means the proven ability to autonomously recognize interrelations between facts and the contexts to which they are linked, to apply this ability to systematically develop new methods, and, if indicated, to apply them to changed situations. This includes application to work or study situations, and in professional and personal development.

In others words:

- **Knowledge** is learnt by heart.
- **Skills** are acquired by training.
- **Competence** is developed, after holding and assimilating knowledge and skills, by using sense and intellect in order to act (or develop new methods) autonomously, under changed situations.

Proposed procedure for accreditation within LLL

The learning outcomes follow a progressive evolution, from the simpler and easier to more complex and difficult. It is our proposal to follow a progressive learning cycle/procedure in the process of accreditation. First to detect the knowledge level of the candidate in Control Systems, and if this level is sufficient, the next step is to detect candidate's Skills and Competencies in following procedure:

- **Knowledge**

The Knowledge identification could be realized with one written examination of multiple-choice questions covering all previously described fields of Control Systems. These questions will be chosen randomly from the developed "Control Systems – Questions Data Base". The data base will contain at least decuple the number of questions given at the examination and the questions will be divided in categories – with different weighting. The philosophy of this system is based on random and secret choice of the questions in order to ensure the isonomy of the examined candidates.

- **Skills**

The candidate has to pass the examination (written or oral test) with the questions concerning the key features in applying control theory on practical cases. In the test/examination, the candidate will be asked to:

1. Model and describe technical/physical system.
2. Make analysis of the described system in time- and frequency- domains.
3. Draw a block diagram of the system.
4. Simplify/reduce the block diagrams.

5. Determine the stability of control systems with mathematical methods or with graphical methods.
6. Evaluate the steady-state errors of control systems for typical inputs and perturbations.
7. Suggest and explain the type of controller for the system.
8. Calculate compensator's coefficients for continuous and discrete compensators.

- **Competences**

The competences of the candidate will be tested by oral examination in connection to the project or case example, which should contain the analysis and design of the complex control system, and the solution should include common used software for control systems like: Matlab, Simulink, LabView or others.

The above described tests for skills and competencies could be connected to the projects previously done by candidate during his/her professional career, if accepted in advance by members of accreditation committee.

Conclusion

The proposed procedure is a well developed method to test the qualifications in the subject of Control Systems for accreditation of the Bachelor level in Electrical Engineering, especially suitable to be used in Life Long Learning procedure. Any other type of accreditation for higher education institutions can also use the proposed method. Our work is based on The European Qualifications Framework for Lifelong Learning (EQF), based on the existing bibliography and on the educational experiences of the authors of this article. Currently, certification of the knowledge and skills based on prior and/or experiential learning experience is not a common procedure in all countries in the European Union and that is why we could not implement our work into practical procedure. However, both authors work at the moment with "Control Systems – Questions Data Base", a library of the questions to be used for proposed tests, in order to have all appropriate tools ready for the proposed certification procedure, once the legal rules allow the certification of the prior and experimental learning in our countries.

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