Towards Harmonization of Engineering Education Curricula in Europe to Promote Student Mobility: a Case Study

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Abstract: - The paper presents results of the research directed towards the improvement of the curriculum "Computer Systems" taught in the Institute of Applied Computer Systems of Riga Technical University. The description of the mentioned curriculum is given. Possibilities to provide academic mobility of higher engineering education students studying at the master level are discussed. Results of the comparison of the curriculum "Computer Systems" with the similar curricula of other countries of the European Union at the level of courses and their groups are presented.

Key-Words: - higher education, engineering education, master studies, curriculum, computer science, student mobility

1 Introduction

On 25 May 1998 in Paris, ministers responsible for the higher education in France, Germany, Italy and the United Kingdom signed the Sorbonne Declaration [1] which emphasized that Europe should become the Europe of Knowledge. This document was a predecessor of the Bologna Declaration [2] that was accepted by 29 states on 19 June 1999. The declaration promotes the improvement of the higher education system, recognizing education as a cornerstone in the consolidation of a stable, peaceful and democratic society. Almost a year later the new strategic goal of the European Union (EU) for the next decade was established in the Lisbon Strategy [3]: Europe should become the most competitive and dynamic knowledge-based economy in the world. In turn, in 2005 the Council of the European Union stressed that the Lisbon goals of competitiveness and economic growth can only be achieved if young people coming onto the labor market are properly equipped through quality education and training in line with the evolution of society [4].

In the context of the mentioned documents it is important to harmonize curricula of universities of the EU as far as it is possible in accordance with traditions of each specific university and regulations of Ministry of Science and Education of each country. Harmonization of curricula is desirable due to the fact that in near future most probably all restrictions which exist today in connection with labor force flows among EU countries will be canceled. In situation when the number of freshmen who are interested in engineering studies decreases practically in all so called "old" European Union countries, e.g., Sweden, Germany, the United Kingdom, etc. shortage of educated people in engineering will be possible to diminish at least partly by attracting universities' graduates from "new" European Union countries, for instance, from Baltic countries, Czech Republic and Poland. It is worth to point out that easy adaptation of new specialists in different labor markets depends not only on the quality of curricula but also on wide opportunities for student mobility. It is quite obvious that the student mobility between universities will be more prolific if their curricula are harmonized till the certain degree.

In 2005 the Institute of Applied Computer Systems at Riga Technical University (RTU) started several ESF projects directed toward the improvement of the curriculum "Computer Systems" at all levels for bachelor, master and doctoral studies. The main objective of the projects is to align the curriculum with the European Educational Space promoting economical and competitive growth both of Latvia and Europe.

Different investigations and activities have been carried out within the mentioned projects. The paper describes results of the research which have two main goals:

- to identify possible curricula which can provide academic mobility of higher engineering education students studying at the master level;
- to determine the correspondence of the curriculum "Computer Systems" of the academic master level to a wide spectrum of curricula in the field of computer science of other institutions of higher education within the

EU. For this purpose a comparison of the curriculum "Computer Systems" with the similar curricula at the level of courses and their groups is carried out.

The paper is organized as follows. Section 2 describes the curriculum “Computer Systems”. The methodology for the selection of higher education institutions of the EU is discussed in Section 3. Results of the research on academic mobility of higher engineering education students are given in Section 4. Section 5 reflects results of the comparison of the curriculum “Computer Systems” with the similar curricula within the EU. The last section presents conclusions.

2 The Curriculum “Computer Systems”

The curriculum „Computer Systems” has been implemented by the Institute of Applied Computer Systems of RTU since the middle of the 1990s. Today it has the 3+2+3 scheme, i.e. 3 year bachelor, 2 year master and 3 year doctoral studies. The curriculum objective is to provide academic education in computer science and to prepare highly qualified professionals in the fields of system analysis, software engineering and design of computer systems (databases, information systems and intelligent systems) with fundamental knowledge base on engineering science, which includes mathematics, physics, chemistry, electrical engineering and electronics.

Curricula development, implementation and modification at RTU is carried out with the perspective to correspond with the common European Educational Space. For this purpose the obligatory accreditation procedure for all curricula is established. One of the criteria for a curriculum accreditation is its comparison with at least two curricula of universities of the European Union countries. So, to be accredited, the curriculum should be similar to curricula of other universities and should contain the core of courses which are characteristics for the definite engineering field. In 2001 the international evaluation commission accredited the curriculum “Computer Systems” for six years. The curriculum was reaccredited in 2007 till the year 2013.

The objective of the academic master level curriculum "Computer Systems" is to give students extended knowledge in computer science, software engineering and design of computer systems with intent that graduates could start working in the university, scientific-research computer companies and organizations, as well as to continue studies at the doctoral level. Studying at the master level students can choose the most suitable for their interests and further career set of courses, by deciding on one of the 3 modules. The module "Computer Systems Design" is directed towards design of information systems, databases, intelligent systems and other software systems. The module "Applied Computer Systems Software" is related to general models, methods and algorithms for the development of applied computer systems. The module "Applied Computer Science" is directed towards modelling of computer systems and problem analysis. The total amount of credit points of the master’s level studies is 121.5 ECTS. After the completion of the curriculum students receive the degree of Master of Engineering Science.

The curriculum “Computer Systems” at the master level includes the following courses:

- First semester (30 ECTS):
  - *Compulsory courses* (18 ECTS): Models for Software Planning and Metrology (6 ECTS), Large Databases (6 ECTS), Object-oriented System Analysis (6 ECTS);
  - *Restricted electives* (9 ECTS): System and Process Theory (6 ECTS), Software Quality (6 ECTS), Computer Networks Software (6 ECTS), Scientific Seminar on Computer Systems Design (3 ECTS), Applied Computer Science Seminar (3 ECTS), Scientific Seminar on Applied Software (3 ECTS);
  - *Humanitarian/social science, economics and management* (3 ECTS);
- Second semester (31.5 ECTS):
  - *Compulsory courses* (19.5 ECTS): Artificial Intelligence (6 ECTS), Process Programming (6 ECTS), Computer Aided Solution Processing (6 ECTS), Fundamentals of Labour Protection (1.5 ECTS);
  - *Free electives* (3 ECTS);
  - *Humanitarian/social science, economics and management* (3 ECTS);
  - *Master's thesis* (6 ECTS);
- Third semester (30 ECTS):
  - *Compulsory courses* (18 ECTS): Specialized Data Processing Technologies (6 ECTS), Requirement Engineering (6 ECTS), Object-oriented Software Development (6 ECTS);
  - *Restricted electives* (9 ECTS): Information Systems and CASE tools (6 ECTS), Tools for Object-oriented System Development (6 ECTS), Methods of Intelligent Applied Computer Systems Engineering (6 ECTS), Scientific Seminar on Methods of Computer Systems Design (3 ECTS), Applied Computer Science Seminar (3 ECTS),

Scientific Seminar on Progressive Software Technologies (3 ECTS);
- *Free electives* (3 ECTS);

- Fourth semester (30 ECTS):
  - *Restricted electives* (6 ECTS): Knowledge Management (6 ECTS), Methods and Development Trends of Applied Computer Science (6 ECTS), Software Reliability Theory (6 ECTS);
  - *State examination: Master's thesis* (24 ECTS).

3 Selection of Higher Education Institutions

The full list of institutions of higher education of the EU is obtained by using information from the following sources:

1. Web sites of institutions responsible for higher education in each country;
2. a portal on learning opportunities throughout the European Space [5];
3. an international education directory of colleges and universities [6];
4. a Web site of higher education in Europe from Graduateshotline.com [7];
5. a directory Colleges.com [8].

However, the following problems impeded acquiring of curricula:

1. Web sites of many higher education institutions support only local language, for example, Hungarian or French, or gives only general information about the institution in English without the description of the curricula;
2. there is a specificity regarding master level curricula in some countries, for example, in Spain there is an information about „official masters" and „neofficial masters", or in the United Kingdom there are „taught masters" and „research masters";
3. sometimes information about a curriculum does not contain the detailed description, i.e. courses, their credit points and semesters.

Taking into account the mentioned problems, the following selection criteria are used:

1. information about a curriculum is in English on the Web site of a corresponding institution of higher education;
2. information about a curriculum includes titles of study courses, credit points for each course, as well as semesters, when the course is taught (only for the identification of mobility opportunities);
3. the level of a curriculum is the academic master studies (the same as the level of the curriculum "Computer Systems");
4. the title of a curriculum contains some of the following words: Computer Science, Computer Systems, Software Engineering, Software Development, Information Systems, Information Technology, Computing;
5. the offered curriculum is not a distance learning programme;
6. the obtained degree is Master of Engineering Science.

4 Opportunities for Mobility

The criteria listed in Section 3 allow to identify 29 curricula in 25 institutions of higher education from 15 countries of the EU for the research of providing academic mobility of higher engineering education students (Table 1). One part of the found institutions are the partners of RTU in Erasmus programme [5]; others were examined from the perspective of potential partners.

Table 1.
Distribution of curricula and institutions by countries for the mobility research

Country	Number of curricula	Number of institutions
United Kingdom	8	6
Belgium	1	1
Czech Republic	1	1
Denmark	1	1
Greece	1	1
Ireland	3	2
Lithuania	1	1
Cyprus	2	2
Luxembourg	1	1
Malta	1	1
Portugal	1	1
Romania	3	2
Slovak Republic	1	1
Germany	2	2
Sweden	2	2
Total	29	25

Results of the comparison of course titles and corresponding credit points show that it is very difficult to provide mobility of engineering students because there are essential differences among curricula. As a rule, credit points of only one course can be transferred for the greater part of students studying at foreign institutions of higher education. Moreover, usually these credit points are provided by free electives or such courses as Software Engineering, Artificial Intelligence and Databases. The greatest number of credit points which can be transferred is 2 or 3 credits, however in this case it is necessary to consider such factors as the specialization chosen by the student at the foreign institution and courses passed by the student in his/her local institution.

The conclusion is that there are few opportunities for master level engineering students of the curriculum "Computer Systems" to go abroad and to get credit points for full semester. The reason is that there is not any suitable curriculum either among universities with which RTU has agreements for student mobility, or among other EU universities. Practically the only possibility is the development of the master thesis in a foreign institution of higher education at the end of studies.

5 Comparison of Curricula

The following tasks are identified for the comparison of the curriculum "Computer Systems" of the master level with the similar curricula of other countries of the EU at the level of courses:

1. to identify the most often included courses in computer science curricula;
2. to group the identified courses accordingly to the groups of courses of the curriculum "Computer Systems" and to compare number of credit points of the groups.

Totally 55 curricula in 43 institutions of higher education from 18 countries are identified (Table 2) for this research because it is not necessary to know a semester when courses are taught.

Table 2.
Distribution of curricula and institutions by countries for the comparison of curricula

Country	Number of curricula	Number of institutions
United Kingdom	17	11
Belgium	3	3
Czech Republic	1	1
Denmark	2	2
Greece	4	3
Estonia	3	2
Ireland	3	2
Lithuania	1	1
Italy	4	3
Cyprus	2	2
Luxembourg	1	1
Malta	1	1
Netherlands	2	1
Portugal	1	1
Romania	3	2
Slovak Republic	1	1
Germany	2	2
Sweden	4	4
Total	55	43

The focus of the research is concentrated on compulsory courses. The analysis of curricula at the level of courses shows that there is an enormous diversity. Totally 262 different titles of courses are identified. The most often offered courses are displayed in Figure 1. Their minimal, maximal and average number of credit points are presented in Table 3. The other 7 courses (Artificial Intelligence, Data Mining, Formal Methods, Human-Computer Interface, Operating Systems, Programming Languages and Computer Security) are included in 3 curricula with very different number of credit points, starting from 2 ECTS and up to 7.5 ECTS. Thirty three courses are found in two curricula, and others only in one curriculum.

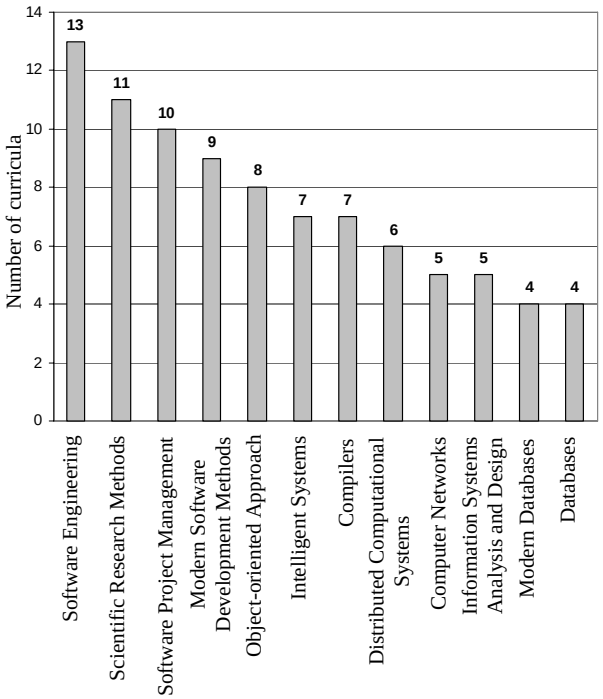

Fig.1. The most often offered courses

The results of the research allow to reveal general tendencies. The main attention is granted to software engineering, including object-oriented approach, project management, artificial intelligence (intelligent and distributed systems, data mining, etc.), databases, information systems, computer networks, compilers and research methods. All of the mentioned courses excluding compilers are incorporated in the curriculum "Computer Systems" as well. Moreover, credit points either are identical with the average number of credit points of other curricula in the EU, for example, in Artificial Intelligence, Modern Databases, Information Systems Analysis and Design, Scientific Research Methods, or are even higher, for example, as for Object-oriented Approach.

Table 3.
Distribution of courses by curricula

Course	Minimal ECTS	Maximal ECTS	Average ECTS
Software Engineering	3	7,5	5,46
Scientific Research Methods	3	7,5	5,91

Table 3 (continued).

Distribution of courses by curricula

Course	Minimal ECTS	Maximal ECTS	Average ECTS
Software Project Management	4	7,5	5,95
Modern Software Development Methods	4	7,5	6,11
Object-oriented Approach	6	7,5	7,31
Intelligent Systems	3,5	7,5	5
Compilers	3	7,5	5,21
Distributed Computational Systems	3	6	4,67
Information Systems Analysis and Design	4	7,5	5,8
Computer Networks	4	7,5	5,6
Modern Databases	4	7,5	5,63
Databases	3	7	4,5

To reduce the variety in the analyzed curricula course grouping is made with respect to the curriculum “Computer Systems”. As a result 32 groups of courses, as well as minimal, maximal and average number of credit points for each group are identified (Table 4).

Table 4

Groups of courses

Groups of courses	Number of curricula	Minimal ECTS	Maximal ECTS	Average ECTS
Software Engineering	62	2	7,5	5,31
Artificial Intelligence	33	3	7,5	4,98
Databases	24	2	7,5	5,01
Computer and Communication Networks	21	3	7,5	5
Information Systems	20	15	5	5,55
Computer Systems and their Different Kinds	20	2,5	7,5	4,83
Safety and Cryptography	14	3	7,5	5,43
Algorithms and Data Structures	13	3	7,5	5,88
Project Management	13	3,5	7,5	5,19
System Theory, Analysis and Design	12	3	7,5	5,21
Mathematics	11	2,5	7,5	4,45
Internet and Web Systems	11	4	7,5	6,2
Scientific Research Methods	11	3	7,5	5,91

Table 4 (continued).

Groups of courses

Groups of courses	Number of curricula	Minimal ECTS	Maximal ECTS	Average ECTS
Operating Systems	10	2	7,5	4,1
Compilers and Formal Languages	10	3	7,5	5,3
Object-oriented Approach	9	4	7,5	6,94
Theoretical and Social Aspects of Computer Science	9	3,5	7,5	5,06
Information Technology	8	1	7,5	3,56
Programming Languages	8	3	7,5	4,94
Computer Graphics and Image Processing	8	3	7,5	5,81
Computer Architecture	7	3	7,5	4,43
Modelling and Simulation	6	3	7,5	5,67
Human-Computer Interfaces and Interactive Systems	6	2	5	3,83
Informatics	5	4	7,5	6,5
Multimedia and Hypermedia Systems	4	3	7,5	6
Data, Information and Knowledge Management	4	4	7,5	5,75
Computer Hardware	3	3	5	4.33
Requirement Engineering	3	4	7,5	5,83
Information Theory	3	4	6	5
Data Communication and Processing	2	3	5	4
Signal Processing	2	5	5	5
E-Commerce	2	4	5	4,5

It is necessary to stress that the formed groups can be further merged into 3 large groups:

1. groups which correspond to the bachelor level of the curriculum "Computer Systems";
2. groups which correspond to the master level of the curriculum "Computer Systems";
3. groups which do not correspond to any level of the curriculum "Computer Systems".

The groups which correspond to the master level are the following:

1. Artificial Intelligence (RTU- 6-12 ECTS, depends on specialization; in EU countries, average- 4,98 ECTS);
2. Databases (RTU- 6 ECTS; in EU countries, average- 5,01 ECTS);
3. Systems Theory, Analysis and Design (RTU- 6-12 ECTS, depends on specialization; in EU countries, average- 5,21 ECTS);
4. Software Engineering (RTU- 6-24 ECTS, depends on specialization; in EU countries, average- 5.31 ECTS);
5. Object-oriented Approach (RTU- 12-18 ECTS, depends on specialization; in EU countries, average- 6,94 ECTS);
6. Information Systems (RTU- 0-6 ECTS, depends on specialization; in EU countries, average- 5,55 ECTS);
7. Data, Information and Knowledge Management (RTU- 0-6 ECTS, depends on specialization; in EU countries, average- 5,75 ECTS);
8. Computer Systems and their Different Kinds (RTU- 6 ECTS; in EU countries, average- 4,83 ECTS);
9. Requirement Engineering (RTU- 6 ECTS; in EU countries, average- 5,83 ECTS);
10. Data Communication and Processing (RTU- 6 ECTS; in EU countries, average- 4 ECTS);
11. Human-Computer Interfaces and Interactive Systems (RTU- 0-6 ECTS, depends on specialization; in EU countries, average- 3,83 ECTS);
12. Scientific Research Methods (RTU- 6 ECTS; in EU countries, average- 5,91 ECTS).

6 Conclusions

Analysis of curricula in the field of computer science within the European Union allows to conclude that regardless of the fact that there is a big diversity among curricula the curriculum "Computer Systems" at RTU falls within the European Educational Space because it includes the most popular courses. However, in order to provide good opportunities for student mobility it is necessary to harmonize study programmes within the European Educational Space. Harmonization of curricula demands extended and coordinated research in all countries of the EU.

It is necessary to stress that some factors limited the analysis presented in the paper. The main of them are inaccessibility of curricula of many higher education institutions or their availability only in a local language, not in English. In order to obtain more valid results the following activity can be implemented in the future: direct contacting of representatives of corresponding institutions with the purpose of translation of curricula given in a local language and comparison of content of courses. This will allow to analyze a broader scope of curricula and to get more precise view about the effective ways how to achieve needed similarity between curricula of EU countries.

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