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e-CF Competences in Software Engineering Course

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***Abstract* – The article describes the definition of competences formed during the acquisition of the study course "Software Engineering" at Riga Technical University. The European e-Competence Framework (e-CF) is adopted for this purpose. Using the steps to determine e-competences, it is established that students can develop 9 competences in the Bachelor and 15 in the Master study programme. Evaluation of practical assignments allows assessing the achievement level of the required competences. Some professions presented in e-CF and the competencies they need are also reviewed.**

***Keywords* – Competence, competency-based learning, European e-Competence Framework, software engineering.**

I. Introduction

At present, at the time of technical progress, the demand for highly qualified personnel is growing steadily, especially engineers and IT specialists are required. In addition, the volume of information necessary for successful work is constantly increasing, but the learning time is limited. At the same time, employers are more often interested not in the knowledge and skills of the applicant, but in the level of his/her competence. Thus, the requirements for the quality of education are increasing. Therefore, more and more higher education institutions in different countries are introducing a competency-based approach to the learning process or already use it.

Many scientists and teachers deal with problems of competency-based learning (CBL). They investigate this approach and possibilities of applying it in higher education. Various questions connected with CBL are described in their studies.

Competence definitions and fundamentals of competency-based education (CBE) are considered in [1]–[6], a model of CBE and its components are described in [3], but a model of learning outcomes – in [7]. Key characteristics, benefits and effectiveness of its usage are reviewed in [1], [6]–[9]. References [2], [5], [10] are devoted to types and forms of competency-based learning. The competences of different IT specialists are considered in [4], [5], [10]. A number of works are devoted to the issues of assessing students' achievements: knowledge, skills and competences [10]–[15]. References [16], [17] show how to use the competency-based approach in education.

The European Qualification Framework implemented a set of competences – the European e-Competence Framework (e-CF) [18], which in 2016 became the European standard.

The aims of the article are to analyse the study course "Software Engineering" at Riga Technical University and to determine the e-Competences according to e-CF, which are formed during the study process, as well as to show how these competences can be assessed.

II. Competences and The European e-Competence Framework

There are many definitions of competence. In Cambridge Dictionary competence is defined very short as the ability to do something well [19]. However, the following concept of competence is more complete and therefore more correct: Competence is a complex characteristic of a graduate's readiness to apply the acquired knowledge, skills and personal qualities in standard and changing situations of professional activity [4]. Thus, competence consists of three components: knowledge, skills and personal qualities (attitudes) [10].

Competency-based education is an outcome-based approach to education that incorporates modes of instructional delivery and assessment efforts designed to evaluate mastery of learning by students through their demonstration of the knowledge, attitudes, values, skills [3]. It can be stated that, competency-based learning focuses on the student's demonstration of desired learning outcomes called competences as central to the learning process [6].

The European e-Competence Framework [18] provides a reference of 40 key competences in the area of Software Engineering. The e-CF is divided into four dimensions. The first one consists of five e-Competence areas derived from the Information and Communication Technology business processes A.PLAN – B.BUILD – C.RUN – D.ENABLE – E.MANAGE. The second dimension contains a generic description for each e-Competence. Dimension 3 defines a proficiency level of each e-Competence ranging between e-1 and e-5. Dimension 4 includes samples of knowledge and skills related to e-Competences in dimension 2. Thus, the following requirements are defined for the B.2. Component Integration: "Integrates hardware, software or sub system components into an existing or a new system. Complies with established processes and procedures such as, configuration management and package maintenance. Takes into account the compatibility of existing and new modules to ensure system integrity, system interoperability and information security. Verifies and tests system capacity and performance and documentation of successful integration". The requirements for each of the possible three proficiency levels (e-2, e-3, e-4) are

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also defined, for example, for e-2 it is indicated: "Acts systematically to identify compatibility of software and hardware specifications. Documents all activities during installation and records deviations and remedial activities" [18].

The e-CF also defines competences and proficiency levels for different professions needed in Software Engineering (Account Manager, Database Administrator, Developer, Network Specialist, System Analyst, Test Specialist, etc.).

Therefore, on the basis of the European e-Competence Framework it is possible to design study programmes for competency-based education, develop the content of courses and define the competences that a definite course or a set of courses provides.

III. Definition of e-CF Competences for Software Engineering Course

To determine the e-CF competences for the study course, it is necessary to perform a sequence of steps, namely [20]:

1) to make a list of all topics and sections of the course (the list can be divided into theoretical and practical parts);
2) based on the analysis of the list of topics, to determine what knowledge and skills will be formed by the student as a result of studying the course, i.e., what competences are received;
3) to compare certain competences with those presented in e-CF in order to identify what e-Competences will be received;
4) taking into account samples of knowledge and skills in Dimension 4 of e-CF, to determine what levels of e-Competences are achieved;
5) to identify methods for assessing the level of competence and learning outcomes (practical and laboratory work, reports, presentations, tests, exams, etc.).

At Riga Technical University, the study course "Software Engineering" (SE) consists of two parts. The Bachelor study programme comprises Part 1of 2 credit points (CP), Part 2 (4 CP) is included in the Master study programme.

The Bachelor study programme provides SE basics and allows forming different types of knowledge and skills. The graduate should:

- know software development stages and models, tasks, deliveries and documents;
- be able to develop a system model, define and specify requirements, to prepare a requirements specification;
- be able to design software system and to describe results according to standards;
- be able to select technology and to implement IS, to prepare user guide;
- be able to develop test cases and to test a program.

Part 1 of the study course "Software Engineering" includes seven main topics. The implementation of the four steps previously described shows that the first part of SE allows forming nine competences according to e-CF of different level. Table I demonstrates these topics, e-CF competences and their levels.

Part 2 of the study course "Software Engineering" (the Master study programme) provides the advanced topics of SE and allows forming different types of knowledge and skills. The graduate should:

- know software development models and methods of their management, models of human work organisation, testing planning, quality management models and risk management methods;
- know different cost estimation models and software measurement principles and metrics;
- be able to plan a software project: to appoint tasks for project development, to assign tasks to developers, to create calendar using CASE-tools;
- be able to estimate cost of a project and its every stage using different models and tools;
- be able to select technology and to implement IS, to prepare a user guide;
- be able to work in software project developer's team, exercising manager's and developer's functions;
- be able to calculate metrics of specification, design and program code, etc.

TABLE I
Topics and e-CF Competences in the Bachelor Study Programme

No	Topic	e-CF competence	Level
1	Software life cycle	–	
2	Software development models	–	
3	Requirements analysis and specification	B.5. Documentation Production	e-3
4	Software design	A.5. Architecture Design, A.6. Application Design, B.5. Documentation Production	e-3 e-3 e-3
5	Implementation	B.1. Application Development, B.2. Component Integration, B.5. Documentation Production, B.6. System Engineering, C.4. Problem Management	e-3 e-2 e-3 e-2 e-2
6	Verification and validation	B.1. Application Development, B.3. Testing, B.5. Documentation Production, C.4. Problem Management	e-3 e-2 e-3 e-2
7	Software maintenance	B.4. Solution Deployment	e-2

This part of SE study course includes eight topics and allows forming the same competences as the first part (the Bachelor study programme) and additionally six competences. Table II shows topics of Part 2, additional e-CF competences and their levels.

TABLE II
TOPICS AND E-CF COMPETENCES IN THE MASTER STUDY PROGRAMME

No	Topic	Additional e-CF competence	Level
1	Software project life cycle	E.6. ICT Quality Management	e-2
2	IT project management (planning, cost estimation, personnel management)	A.3. Business Plan Development, A.4. Product/Service Planning, D.9. Personnel Development, E.2. Project and Portfolio Management	e-4 e-4 e-3 e-4
3	CASE tools for project management	A.3. Business Plan Development, A.4. Product/Service Planning, D.9. Personnel Development, E.2. Project and Portfolio Management	e-4 e-4 e-3 e-4
4	Software metrics and QA	A.3. Business Plan Development E.6. ICT Quality Management	e-2
5	Risk management	E.3. Risk Management	e-2
6	Software reviews	E.6. ICT Quality Management	e-2
7	Testing management & documentation	A.4. Product/Service Planning, D.9. Personnel Development	e-4 e-3
8	SE kinds: Reengineering, Reuse, Agile, Component-based, etc.	–	

Thus, the SE study course allows forming 9 e-Competences in the Bachelor study programme and 15 e-Competences in the Master study programme according to the European e-Competence Framework.

The competences can only be obtained by performing certain practical work. Thus, learning outcomes and methods for assessing the level of competence should be considered.

IV. LEARNING OUTCOMES AND E-COMPETENCE ASSESSMENT

For the formation and assessment of students' knowledge and skills, practical work, e-learning courses, etc. are used in the study course "Software Engineering".

The Bachelor study programme provides four laboratory assignments, in which the student must develop a small software system. Practical work begins from a system analysis, definition and specification of requirements (Assignment 1), followed by architectural and detailed design (Assignment 2), implementation and debugging of the system (Assignment 3). Assignment 4 involves testing a small program using different testing methods. Learning outcomes of the assignments are a set of documents usually according to the Latvian State Standards. Table III shows a list of practical (laboratory) assignments that the student must accomplish in the study course, learning outcomes of every assignment and e-CF competences, the formation of which is ensured by the assignment.

TABLE III
PRACTICAL ASSIGNMENTS AND E-CF COMPETENCES IN THE BACHELOR STUDY PROGRAMME

No	Practical assignment	Learning outcomes	e-Competences
1	Software requirements definition and specification	Requirements Specification	B.5
2	Software design	Design Description	A.5, A.6, B.5
3	Software implementation	Software System, System Description, User Manual	B.1, B.2, B.4, B.5, B.6, C4
4	Program testing	Testing Report	B.1, B.3, B.5, C4

Three laboratory assignments are foreseen in the Master study programme. The first two are carried out individually – here a student using CASE tools has to draw up a project schedule, calculate its cost, and perform a series of actions to change the schedule, for example, if one of the developers is ill for a long time. The third assignment is performed by a group of students (3–4 people) that develops the selected software project. One of the students is a project manager, the rest are developers. According to the results of the group work, students draw up reports and demonstrate the developed system. Table IV shows a list of laboratory assignments, learning outcomes of every assignment and e-CF competences, the formation of which is provided by the assignment.

TABLE IV
LABORATORY ASSIGNMENTS AND E-CF COMPETENCES IN THE MASTER STUDY PROGRAMME

No	Laboratory assignment	Learning outcomes	e-Competences
1	Software development planning	Software Project Management Plan (SPMP)	A.3, A.4, B.5, E.2, E.3
2	Software development cost estimation	Cost Estimation Report	A.3, A.4, B.5
3	Software project development in group	SPMP, Software System v.1.0, System Description and User Manual	A.3, A.4, A.5, A.6, B.1, B.2, B.3, B.4, B.5, C4, D9, E.2, E.3, E6

In grading each assignment, a 10-point scale adopted in Latvia is used. The quality of the assignment fulfilled, the quality of prepared document (report) and the presentation of the assignment (including answers to questions) are taken into account. A student is considered to have reached the required level of appropriate competence if his/her mark is greater than or equal to 7 (good). Obtaining a mark "5" (average) or "6" (almost good), the level of competence is reduced by 1. Mark "4" (almost average) means that the student has not mastered the competence.

Considering that competence includes knowledge and skills, e-courses are used to evaluate them in the study course "Software Engineering". E-learning course is a set of learning objects implemented using modern computer technologies and consolidated into a scenario that is used for learning a definite topic [21]. These courses can be used for knowledge control (KC) and training (T), but some of them – for learning (L), too. In this case, a computer-aided system puts a mark using special algorithms. For knowledge control, non-adaptive and partly adaptive methods can be used [22]. Students can also use e-courses for self-control. Table V presents the list of e-courses for the SE course. Some e-courses contain special tasks to assess skills. These are e-courses No. 5, 6, 9, and 10.

TABLE V
E-COURSES FOR KNOWLEDGE AND SKILL TESTING

No	E-courses	SE part	Modes	Learning objects	e-Competences
1	Software Life Cycle – Basics	1	KC	14	
2	Software Development Models	1	L, T, KC	69	
3	Functional and Non-functional Requirement	1	L, T, KC	30	
4	Software Implementation	1	L, T, KC	45	B.1
5	Verification and Validation	1	KC	34	B.3, B.6
6	Software Testing	1	KC	46	B.3, B.6
7	Software Maintenance	1	L, T, KC	30	B.4
8	Software Life Cycle	2	KC	19	A.4, A.6
9	Software Cost Estimation	2	KC	29	A.3, A.4
10	Software Metrics	2	KC	30	A.3

Table V also indicates the e-competences that require knowledge and skills that are studied or tested in the e-course.

V. RESULTS AND DISCUSSION

As a result of the analysis of the study course "Software Engineering" and comparison of the topics studied in it with the ones included in the European e-Competence Framework (the European standard), it has been found that the course allows students to gain 15 e-competences in the Master study programme and 9 in the Bachelor study programme (Table VI). Obviously, this result should be considered good, as it gives the opportunity for students to develop 37.5 % (22.5 % in the Bachelor study programme) of the e-competences necessary for a software engineer in one course. However, some of the topics studied in the SE course are not mentioned in the e-CF, which means that they do not contribute to the formation of competences. These topics are: 1, 2 and 3 (partly) of the Bachelor study programme; topic 8 of the Master study programme. In fact, topic 1 is an introduction to the CE course. Topics 2 and 8, which consider different approaches and models of software development, are necessary for the formation of competences of almost all sections Dimension 1 of e-CF, but mostly B.BUILD. Somewhat surprising is the lack in the e-CF of an explicit reference to requirements analysis and specification, although in some sections of A.PLAN "change requirements" and "user / customer needs" are mentioned.

The European e-Competence Framework also describes 23 professions used in the IT area. Mission, responsibility, main tasks, necessary competences and their proficiency levels are defined for each profession. Table VII shows ten professions that are presented in e-CF, e-competences required for these professions and competences achieved in SE course. As can be seen from Table VII, the study course "Software Engineering" provides all competences needed for Developer and Test Specialist, as well as almost all for some other professions such as System Analyst, Database Administrator, Network Specialist, etc. For example, the profession of System Analyst additionally requires one competence E.5, but Project Manager – two competences E.4 and E.7. There are some differences in e-competence levels between the needed and achieved: C.4 for Developer, E.3 for Project Manager, etc. The required levels of e-competences can be achieved in other courses of the study programme.

TABLE VI
E-COMPETENCES IN SOFTWARE ENGINEERING COURSE

Dimension 1	**Dimension 2** (e-Competences)	**Dimension 3** (e-Competence proficiency levels)	**e-Competence levels in the Bachelor study programme**	**e-Competence levels in the Master study programme**
A. PLAN	A.3. Business Plan Development	e-3 – e-5		e-4
	A.4. Product/Service Planning	e-2 – e-4		e-4
	A.5. Architecture Design	e-3 – e-5	e-3	e-4
	A.6. Application Design	e-1 – e-3	e-3	e-3
B. BUILD	B.1.Application Development	e-1 – e-3	e-3	e-3
	B.2. Component Integration	e-2 – e-4	e-2	e-3
	B.3. Testing	e-1 – e-4	e-2	e-2
	B.4. Solution Deployment	e-1 – e-3	e-2	e-2
	B.5. Documentation Production	e-1 – e-3	e-3	e-3
	B.6.System Engineering	e-3 – e-4	e-2	e-3
C. RUN	C.4. Problem Management	e-2 – e-4	e-2	e-2
D. ENABLE	D.9. Personnel Development	e-2 – e-4		e-3
E. MANAGE	E.2. Project and Portfolio Management	e-2 – e-5		e-4
	E.3. Risk Management	e-2 – e-4		e-2
	E.6. ICT Quality Management	e-2 – e-4		e-2

TABLE VII
PROFESSIONS AND E-COMPETENCES

Profession	**Needed e-Competences (levels)**	**e-Competences (levels) achieved in the SE study course**	**Programme**	**Additionally required competences**
Database Administrator	A.6(1), B.1(3), B.2(2), C.4(3), D.10(3)	A.6(3), B.1(3), B.2(2-3), C.4(2)	B, M	D.10. Information and Knowledge Management
Developer	B.1(3), B.2(2), B.3(2), B.5(3), C.4(3)	B.1(3), B.2(2-3), B.3(2), B.5(3), C.4(2)	B, M	–
Digital Media Specialist	A.6(2), B.1(3), B.3(2), B.4(3), B.5(3), D.12(2)	A.6(3), B.1(3), B.3(2), B.4(2), B.5(3)	B, M	D.12. Digital Marketing
Network Specialist	B.1(2-3), B.2(2-3), B.4(2-3), C.4(2-3), E.8(2)	B.1(3), B.2(2-3), B.4(2), C.4(2)	B, M	E.8. Information Security Management
Project Manager	A.4(4), E.2(4), E.3(3), E.4(3), E.7(3)	A.4(4), E.2(4), E.3(2)	M	E.4. Relationship Management, E.7. Business Change Management
Quality Assurance Manager	D.2(4-5), E.3(3), E.5(3), E.6(4)	E.3(2), E.6(2)	M	D.2. ICT Quality Strategy Development, E.5. Process Improvement
Systems Administrator	B.2(2), B.3(2), C.1(2-3), C.4(2), E.8(2)	B.2(2-3), B.3(2), C.4(2)	B, M	C.1. User Support, E.8. Information Security Management
Systems Analyst	A.5(3), B.1(3), B.5(3), B.6(3), E.5(3)	A.5(3-4), B.1(3), B.5(3), B.6(2-3)	B, M	E.5. Process Improvement
Systems Architect	A.5(4), A.7(4), A.9(4), B.2(4), B.6(3-4)	A.5(3-4), B.2(2-3), B.6(2-3)	B, M	A.7. Technology Trend Monitoring, A.9. Innovating
Test Specialist	B.1(3), B.2(2-3), B.3(2-3), B.4(3), C.4(2-3)	B.1(3), B.2(2-3), B.3(2), B.4(2), C.4(2)	B, M	–

VI. CONCLUSION

Nowadays when a competency-based approach to education is being introduced everywhere, it is important to determine the competences that students can acquire by studying according to the programmes offered by higher education. This will allow further adjusting (changing) the existing programmes in accordance with the requirements of time. This study has been devoted to the analysis of the study course "Software Engineering" in order to determine the formed competences required for an IT specialist to work successfully. A set of 40 competences needed for SE professionals is presented in the European e-Competence Framework, which is the European standard.

As a result of the study, it has been found that Part 1 of the study course "Software Engineering" (the Bachelor study programme) allows developing 9 competencies, Part 2 (the Master study programme) – 15. These competences are necessary for almost all professions listed in e-CF. For example, the study course "Software Engineering" provides all competences needed for Developer and Test Specialist. Other IT professions additionally require developing 1–4 competences. For the formation of competences and assessment of the level of their mastering, practical (laboratory) assignments, as well as e-courses are used.

As part of further research, it is planned to analyse the remaining courses of the programme to determine a set of competences that a graduate of the Bachelor study programme and the Master study programme can acquire.

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