Development of the ICT-standard of Higher Education in Ukraine within the Framework of European Requirements

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Abstract. The article describes the development of the higher education standard on the specialty 121 "Software Engineering" for the first (Bachelor) level of higher education in Ukraine. The article substantiates that this standard meets e-Competence Framework 3.0 and Ukrainian legislation. A brief outline of e-Competencies is offered. For the problem better understanding, lists of graduates' general and professional (special) competencies and the standard content of the higher education students' teaching, formulated in terms of the learning outcomes are given. Special professional competencies and learning outcomes according to the standard of Bachelor's level of higher education are suggested in the article. Comparative analysis of competencies and learning outcomes of the future specialists in the field of IT technologies with the descriptors of the target ICT profiles of e-Competence Framework 3.0 are carried out by the authors. They claim that the creation of a new level of Bachelor's degree in higher education on the specialty 121 "Software Engineering" will ensure conformity with the requirements of the IT industry, as well as promote the graduates' competitiveness in IT companies.

Keywords: Information Technologies, Software Engineering, Higher Education Standard, e-Competence Framework 3.0.

1 Introduction

1.1 Problem Statement

The issue of improving the quality of teaching specialists, in particular in the field of Information Technologies (IT), is very important today. According to some estimations, higher educational institutions (HEI) in Ukraine graduate about 16 thousand young specialists annually, while the needs of the industry are more than 20 thousand [1]. However, only a part of graduates have an opportunity to be employed to an IT company, and the qualifications of the rest of the HEI graduates do not meet employers' requirements. The rapid development of IT technologies leads to a frequent review of university educational programs. In our opinion, in order to

raise the level of IT education in Ukraine, it is necessary to introduce an assessment of the content quality and results of the HEI educational activities on IT specialties, based on competencies and learning outcomes that will contribute to increasing the graduates' competitiveness in Ukraine and the world. The necessary requirement for such an assessment is the development and implementation of higher education standards that meet the requirements of the IT industry, acknowledged world standards for vocational education and training, taking into consideration the Ukrainian legislation requirements.

A characteristic feature of the orientation towards the world practice of the IT training system in Ukraine at present is a certain conformity with the fields of Bachelor's training, approved by the Ministry of Education and Science of Ukraine in the field of Information Technologies to the world practice (Computer Science, Computer Engineering, Software Engineering, Information Technology, Information Systems: 121 Software Engineering, 122 Computer Science, 123 Computer Engineering, 124 System Analysis, 125 Cybersecurity, 126 Information Systems and Technologies [2].

1.2 Related Works

The primary task of the higher education standard of Ukraine is to form both a list of graduates' competencies (integral, general and professional) and one of the learning outcomes. For this purpose, the following sources of information were worked out: the Law of Ukraine "On Higher Education" [3], methodological recommendations for the development of higher education standards [4], the National Qualifications Framework (NQF) [5], the National Classifier of Ukraine [6], standards and guidelines for quality assurance in the European Higher Education Area [7], the European e-Competence Framework 3.0 (e-CF) for ICT Professionals [8], Computer Science Curriculum [9], Software Engineering Curriculum [10], SWEBOK [11], the materials of the European Commission's "Tuning Educational Structures in Europe" (Tuning Educational Structures in Europe, TUNING) [12], Software Engineering Competency Model (SWECOM) [13].

The problems of improvement the quality of IT education based on a competence-oriented standard are studied by researches and education managers such as I. Mendzebrovsky, T. Morozova, M. Nikitchenko, V. Zaslavsky, L. Omelchuk, Z. Saydametova, and I. Turkin, V. Narozhny, T. Dehtyareva and others [15-19]. In the process of the National Qualifications Framework development, Ukrainian scholars have made a number of comprehensive generalizations regarding the conceptual foundations justification for the NQF creation and the comparison of Ukrainian qualifications with the European framework of professional qualifications.

In accordance with the Law of Ukraine "On Higher Education": "higher education standards are developed for each level of higher education within each specialty in accordance with the NQF and used to determine and assess the quality of the content and results of educational activities of higher educational institutions (scientific institutions)" [3]. Thus, on the other hand, the list of competencies and learning outcomes on specialty 121 "Software Engineering" was made in accordance with the qualifica-

tion levels of the NQF, on the other hand, it was agreed with the relevant qualifications framework of the European Higher Educational Space to ensure academic and professional mobility and lifelong learning.

One of the main standards of ICT competencies in the European Union is e-CF. In July 2016, the European standard e-CF EN 16234-1 [8] was adopted, which contains a reference to 40 competences in the field of ICT required by employers [8]. The e-CF uses five levels of competencies that include skills, knowledge, and proficiency that can be applied across Europe and are also in demand in the IT industry.

In accordance with the Law of Ukraine "On Education" and the e-Competence Framework, the first (Bachelor) level of higher education corresponds to the Bachelor's degree, the seventh level of the NQF and the third one of e-CF.

When using e-CF it is important to take into consideration that this standard is primarily a professional-oriented framework for ICT competencies. This is indicated in the e-CF description [8]. Therefore, the above correlation should be aimed at, but at the same time, one should not forget the crucial importance of professional experience for gaining competences in accordance with e-CF levels.

The purpose of the article is to develop of the standard of the first (Bachelor) level of higher education on specialty 121 "Software Engineering" [18] and to analyze its compliance with the e-CF for ICT Professionals [8].

2 Results of Investigation

One of the authors of this article was a member of the group which developed the standard of the first (Bachelor) level of higher education in the specialty 121 "Software Engineering". While developing this standard, the authors analyzed e-CF, employers' requirements, international standards in the IT industry and the legislative framework of Ukraine. Thus, this standard was developed taking into account all of the requirements mentioned above.

Having analyzed the existing sources, we will present the conformity of developed the first level of higher education standard on specialty 121 "Software Engineering" to the e-CF.

According to the National Occupational Classification [6], a Bachelor's Degree Educational and Training Program on Software Engineering should set up requirements for the content, amount and level of education and training of IT specialists. In particular, specialists in the qualification group of Technician Programmer (code 3121) include: a Software Technician, an IT Specialist, a Computer Graphics (Design) Specialist, a Specialist in Software Development and Testing, and a Specialist on Computer Software Development.

According to the authors opinions, occupational activities of the National Occupational Classifier correspond to the following profiles of the e-CF: a Developer, a Testing Specialist, a Media Specialist (see Table 1).

Table 1. Correspondence between e-CF profiles and professions represented by the National Occupational Classifier

e-CF profiles	Ukrainian names of professions
Developer	Technician-programmer, specialist in the development of computer programs
Digital Media Specialist	Computer graphics specialist (designer)
Test Specialist	Specialist in software development and testing

The profiles, which found the correspondence to the target specialty for professional work have been named as "core profiles". The core profiles are not enough to determine the target competencies of training specialists in the field of "Software Engineering". Thus, we will consider profiles of the Developer, Test Specialist, Digital Media Specialist, System Analyst, System Architect, Database Administrator, System Administrator, Specialist in Telecommunication Technologies. At the same time, we are to emphasize the necessity to confirm the competencies and learning results to the e-Competence level higher education standard according to the core profile, namely the Developer, the Test Specialist, the Digital Media Specialist and the possibility of expanding the list of competencies and learning outcomes towards the profiles of the System Analyst, System Architect, Database Administrator, System Administrator, Specialist in Telecommunication Technologies. Table 2 demonstrates the e-CF competency codes at e-3 level, which correspond to the profiles being pointed out as well as offers the core profiles.

Table 2. e-CF descriptors of the skill at level e-3

European ICT-profile	Competency Criteria according to e-CF (descriptors 1) at level e-3 (1 higher education level)
Data Administrator	B.1, B.2, C.4, D.10
Developer	**B.1, B.5, C.4**
Digital Media Specialist	**B.1, B.4, B.5**
System Architect	A.3
ICT Specialist	B.1, B.2, B.4, C.4
System Administrator	C.1
System Analyst	A.5, B.1, B.6, E.5
System Architect	B.6
Test Specialist	**B.1, B.2, B.3, B.4, C.4**

It should be noted that educational standards should be aimed at determining competencies and outcomes of educational activities, rather than defining professional qualifications. They should develop competencies aimed at achieving professional qualifications, but they cannot fully ensure it due to the lack of substantial professional experience. Thus, it is impossible to achieve some e-CF descriptors without the availability of professional experience in certain positions, which is not always possible to guarantee within the educational activities. On the other hand, the specificity of educational activ-

ities implies the possibility of additional educational competencies and learning outcomes aimed at developing professional skills, but they are not directly as such.

Another important aspect that should have been taken into account while developing the standard is the correspondence of the competencies and learning outcomes suggested in the standard to the Ukrainian legislation, in particular, the Law of Ukraine "On Higher Education", the National Qualifications Framework and the employers' requirements in the field of information technology.

The standard of the first (Bachelor) level of higher education on the specialty 121 "Software Engineering" lists of the graduates' general and professional (special) competences and the regulatory content of the graduates' study is formulated in terms of learning outcomes. The special (professional) competencies and graduates' learning outcomes are the most important in the formation of professional qualities. Therefore, it is them that we will compare with the descriptors of target ICT profiles of e-CF corresponding to the education level.

In the developed standard that is being analyzed, the following special (professional) competencies are offered [19]:

C13. Ability to identify, classify and formulate software requirements.

C14. Ability to participate in software projecting, including simulation (formal description) of its structure, behavior and processes of operation.

C15. Ability to develop architectures, modules and components of software systems.

C16. Ability to formulate and provide software quality requirements in accordance with employer's requirements, technical specifications and standards.

C17. Ability to follow the specifications, standards, rules and recommendations in the professional field while implementing lifecycle processes.

C18. Ability to analyze, select and apply methods and tools for providing information security (including cyber security).

C19. Mastering the knowledge about data information models, the ability to create software for storing, extracting and processing data.

C20. Ability to apply fundamental and interdisciplinary knowledge to successfully solving the tasks of software engineering.

C21. Ability to assess and take into account the economic, social, technological and environmental factors that influence the field of professional activity.

C22. Ability to accumulate process and systematize professional knowledge as to software creation and maintenance as well as recognition of the lifelong learning importance.

C23. Ability to implement the phases and the life cycle iterations of software systems and information technologies based on corresponding models and approaches to software development.

C24. Ability to implement the process of system integration, apply standards and procedures for managing changes to maintain integrity, general functionality and reliability of the software.

C25. Ability to choose argumentatively and master instrumental tools and resources of software development and support.

C26. Ability to algorithmic and logical thinking.

Also, this standard offers the following learning outcomes [19]:

PR01. To analyze, purposefully search and choose the resources and knowledge necessary for the professional tasks of the information resource solution, taking into consideration the modern achievements of science and technology.

PR02. Know the code of professional ethics, understand the social significance and cultural aspects of software engineering and follow them in professional activities.

PR03. Know the basic processes, phases and iterations of the software lifecycle.

PR04. Know and apply professional standards and other normative and legal documents in the field of software engineering.

PR05. Know and apply appropriate mathematical concepts, methods of domain, system and object-oriented analysis and mathematical modeling for software development.

PR06. Ability to choose and use appropriate methodology for developing software.

PR07. Know and apply in practice the fundamental concepts, paradigms and basic principles of language functioning, instrumental and computing software engineering.

PR08. Be able to develop a human-machine interface.

PR09. Know and be able to use methods and tools for collecting, formulating and analyzing software requirements.

PR10. Conduct a pre-project survey of the subject area, a systematic analysis of the object design.

PR11. Choose input data for design, guided by formal descriptions of requirements and modeling.

PR12. Apply in practice effective approaches to software design.

PR13. Know and apply methods of algorithms developing, software design, data and knowledge structures.

PR14. Apply in practice instrumental software tools for domain analysis, design, testing, visualization, measurement and documentation of software.

PR15. Choose reasonably programming languages and development technology to solve the tasks of creating and maintaining software.

PR16. Have skills in team development, approval, design and software documentation of all kinds.

PR17. Be able to apply techniques of component software development.

PR18. Know and be able to apply information technologies of processing, storage and data transmission technologies.

PR19. Know and be able to apply the methods of software verification and validation.

PR20. Know the approaches to assessment and software quality assurance.

PR21. Know, analyze, choose, apply information security (including cyber security) and data integrity in a qualified manner in accordance with application tasks being solved and software systems being developed.

PR22. Know and be able to apply methods and tools for project management.

PR23. Be able to document and present the results of software development.

PR24. Be able to calculate the economic efficiency of software systems.

In Table 3 we carried out the analysis of the correspondence of the competencies and learning outcomes suggested in the first-level higher education standard on the specialty 121 “Software Engineering” to e-CF descriptors for ICT professionals.

Table 3. Correspondence the e-CF descriptors and competencies to the first level higher education standard on specialty 121 “Software Engineering”

e-CF descriptors		**The standard of the first level of higher education by specialty 121 "Software engineering"**	
1	**2**	**Competence**	**Program learning outcomes**
A. Plan	A.3. Business Plan Development	C13	PR08, PR09, PR10
		C16	PR04, PR14, PR19, PR20
	A.5. Architecture Design	C15	PR05, PR12, PR13, PR14
		C25	PR14, PR15, PR18
	A.6. Application Design	C14	PR05, PR11, PR12, PR14
		C26	PR05, PR13
	A.8. Sustainable Development	C20	PR01, PR05, PR07
		C21	PR02, PR20, PR24
		C22	PR01, PR06, PR08, PR15, PR21
B. Build	B.1. Application Development	C23	PR03, PR06, PR07, PR15, PR22
		C25	PR14, PR15, PR18
	B.2. Component I ntegration	C24	PR03, PR04, PR16
	B.3. Testing	C16	PR04, PR14, PR19, PR20
	B.4. Solution Deployment	C17	PR02, PR04
	B.5. Documentation Poduction	C13	PR08, PR09, PR10, PR23
		C16	PR04, PR14, PR19, PR20
	B.6. Systems Engineering	C18	PR07, PR17
C. Run	C.1. User Support (from the System Administrator profile)	-	-
	C.4. Problem Management	C21	PR02, PR20, PR24
D. Enable	D.10. Information and Knowledge Management	C19	PR13, PR18
E. Manage	E.5. Process Improvement	C22	PR01, PR06, PR08, PR15, PR21

According to the analysis given in Table 3, we see that:

- All specialist (special) competencies and learning outcomes offered in the first-level higher education standard on specialty 121 “Software Engineering” are reflected in the competencies offered for profiles of e-CF e-3 levels.
- For all competencies of the “core profiles” of e-CF of e-3 level, the relevant professional competencies and learning outcomes in the first-level higher education standard on specialty 121 Software Engineering were found out.
- Of the selected e-CF descriptors only the “C.1 User Support” descriptor was not reflected in the first-level higher education standard on specialty 121 “Software Engineering”, but this descriptor belongs to the additional system of administrator profile, and as it was indicated above not to be required for the specialty being investigated.

We offer a brief description of the e-Competencies given in Table 3 [8].

Dimension 1 e-Competence area: A. PLAN. Dimension 2 e-Competence: Title + generic description: A.3. Business Plan Development. Addresses the design and structure of a business or product plan including the identification of alternative approaches as well as return on investment propositions. Considers the possible and applicable sourcing models. Presents cost benefit analysis and reasoned arguments in support of the selected strategy. Ensures compliance with business and technology strategies. Communicates and sells business plan to relevant stakeholders and addresses political, financial, and organisational interests. **Dimension 3 e-Competence proficiency level e-3:** Exploits specialist knowledge to provide analysis of market environment etc.

Dimension 1 e-Competence area: A. PLAN. Dimension 2 e-Competence: Title + generic description: A.5. Architecture Design. Specifies, refines, updates and makes available a formal approach to implement solutions, necessary to develop and operate the IS architecture. Identifies change requirements and the components involved: hardware, software, applications, processes, information and technology platform. Takes into account interoperability, scalability, usability and security. Maintains alignment between business evolution and technology developments. **Dimension 3 e-Competence proficiency level e-3:** Exploits specialist knowledge to define relevant ICT technology and specifications to be deployed in the construction of multiple ICT projects, applications or infrastructure improvements.

Dimension 1 e-Competence area: A. PLAN. Dimension 2 e-Competence: Title + generic description: A.6. Application Design. Analyses, specifies, updates and makes available a model to implement applications in accordance with IS policy and user/ customer needs. Selects appropriate technical options for application design, optimising the balance between cost and quality. Designs data structures and builds system structure models according to analysis results through modelling languages. Ensures that all aspects take account of interoperability, usability and security. Identifies a common reference framework to validate the models with representative users, based upon development models (e.g. iterative approach). **Dimension 3 e-Competence proficiency level e-3:** Accounts for own and others actions in ensuring that the application is correctly integrated within a complex environment and complies with user/ customer needs.

Dimension 1 e-Competence area: A. PLAN. Dimension 2 e-Competence: Title + generic description: A.8. Sustainable Development. Estimates the impact of ICT solutions in terms of eco responsibilities including energy consumption. Advises business and ICT stakeholders on sustainable alternatives that are consistent with the business strategy. Applies an ICT purchasing and sales policy which fulfills eco-responsibilities. **Dimension 3 e-Competence proficiency level e-3:** Promotes awareness, training and commitment for the deployment of sustainable development and applies the necessary tools for piloting this approach.

Dimension 1 e-Competence area: B. BUILD. Dimension 2 e-Competence: Title + generic description: B.1. Application Development. Interprets the application design to develop a suitable application in accordance with customer needs. Adapts existing solutions by e.g. porting an application to another operating system.

Codes, debugs, tests and documents and communicates product development stages. Selects appropriate technical options for development such as reusing, improving or reconfiguration of existing components. Optimises efficiency, cost and quality. Validates results with user representatives, integrates and commissions the overall solution. **Dimension 3 e-Competence proficiency level e-3:** Acts creatively to develop applications and to select appropriate technical options. Accounts for others development activities. Optimizes application development, maintenance and performance by employing design patterns and by reusing proved solutions.

Dimension 1 e-Competence area: B. BUILD. Dimension 2 e-Competence: Title + generic description: 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. **Dimension 3 e-Competence proficiency level e-3:** Accounts for own and others actions in the integration process. Complies with appropriate standards and change control procedures to maintain integrity of the overall system functionality and reliability.

Dimension 1 e-Competence area: B. BUILD. Dimension 2 e-Competence: Title + generic description: B.3. Testing. Constructs and executes systematic test procedures for ICT systems or customer usability requirements to establish compliance with design specifications. Ensures that new or revised components or systems perform to expectation. Ensures meeting of internal, external, national and international standards; including health and safety, usability, performance, reliability or compatibility. Produces documents and reports to evidence certification requirements. **Dimension 3 e-Competence proficiency level e-3:** Exploits specialist knowledge to supervise complex testing programmes. Ensures tests and results are documented to provide input to subsequent process owners such as designers, users or maintainers. Accountable for compliance with testing procedures including a documented audit trail.

Dimension 1 e-Competence area: B. BUILD. Dimension 2 e-Competence: Title + generic description: B.4. Solution Deployment. Following predefined general standards of practice carries out planned necessary interventions to implement solution, including installing, upgrading or decommissioning. Configures hardware, software or network to ensure interoperability of system components and debugs any resultant faults or incompatibilities. Engages additional specialist resources if required, such as third party network providers. Formally hands over fully operational solution to user and completes documentation recording all relevant information, including equipment addressees, configuration and performance data. **Dimension 3 e-Competence proficiency level e-3:** Accounts for own and others actions for solution provision and initiates comprehensive communication with stakeholders. Exploits specialist knowledge to influence solution construction providing advice and guidance.

Dimension 1 e-Competence area: B. BUILD. Dimension 2 e-Competence: Title + generic description: B.5. Documentation Production. Produces documents describing products, services, components or applications to establish compliance with relevant documentation requirements. Selects appropriate style and media for presentation materials. Creates templates for document-management systems. Ensures that functions and features are documented in an appropriate way. Ensures that existing documents are valid and up to date. **Dimension 3 e-Competence proficiency level e-3:** Adapts the level of detail according to the objective of the documentation and the targeted population.

Dimension 1 e-Competence area: B. BUILD. Dimension 2 e-Competence: Title + generic description: B.6. Systems Engineering. Engineers software and/or hardware components to meet solution requirements such as specifications, costs, quality, time, energy efficiency, information security and data protection. Follows a systematic methodology to analyse and build the required components and interfaces. Builds system structure models and conducts system behavior simulation. Performs unit and system tests to ensure requirements are met. **Dimension 3 e-Competence proficiency level e-3:** Ensures interoperability of the system components. Exploits wide ranging specialist knowledge to create a complete system that will satisfy the system constraints and meet the customer's expectations.

Dimension 1 e-Competence area: C. RUN. Dimension 2 e-Competence: Title + generic description: C.1. User Support. Responds to user requests and issues, recording relevant information. Assures resolution or escalates incidents and optimises system performance in accordance with predefined service level agreements (SLAs). Understands how to monitor solution outcome and resultant customer satisfaction. **Dimension 3 e-Competence proficiency level e-3:** Manages the support process and accountable for agreed SLA. Plans resource allocation to meet defined service level. Acts creatively, and applies continuous service improvement. Manages the support function budget.

Dimension 1 e-Competence area: C. RUN. Dimension 2 e-Competence: Title + generic description: C.4. Problem Management. Identifies and resolves the root cause of incidents. Takes a proactive approach to avoidance or identification of root cause of ICT problems. Deploys a knowledge system based on recurrence of common errors. Resolves or escalates incidents. Optimises system or component performance. **Dimension 3 e-Competence proficiency level e-3:** Exploits specialist knowledge and in-depth understanding of the ICT infrastructure and problem management process to identify failures and resolve with minimum outage. Makes sound decisions in emotionally charged environments on appropriate action required to minimise business impact. Rapidly identifies failing component, selects alternatives such as repair, replace or reconfigure.

Dimension 1 e-Competence area: D. ENABLE. Dimension 2 e-Competence: Title + generic description: D.10. Information and Knowledge Management. Identifies and manages structured and unstructured information and considers information distribution policies. Creates information structure to enable exploitation and optimisation of information. Understands appropriate tools to be deployed to create, extract, maintain, renew and propagate business knowledge in order to capi-

talise from the information asset. **Dimension 3 e-Competence proficiency level e-3:** Analyses business processes and associated information requirements and provides the most appropriate information structure.

Dimension 1 e-Competence area: E. MANAGE. Dimension 2 e-Competence: Title + generic description: E.5. Process Improvement. Measures effectiveness of existing ICT processes. Researches and benchmarks ICT process design from a variety of sources. Follows a systematic methodology to evaluate, design and implement process or technology changes for measurable business benefit. Assesses potential adverse consequences of process change. **Dimension 3 e-Competence proficiency level e-3:** Exploits specialist knowledge to research existing ICT processes and solutions in order to define possible innovations. Makes recommendations based on reasoned arguments.

3 Conclusions and Future Perspectives

Thus, in our opinion, when creating a list of competencies and learning outcomes of the first-level higher education standard on specialty 121 “Software Engineering”, competencies are taken into consideration, which are offered in the e-CF for ICT-profiles that correspond to the professional qualifications and can be obtained on mastering educational programs on this specialty taking into account the specificity of educational activity in Ukraine and Ukrainian legislation.

The developed standard of higher education in the specialty 121 “Software Engineering” is approved by the Ministry of Education and Science of Ukraine in October 2018 [18]. All higher educational institutions of Ukraine use the standard of Educational programs for the preparation of bachelors in the specialty 121 “Software Engineering”.

Agreement with the new Ukrainian first level higher education standard on the specialty 121 “Software Engineering” to IT industry requirements and international standards will promote graduates’ competitiveness in the IT-companies, that is the recognition results provided by the educational system abroad, including international recognition of Ukrainian diplomas and students’ mobility.

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