Model of the Curriculum Revision System in Computer Science

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Abstract. The onrush of information technology raises the task of revising curricula of specialties in computer science. The *objectives of the study* are to define the requirements and develop a model of the curriculum revision system in computer science.
Subject of research: curriculum revision system in computer science.
Research methods: review and analysis of scientific publications, modeling of complex systems, questionnaires, expert method of evaluation.
The model of the revision system of the curriculum is built taking into account the modern requirements of employers to the competence of university graduates in computer sciences. The architecture of this system is built on the basis of research on the functionality of such elements as the Top Competences (required in the labor market), Employers' Requirements, Learning outcomes (expected results of teachers) and the formation of the ICT curriculum. The expert method is used to assess the quality of the revision model of the curriculum on the example of a specialty in the field of computer science.
Results of the research: the requirements of the labor market to the competence of university graduates were investigated, systematized and formulated in the field of computer science. These requirements are the basis for the formation of a new or improvement of the existing curriculum at the university.

Keywords: Curriculum in Computer Science, Curriculum Revision Model, Requirements for the Competences, Learning Outcomes.

1 Introduction

Universities play an important part in modeling, creating and developing innovative systems in the economy. To successfully promote innovative systems, universities must effectively manage the dissemination of knowledge [1]. Entrepreneurial skills and innovative efforts in the field of information technology increase the scale, complexity and connect an increasing number of key stakeholders who can offer key innovative changes in the curriculum of ICT. In an era of growing global competition, it is asserted that innovative and entrepreneurial competencies are key sources of the competitive advantage of the curriculum in the field of computer science [2]. An innovative curriculum in informatics should take into account the importance of crossing and revising the global, national, industrial and local needs of stakeholders that

form the ultimate demand for university graduates. This approach offers a way to develop and improve the curriculum in the field of computer science as a link between education, technological innovation, production and development [3].

It is especially important to reach a high level of education in the field of computer science in Ukrainian universities, because by 2020 the IT industry of Ukraine has every chance to take the second place in the country's export structure, reaching 7.7 billion dollars. Within five years, the number of IT professionals in Ukraine should reach 200,000 people. The need for highly qualified specialists also occurs in all developed and developing countries. Broad and intensive development of IT technologies, their use in the economy determines the need for specialists in new specialties in the field of computer science, and also requires more frequent updating of university curricula.

The purpose of this study is to develop a model for creating a new system and revising the existing curriculum in informatics for a master's program using the requirements of stakeholders at the international and local levels.

2 System Analysis

2.1 Modern Requirements for the Curriculum

The model of the curriculum is designed to eliminate the difference between the traditional approach to the development of curricula with normative disciplines and the modern approach to the development of curricula with normative competences. According to modern approach a curriculum is specified using graduate competencies as its foundational element, instead of courses or knowledge areas, units, and topics (Fig. 1). Traditionally, most ICT curriculums have been structured around a typically hierarchical Knowledge Area – Knowledge Unit – Topic structure that together forms a Body of Knowledge. Knowledge areas include several knowledge units. Each knowledge unit, in turn, is divided into topics [4].

A potential problem with the traditional structure is that it focuses mostly on cognitive aspects of learning and leaves requirements of labor market out. A curriculum based on a knowledge area structure conveys relatively few skills and attitudes on what the graduates are able to do at the time of graduation. Instead of defining a knowledge area or a set of courses, a modern approach to the specification of the curriculum defines a set of graduate competencies, through which they can use their knowledge, skills and attitudes to successfully perform assigned tasks.

The curriculum specifies high-level competency areas. The competency areas are divided into competency categories which consist of actual competencies. Competency areas and competency categories are much more stable and less technology-dependent than the competencies themselves which have relatively high likelihood of changes and local variations than at the higher levels. Each competency area has a name, a brief description and a few high-level dimensions. Each category and competency within a category is specified with a name and a brief description too. Competence area covers high-level competencies which enable the graduates to achieve their

goals. Competence categories consist of low-level competences which are the tactical tasks to achieve strategic goal.

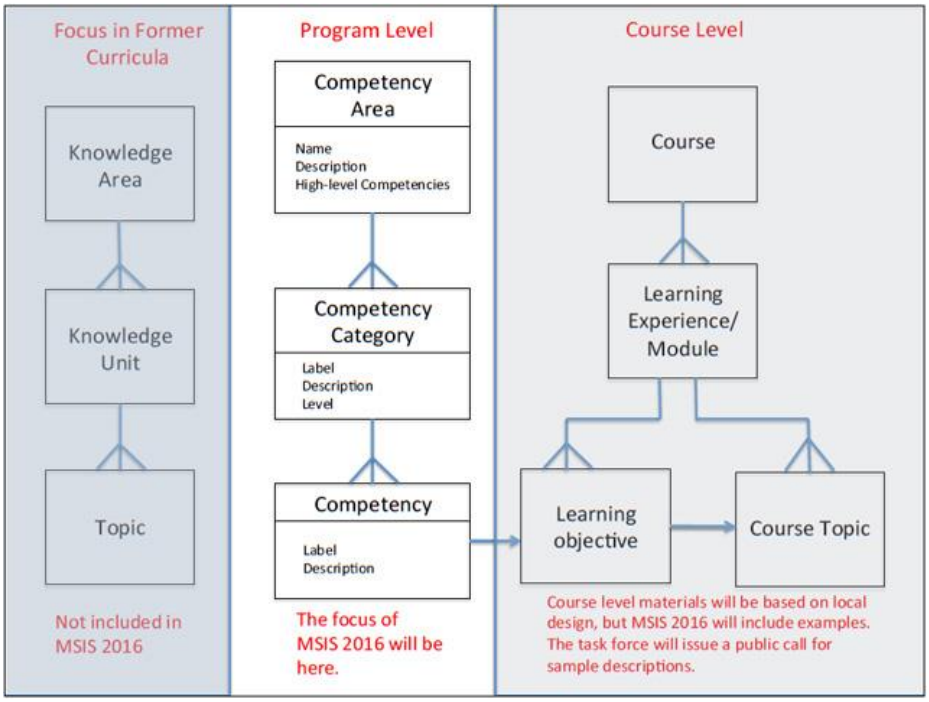

Fig. 1. Curriculum model for traditional and modern approach.

2.2 Requirements of Stakeholders

In a competitive environment, universities take into account changes in the world labor market and the sphere of world education. They respond to the needs of employers; make changes in the educational process in order to improve quality, to provide graduates with better employment opportunities.

The needs of Stakeholders can be studied by the survey method as a result of the questionnaire. For example, employers' requirements for the qualification of graduates of the Kherson State University (KSU) were investigated [5] within the framework of the MASTIS project [6]. The largest employers of our graduates are such leading companies as DataArt, Logicify, Wezom, Autoplaneta, PrivatBank, Raiffeisen Bank Aval and others.

The reason for creation of new curriculum is new insights and the strategic view of our university on future IT education [7] where simulation business model for different information systems will be used [8]. We conclude that at each company all vacancies are different so requirements of employers are different too. Good analytical skills and open mind are great results of completed master degree education. Actually,

companies don't need ALL these competences of employees; it depends on their position in the company.

Stakeholders requirements to MASTER in Information Systems include:

1. Pre-research – analysis of official reports, research and strategies in order to create an overview of Kherson IT sector. We have used data and references available from official data of Ukrainian statistics, Ministry of Science and Education, Reports of IT Industry 2015. KSU has been engaged in collecting and maintaining lists of IT companies and IT departments, with CEO & Heads' names, phone numbers, e-mail and web addresses, etc.
2. Online questionnaire of IT companies (https://goo.gl/N7QbFp)
3. Interviews and meetings with stakeholders. CISEEC of KSU organized separate interviews with different stakeholders.
4. Collection and analysis of information obtained from pre-research, online questionnaire and meetings with stakeholders to assess the courses according to the requirements to specialists training in the field of information systems. CISEEC of KSU is engaged in the analysis of the results.

Among our stakeholders were representatives of small, medium and large companies [5].

After processing the online questionnaire of employers, a list of required competences for the Master of Science in Information Systems (MSIS) was generated (Table 1).

Table 1. Stakeholders grades of MSIS 2016 competences [5].

Competency Areas	**Relevance of area, %**
Business Continuity and Information Assurance	8,78
Systems Development and Deployment	10,61
Data, Information and Content Management	11,33
Ethics, Impacts and Sustainability	12,19
Enterprise Architecture	12,55
IS Strategy and Governance	12,84
Innovation, Organizational Change and Entrepreneurship	13,27
IS Management and Operations	9,47
IT Infrastructure	8,96

After interview with employers at Kherson (Ukraine) we obtained following results (Fig. 2).

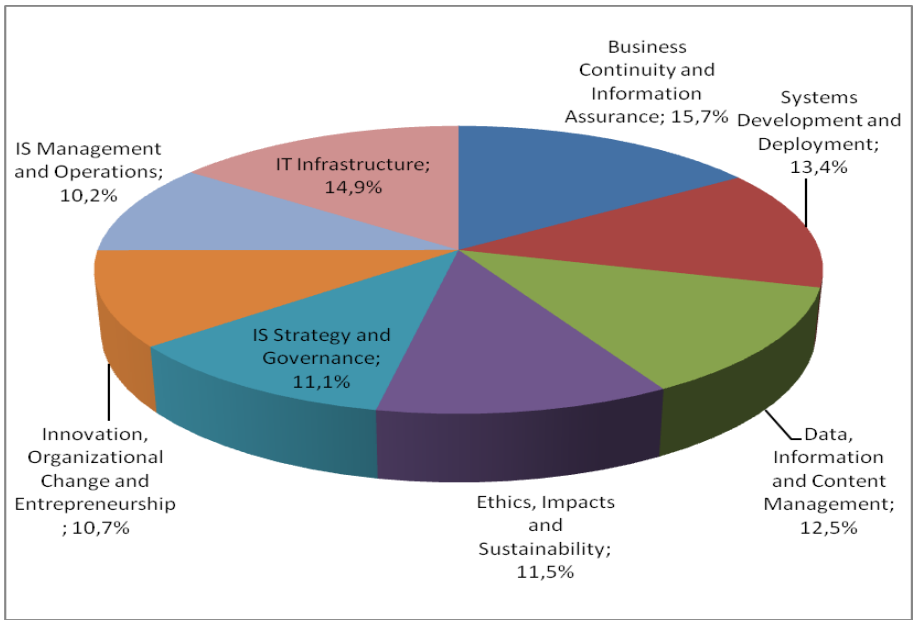

Fig. 2. Relevance for competency areas of Kherson employers, %.

After comparing of requirements of global (Table 1) and local Kherson labor market (Fig. 2) we got significant overestimation for IS Management and Operations (+3.1%) and significant underestimation for Business Continuity and Information Assurance (-6.92%) and IT Infrastructure (-5.4%).

A comparative analysis of preliminary and subsequent requirements demonstrates a significantly revised opinion of employers on some competencies (Table 2).

Table 2. Comparative analysis of stakeholders' requirements to competences of graduates for MSIS.

Online questionnaire competence specification grades	**(1 - min; 5 - max)**	**Average result of stakeholders' grades for AIS MSIS 2016 competences**	**(1 - min; 5 - max)**	**Interdependence («-» means revised opinion)**
Systematic competences	3,86	6. IS Strategy and Governance	3,58	+
		8. IS Management and Operations	2,64	-
Methodological competences	4,17	3. Data, Information and Content Management	3,16	?
Social/personal competences	3,37	4. Ethics, Impacts and Sustainability	3,40	+
		9. IT Infrastructure	2,50	-

Professional competences: analysis, design, and project management	4,17	2. Systems Development and Deployment	2,96	-
Professional competences: implementation and systems administration	4,10	1. Business Continuity and Information Assurance	2,45	-
		5. Enterprise Architecture	3,50	+
Research and academic/analytical competences	4,13	7. Innovation, Organizational Change and Entrepreneurship	3,70	+

3 Model

When building a model of the curriculum revision system in computer science, we will use the E-Competence Framework 3.0 specification as an educational standard [9, 10]. The employers' requirements for the master program in Information Systems (MPIS) are the combination of the following realms (Fig. 3):

1. Computing/ICT subject area (IT industry);
2. IS Management (IT departments of small and medium enterprises and large companies);
3. Domain of practice (or Internship of master students);
4. Generic individual skills (soft skills).

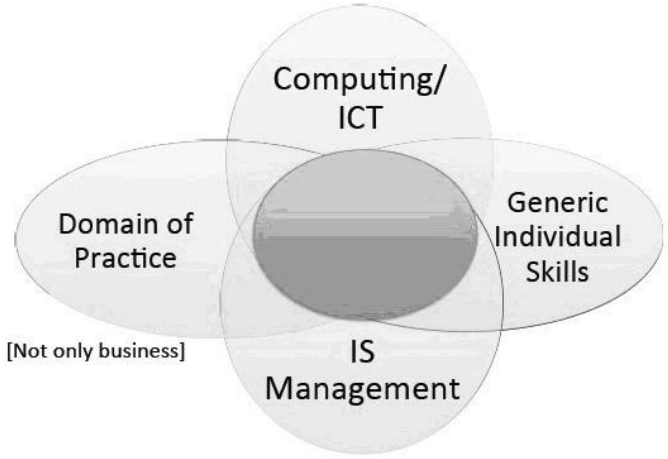

Fig. 3. Elements of MPIS.

After processing of several hundred stakeholders' requirements (according to competences area of international Master of Science in Information Systems (MSIS) standards) prepared by 6 Ukraine universities (Simon Kuznets Kharkiv National University of Economics, Ukraine National Technical University of Ukraine "KPI", Lviv Polytechnic National University, Vinnytsia National Technical University, Kherson

State University, National Technical University “Kharkiv Polytechnic Institute”) and 2 Montenegro universities (University of Donja Gorica, University "Mediterranean" Podgorica) all project members reveal top competences. Stakeholders range competences from different competency area of MSIS 2016 standard according to their experience on labor market. To cover key competences required by employers in labor market teachers prepare necessary learning outcomes (as indicators of forming competences) which later will form the disciplines of ICT curriculum. Competence-oriented approach means that employers can form main requirements to graduates and curriculum because they are final consumers of labor force (Fig. 4).

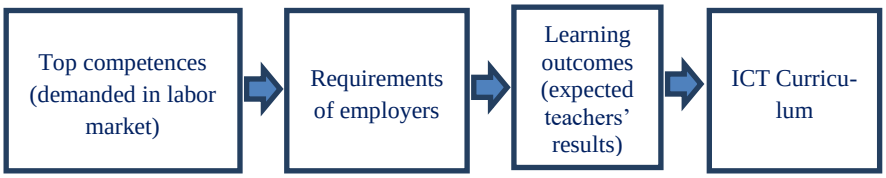

Fig. 4. Architecture of ICT curriculum as competence-oriented approach.

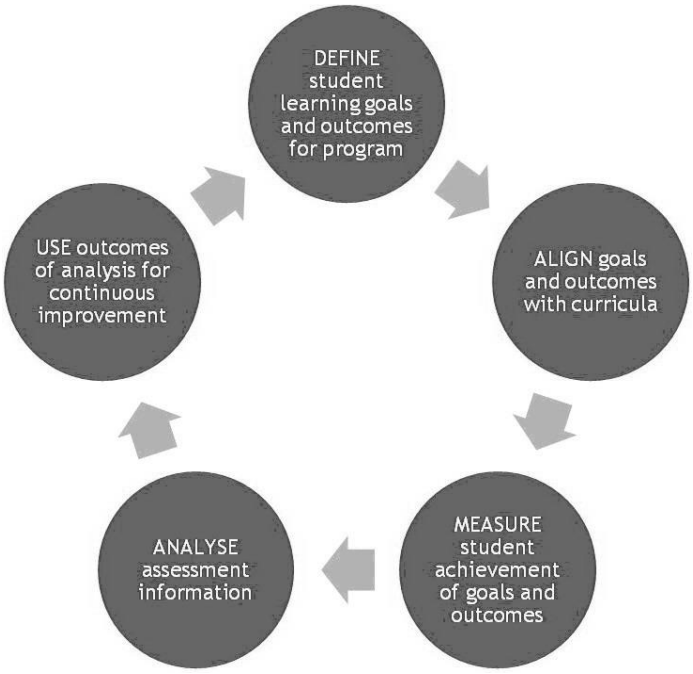

Fig. 5. AoL process modelling.

When revising curricula, universities should take into account international accreditation standards for providing training, such as the Association for Promoting Collegiate Schools of Business (AACSB). Learning provision (AoL) refers to a systematic process of collecting data on learning outcomes, reviewing and using it for the continuous development and improvement of degree programs (Fig. 5).

AoL ensures that university graduates achieve goals and outcomes if universities manage the quality of curricula. AoL supports the continuous improvement of curricula. Accreditation agencies suggest critical revision of module compendium from courses of ICT curriculum after 3-4 years, e.g. in the process of re-accreditation.

The expert method should be used to assess the quality of the curriculum revision model in the field of computer science.

Thus, the curriculum is built using competencies as the main element, rather than courses or knowledge areas, units and topics.

4 Approbation of the Model in the Educational Process

The presented model was used to create a new master program in Information Systems and Technologies at the Department of Informatics, Software Engineering and Economic Cybernetics of KSU. The competences of the graduates were determined in accordance with the requirements of the stakeholders described above.

We developed correspondence between competences and learning outcomes for general (Table 3) and specific subject competences (Table 4) for MPIS using requirements of global and local labor market.

Table 3. Generic competences for MPIS.

	Learning Outcomes	Competences					
		1	2	3	4	5	6
		Developing a business plan	Know and apply widely used Project Management tools and techniques	Analyzing and documenting business activities	Maintaining an ethical culture	Engaging entrepreneurial thinking	Understanding enterprise architecture principles and the value it provides to business
1	to coordinate different needs and expectations of various project stakeholders, including team members, resource managers, senior management customers, and sponsors	X					
2	to plan, execute, and control tasks,		X				

	phases, and deliverables of the project based on the identified project goals and objectives using Project Management						
3	be able to reasonably choose modelling method to construct an adequate model of the system or process using modem computer tools to interpret and analyze the simulation results			X			
4	to use own methods and techniques work in CASE-tools, methods and techniques of work in the simulation system design and development of computer programs			X			
5	to use tools for detecting plagiarism and checking the originality of submitted reports, seminar works and theses; ability to comply with ethical requirements and to comply with copyright. in professional activities				X		
6	counteraction to attempt to get honour of work that somebody else has done				X		
7	to apply different concepts and skills in various business contexts using case studies and hands-on exercises with leading software applications					X	
8	to have an understanding of business intelligence and analytics and how businesses use them						X
9	to extract, manipulate and transform data from different sources						X

Table 4. Specific subject competences for MPIS.

Learning Outcomes		Competences					
		7	8	9	10	11	12
		Selecting and using appropriate analytics methods	Integrating and preparing data captured from various sources for analytical use	Implementing and managing quality audit processes	Specifying and documenting systems requirements	Designing systems	Selecting between systems development approaches
10	to apply different concepts and skills in various business contexts using case studies and hands-on exercises with leading software applications	X					

11	to be able for metadata and data quality management to integrate data and convert data in any format for storage and delivery to any system		X				
12	to use the requirements, specifications and application of international quality standards to apply methods for determining of indicators and quality criteria			X			
13	to be able to simulate and manage the process of quality monitoring in the firm			X			
14	to be able to reasonably choose the modelling method to construct an adequate model of the system or process using modern computer tools to interpret and analyze the simulation results				X		
15	to use own methods and techniques work in CASE-tools, methods and techniques of work in the simulation system design and development of computer programs				X		
16	be able to understand basic features of the systems and their connection with their environment using tools and techniques of Analysis and Planning systems					X	
17	be able to cooperate in a team in order to deal with a system case study					X	
18	to use methods of structural and object-oriented analysis and design of modern software complexes to reveal the business processes requirements of enterprises						X

Considering competencies proposed by our employers we created the following courses for Curriculum Master of Information System (Table 5), which take into account global and regional requirements to alumni of MPIS. These requirements are presented in the European e-Competence Framework (e-CF 3.0), which contains a reference to 40 competencies as applied at the Information and Communication Technology (ICT) workplace, using a common language for competencies, skills, knowledge and proficiency levels that can be understood throughout Europe [9].

Table 5. Developed Curriculum Master of Information System.

Number	Mandatory courses	Elective courses
1	IS Development and Deployment	Scientific research and intellectual property
2	MIS and Data Warehousing	Standardization and certification of information technologies
3	Enterprise Architecture Management	Business process modeling
4	Management of IS Projects	Advances in Programming and IS

5	IT Infrastructure	E-commerce and e-business systems
6	Innovations and Entrepreneurship	Formal methods of analysis and verification of IS
7	IS Strategy	Data Mining
8	IS Security	Elective courses from university pool

Each course of Computer Science Curriculum is aimed to cover demanded competencies of labor market. Each year at a meeting of employers and faculty members of the department, the list of generic and specific subject competencies should be revised. It creates the need to revise the relevant learning outcomes (LO) that are determined by university professors and are formed in students during their study of the course.

To revise the adequacy of competencies, learning outcomes, topics and disciplines to the needs of the labor market, a group of experts put points from 0 to 10. Experts are selected among the main employers for graduates of the department, the main faculty members, and representative students to review the adequacy of competencies, learning outcomes, topics and disciplines to meet the needs of the labor market. An example of an expert evaluation is presented in table 6.

Table 6. Assessment form for expert 1 about topics of discipline.

Expert 1	**Competence 1**			**…**	**Competence 16**		
List of topics	LO_1	…	LO_{19}	…	LO_1	…	LO_{19}
Topic 1	$e1_{1\_1}^{(1)}$	…	$e1_{1\_19}^{(1)}$	…	$e1_{1\_1}^{(16)}$	…	$e1_{1\_19}^{(16)}$
Topic 2	$e1_{2\_1}^{(1)}$	…	$e1_{2\_19}^{(1)}$	…	$e1_{2\_1}^{(16)}$	…	$e1_{2\_19}^{(16)}$
…	…	…	…	…	…	…	…
Topic 10	$e1_{10\_1}^{(1)}$	…	$e1_{10\_19}^{(1)}$	…	$e1_{10\_1}^{(16)}$	…	$e1_{10\_19}^{(16)}$

where $ex_{y\_z}^{(t)}$ - expert's grade, x - expert's number, y - topic's number, z - number of LO, t - number of competence.

After questionnaire of all experts, we will determine the average grade and the degree of variation obtained after each round. When the grades of the experts will no longer go out of the first and third quartiles then the poll will be stopped. Then the coefficient of variation $V_{x\_y}^{(t)}$ is calculated as the ratio of the root of variation to the average grade. If $V_{x\_y}^{(t)} \le \frac{1}{3}$ then the opinions of the experts are considered as compatible. Whereas if $V_{x\_y}^{(t)} \le \frac{1}{3}$ then the opinions of experts have low degree of consensus and then they need further revisions of the disciplines of curriculum. If expert assessments are also low, then the corresponding LO and the topics (or their sections) are recommended for removal from the discipline for the next academic year. If expert

assessments are high, then the appropriate LO and topics are recommended to be left in the academic discipline for the next academic year.
So, the curriculum is specified using the competencies as its foundational element, rather than courses or knowledge areas, units, and topics. Global labor market forms requirements to list of mandatory courses using proposals of EU universities (members of MASTIS project), among them are University Lumiere Lyon 2 (France), Guido Carli Free International University for Social Studies (Italy), University of Münster (Germany), Kaunas University of Technology (Lithuania), University of Maribor (Slovenia), University of Agder (Norway), Lulea University of Technology (Sweden), University of Liechtenstein (Liechtenstein), Italian Association for Informatics and Automatic Calculation (Italy), whereas local labor markets – list of elective courses revealed by project members of Kherson State University.

5 Conclusions and Outlook

The model of the curriculum revision system in computer science was designed and developed, the curriculum of ICT was improved, which includes the following provisions:

1. Analysis of the results of the stakeholder survey in the local and global labor market determines the key ICT competencies of graduates in accordance with the requirements of employers.
2. Requirements for the competence of graduates determine the expected learning outcomes in accordance with the specifications of e-CF v.3.0.
3. To obtain the expected learning outcomes, a list of curriculum courses is formed, the compliance of which is determined by the European e-Competence Framework (e-CF 3.0).

Evolving of the curriculum revision system in computer science is related to the optimization of the developed model by introducing quality management elements in accordance with ISO standards.
The experimental approbation of the presented model of revision of the curriculum was held at the Kherson State University in the development and introduction of the new specialty "Information Systems and Technologies" into the educational process.

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