INDUSTRIAL INFORMATION SYSTEMS – NEW INTERNATIONALLY DEVELOPED UNDERGRADUATE CURRICULUM

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Abstract

Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) provided a set of standards for Computing Curricula for Undergraduate Degree Programmes in Computer Science. These standards have been used by many universities all over the world. Computing Curricula have been divided by ACM/IEEE into five different sub-disciplines: Computer Engineering, Computer Science, Information Systems, Information Technology, and Software Engineering. In the development plans ACM/IEEE has left place for future models of curricula.

Contemporary industry is increasingly using information technology (IT) for control of production lines. Meanwhile, companies operate IT systems supporting their management. The research shows a lack of specialists who know computer systems in automation and management. The gap between computing technologies and automatics is noticeable. To reduce the gap, a new and innovative curriculum was proposed: Industrial Information Systems (IIS).

A developed Industrial Information Systems curriculum is an attempt to combine in one undergraduate study programme the best elements from the Information Systems and Computer Engineering sub-disciplines. An international and interdisciplinary team was engaged to develop the IIS curriculum.

The paper presents the methodology used for the design of the new curriculum. International cooperation in the process of curriculum development was particularly stressed. The structure and organisation of the new study programme is also presented.

Keywords: undergraduate study program, Industrial Information Systems, innovative curriculum development, international cooperation.

1 INTRODUCTION

Universities educate staff for the needs of their countries' economies. Therefore, they should constantly adapt their educational offer to the needs of the labour market. These needs are diagnosed using market research [1], [2] or are shaped by the policy of the state and other authorities, eg the European Union (EU) [3]. This policy is expressed by means of various programmes supporting the development of the offer of universities and ordering the education of students in specific areas of knowledge and skills [4].

The needs of industry and the entire economy are rapidly changing in the information technology (IT) area. The fast development of web and mobile technologies, and recently the Internet of Things (IoT), generates a huge demand for specialists in this field, which unfortunately is not satisfied [5]. In 2014, from 14% (in Spain) to 59% (in the Czech Republic and Luxembourg) of enterprises reported that they had hard-to-fill vacancies for jobs requiring specialist ICT skills [6]. The average for the entire EU was 38% [6].

The lack of specialists is also visible in the area of production process control technologies. Control systems have evolved from analog to digital systems, and more recently from closed to open systems. Open control systems are characterised by the use of generally available standards and external access, implemented by protocols known from the Internet. Increasingly, control systems for production lines, including CNC machines and programmable robots, are integrated with Management Information Systems (MIS). The currently observed fourth industrial revolution leads to the merger of industry and services [7]. The connecting link is IT. This situation requires specific and very wide knowledge from specialists involved in the processes of specifying, designing, building and implementing these heterogeneous systems. Such specialists should also have knowledge about

control objects. Therefore, they should be a bridge between IT specialists and management staff as well as automation specialists in the industry.

The article presents the methodology and result of the development of a new education programme in the field of Industrial Information Systems (IIS) at the al-Farabi Kazakh National University, Almaty, Kazakhstan (KazNU). An important innovation in the development of the programme of this new field was the invitation of specialists from many European countries. The new curriculum significantly extends the education models developed by the Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE). These models are used in many countries, whether in similar of different ways [8].

2 ACM STANDARDS FOR COMPUTING CURRICULA AND INDUSTRY NEEDS

Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) provided a set of standards for Computing Curricula for Undergraduate Degree Programmes in Computer Science [9]. These standards have been divided by ACM/IEEE into five different sub-disciplines: Computer Engineering, Computer Science, Information Systems, Information Technology, and Software Engineering. Document [9] allows other curricula to be defined for emerging disciplines. Standards for individual well-defined sub-disciplines are constantly updated – Tab. 1.

Table 1. *Current update of ACM/IEEE standards for Computing Curricula [10].*

Sub-discipline	Last year of update
Computer Engineering	2016
Computer Science	2013
Information Systems	2016
Information Technology	2017
Software Engineering	2014

Standards for Computing Curricula for Undergraduate Degree Programs defined in [9] include a two-dimensional view of education:

1 Development Level: from theory to application

2 Computing Level: from hardware and architecture to organisational issues.

Five defined sub-disciplines cover different areas of knowledge and skills in different ways – Fig. 1.

Standards for Computing Curricula for Undergraduate Degree Programmes allow them to be expanded to meet the current needs of the IT market. These needs are usually obtained during appropriate research. An example of such research is [11]. The results of this research indicate the need for education in different sub-disciplines, mainly in Software Engineering and Information Systems. Of course, the results of these studies [11] are not necessarily relevant in other countries. Analogous research, combined with the analysis of education programmes at universities in Kazakhstan, showed the need to launch a new specialty: Industrial Information Systems. This specialty significantly extends the IS ACM/IEEE CC sub-discipline. The model of areas of knowledge and skills of the new curriculum is presented in Fig. 2.

3 THE INNOVATIVE NATURE OF THE IIS CURRICULUM

The purpose of the Industrial Information Systems programme is to form the complex of knowledge and skills necessary for the design, development, deployment, maintenance, and improvement of industrial information systems for an industrial enterprise.

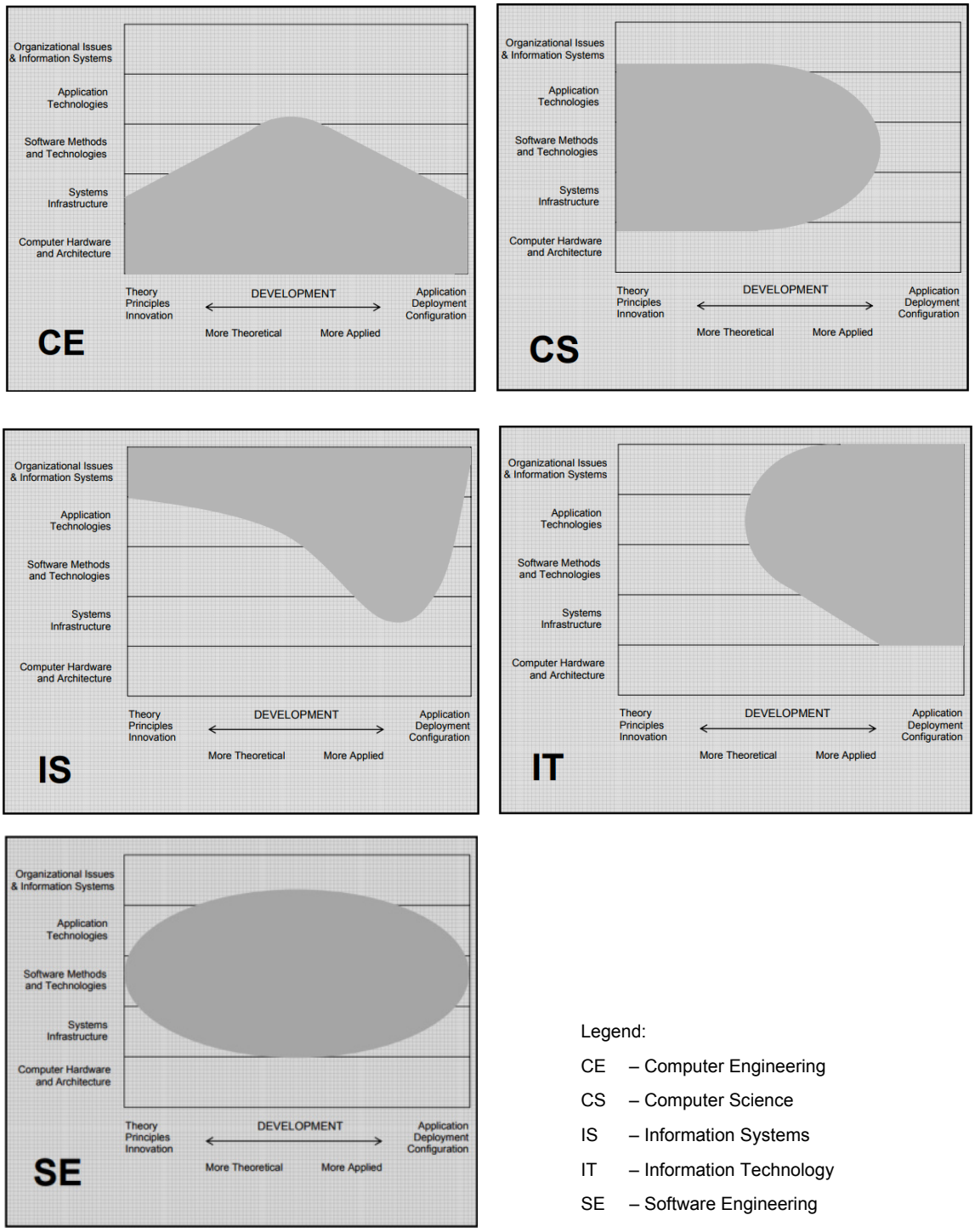

Figure 1. Areas of knowledge and skills covered by the discipline of ACM/IEEE Computing Curricula [9].

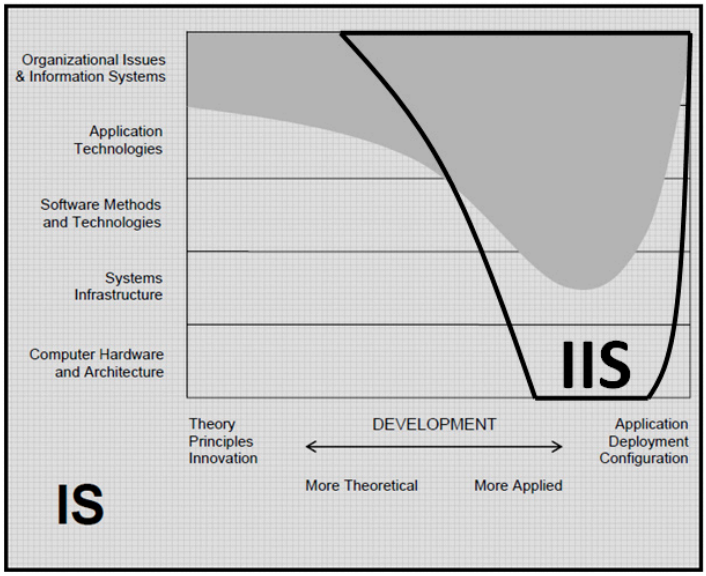

Figure 2. Areas of knowledge and skills covered by the Industrial Information Systems (IIS) curriculum against the background defined by ACM/IEEE.

The IIS curriculum covers all knowledge and skills levels in industrial enterprises management:

- Level 4. Strategic management of enterprise level.
- Level 3.Tactic level of enterprise management.
- Level 2. Operational management.
- Level 1. Control and management of industrial objects.
- Level 0. Industrial object characteristics.

The following competences are covered by the new IIS curriculum:

- design and software implementation of components of industrial information systems for industrial enterprise;
- maintenance of industrial information systems for the management of an industrial enterprise;
- planning and management of work on the design, implementation, maintenance and development of industrial information systems for the industrial enterprise;
- making decisions in complex, unpredictable production situations.

Upon completion of the IIS educational programme, graduates will receive a set of knowledge and skills in the design, implementation, maintenance and development of industrial information systems that take into account the features of all four levels of industrial enterprise management. They can work in the fourth generation industry.

4 THE NEW IIS CURRICULUM

The developed IIS curriculum covers 8 semesters, 240 ECTs (30 ECTS per each semester), and 2310 contact hours. The detailed programme is shown in Tab. 2. Some items (e.g. The Modern History of Kazakhstan or Philosophy) have been included in the curriculum in connection with state-wide requirements.

Table 2. *New curriculum of Industrial Information Systems.*

Course	ECTS
Semester 1	
The Modern History of Kazakhstan	5
Kazakh (Russian) Language	5
Foreign Language	5

Physics	4
Mathematic I (Calculus)	5
Programming	6
Semester 2	
Kazakh (Russian) Language	5
Foreign Language	5
ICT Technologies	5
Mathematic II (Algebra)	4
Algorithms, Data structures and Programming	5
Electronic, Sensors, Actuators and Metrology	6
Semester 3	
Mathematic III (Probability Theory and Statistics)	5
Fundamentals of Automation and Control	5
Industrial Computing	5
Operations Research and Methods of Optimization	5
Business I	6
Professionally-Oriented Kazakh (Russian) Language	4
Semester 4	
Philosophy	5
Fundamentals of Information Systems	5
Microcontrollers	5
Industrial Production Systems	5
Continuous and Digital Control	5
Business II	5
Semester 5	
IT Infrastructure	5
Database in IS	5
Programming Web Applications IIS	5
Industrial Simulation Techniques	5
Industrial System Analysis and Design	5
OO Programming / Business Process Management	5
Semester 6	
IIS Audit and Control	5
Process Monitoring and Control	5
Information Security Management in the IIS	5
IIS Project Management	5
IIS Software Engineering / Database Administration	5
Real Times Systems / Network Administration	5
Semester 7	
Data mining	5
IIS Strategy, Management, Acquisition and Ecology	6
Enterprise Architecture and ERP-system	5
IIS Deployment and Maintenance	4
Artificial Intelligence / Standards of IIS Services	5
Robotic Systems / Cloud Technology	5
Semester 8	
Practice Training	16
Pre-diploma Practice	8
Final Examination	1
Writing and Presentation of Diploma Thesis	5

5 METHODOLOGY OF NEW INDUSTRIAL INFORMATION SYSTEMS CURRICULUM DEVELOPMENT

KazNU has extensive experience in implementing international educational projects [12], including collective production of common teaching materials [13].

Based on previous experience KazNu has adopted an innovative methodology of new curriculum developing. It consists of the following phases:

- Phase 1. Developing a curriculum together with professors from partner universities.
- Phase 2. Expertise of the developed curriculum by independent universities and companies.
- Phase 3. Development of course syllabuses.
- Phase 4. Formal approval of the IIS programme.
- Phase 5. Start of education under IIS programme.

This educational programme was started in September 2017. First year students in the number of 28 were accepted and have started their education.

In Phase 1, an international team of experts was used, consisting of experienced academicians from universities from the following countries: Finland, Germany, Lithuania, Poland, Portugal, Russia, Spain, Sweden, and Ukraine. KazNU (12 academicians) and external Kazakh experts (10 specialists, mainly IT specialists from industry and other Kazakh universities) collaborated with the international team.

6 CONCLUSIONS

The Industrial Information Systems educational programme is based on the well-known ACM/IEEE standard for Computing Curricula for Undergraduate Degree Programmes in Computer Science. The developed ISS curriculum has been improved and expanded the ACM/IEEE curricula and the orientation towards the fourth revolution in industry (called Industry 4.0). This educational programme was supported by Ministry of Education and Science of Republic of Kazakhstan. The Industrial Information Systems educational programme includes the following group of courses: 1) non-technical compulsory subjects defined by the educational standard of Kazakhstan; 2) courses in fundamental sciences (mathematics and physics); 3) courses in information science; 4) courses in business administration; 5) courses in intelligent and embedded control systems. A security aspects are also important in the curricula. All automatic solutions are controlled by IT systems with network usage. Security gaps can cause serious problems and controlled devices malfunction. This gap should be closed during study [14].

This curriculum was positively evaluated by different professionals from universities and enterprises.

The involvement of academicians from abroad allowed them to transfer their experience to the program and significantly improve the quality of the ISS curriculum.

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