

NEW EDUCATIONAL STANDARDS CASE STUDY - COMPUTER SCIENCE

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Abstract

One of the elements of the Bologna Process is transformation of the system of long-cycle master's degree studies into a two-level system. To this end both general and detailed principles for creation of curricula and study plans were elaborated. Programme requirements are a collection of rules for higher education in a given subject area and at a specified level of education. Apart from general data such as length of duration of studies, number of ECTS points etc, the requirements outline the content of education and the qualifications and competences of a graduate defined by the outcomes of education. The subject of Computer Engineering discussed here in detail is an illustration of the new requirements.

Keywords: study programs, Bologna Process, programme requirements, Computer Engineering

1. INTRODUCTION

Every area of knowledge needs educated specialists. In the educational process, apart from well-prepared teaching staff and appropriate laboratory facilities, a coherent and well considered teaching programme is needed. Universities accept that the future engineer must have the particular stock of core-knowledge common to all graduates of a given field. Of course questions arise whether such a particular indispensable portion of information exists for a given field, and whether it is really necessary. In the Polish system of higher education for many years the principle has been accepted of creation of so called programme minima for every field of study regardless of the type of higher education institution. The process of creation of programme minima has always elicited heated discussion throughout academia from university departments to the ministry of education.

As a consequence, programme minima incorporated the most essential aspects of a given field, but their unambiguous definition was particularly difficult, because usually each lecturer believes their subject to be the most important and indispensable for future engineers. Perhaps this is one of the reasons that programme minima are subject to constant changes, but without doubt these are imposed by the development of science, changes in the system of education and the requirements of the employment market.

It is well known that universities with a strong academic tradition will educate at an appropriate level and highly qualified staff ensure that programme content will correspond to the latest global tendencies. A decisive factor in the need to define such programme

minima is the enormous development of [higher] education, in particular the establishment of a large number of private [higher] education institutions.

2. THE LEGAL CONTEXT

The Law on Higher Education enacted by the Polish Parliament on 27 July 2005, despite significant changes in the approach to programme minimum criteria, has maintained the necessity of specifying so called “programme requirements”.

There is no uniform approach in European legislation to the question of teaching programmes, similarly there is no solution similar to that proposed in our country. In some countries the universities themselves shape their teaching programmes, and in those where study programmes are subject to some form of state control this is a matter of acceptance of proposals put forward by the universities.

Moreover, some European documents such as for example the OECD report from 1996 “Review of Science and Technology Policy in Poland” [2] expresses the opinion that

„There should be not central minimum programme requirements for particular subjects that can offer degree, not even if these decisions are made by the ministry in consultation with democratically elected Central Council. Various schools may wish to try new programmes, which may lead to new degrees”.

A similar standpoint is to be found in a European Commission document from 2004 [3]

“Standards in this context are criteria or reference points used by agencies when they evaluate or accredit institutions or programmes. Agreed set of standards should, however, not become straightjackets. Standards should be used as reference points, providing the common language to refer to (...). They would help to highlight similarities and differences between study programmes, without harmonizing them. Universities and other higher education institutions should have freedom to differ, to innovate and to go beyond what is described in the agreed set of standards”.

The task therefore of the working groups appointed by the ministry of education to elaborate new principles for creation of curricula and new programme requirements was to reconcile different standpoints while at the same time harmonizing our system with the processes happening in the wider world.

At the same time the principle was accepted of increasing requirements with respect to mechanisms of control and assurance of the quality of the didactic process and of the final outcomes of education whilst giving universities greater freedom in the creation of the content of programmes particularly with regard to universities distinguishing themselves in the area of academic research [4].

3. CONDITIONS FOR CREATION OF NEW PROGRAMME REQUIREMENTS

The aim of the new programme requirements is to establish [4]:

- guidelines enabling creating and running high quality studies by universities,
- conditions favourable to variety of forms and contents of education,
- conditions enabling full student mobility (vertical and horizontal),

- bases for working out efficient tools of quality of education control for the Ministry bodies and the State Accreditation Committee, enabling eliminating study programmes that do not meet the standards for the quality of education.

4. WHAT ARE PROGRAMME REQUIREMENTS?

According to the Law [1] the requirements are “*a set of rules concerning higher studies education offered in different forms within fields of studies, macro-fields of studies, and interdisciplinary studies*”. The task of the Minister is to issue appropriate regulations defining educational standards for particular fields of studies and study levels, which comply with graduates’ qualifications, primary study contents, minimum required period of studies, length of practical placement and requirements concerning specific study forms.

The Bergen Declaration [5] recommends that countries taking part in the Bologna Process begin work on national structures of qualifications of graduates and their conformity to European framework structures of qualifications. Particular emphasis is put on the fact that graduates’ qualifications should be the basis for creation of programme requirements and also for standards of accreditation.

The first work began in 2005 when the Minister for National Education and Sport along with the Sejm appointed a working group to elaborate teaching requirements in accordance with the Central Council of Higher Education guidelines (Law No. 120/2004 of 21.10.2004) which later gave its opinion of the prepared draft. Before the long vacation in that year a significant portion of the drafts of requirements for technical fields were prepared, and published in October 2005.

The Education Commission of the Central Council of Higher Education, the Accreditation Commission of Technical Universities and the Conference of Pro-Rectors of Technical Universities collaborated on harmonization of requirements. The newly appointed Central Council of Higher Education modified the structure of requirements in a significant way, taking into account, among other things, the postulates of the technical universities. In December 2006 the overwhelming majority of fields of study possessed drafts of programme requirements.

The disintegration of fields of study in Poland (currently a decision of the Minister defines 118 subjects) does not favour the creation of adequate requirements. In the view of many specialists the list of fields should coincide to a significant extent, if not with areas of study, then with academic disciplines (there are 61 of these).

Requirements should also define the mode of creation and the conditions to be fulfilled by a university in order to conduct interdisciplinary studies or macro-fields taking into account the content of the programmes of the individual fields of which the macro-field or interdisciplinary studies are comprised.

5. PRINCIPLES FOR CONDUCTING STUDIES IN A GIVEN SUBJECT

The regulations contained in requirements for first cycle studies stipulate that such studies should last 6-7 semesters, the number of teaching hours should amount to 1800-2500 and the number of ECTS points 180-210. Qualifications of graduates must be specified along with the content of education (with a description of the outcomes of education) comprising in total 645-990 hours with a minimal number of 78-99 ECTS points. An important

component of engineering studies are practical placements lasting 208 weeks and also other requirements concerning the teaching of foreign languages, physical education, humanities subjects, production of a diploma thesis and an engineering project (15 pts).

A similar situation arises with respect to second cycle studies. Minimum numbers of semesters (3-4), number of hours (780-1000) and number of ECTS points (90-120) are stipulated. As in the case of first cycle studies the graduate's qualifications must be specified along with general and particular content of education (150-315 hours and 15-33 ECTS points), and other requirements (usually 50-60% practical exercises, master's thesis (20 pts) and fulfilment of eg FEANI criteria).

It is accepted that in the entire programme of first cycle (engineering) studies at least 40% of classes for subjects in the basic group and field related subjects should have a practical character ie workshops, laboratory sessions and projects. In turn, technical subjects must constitute not less than half of the classes of the whole curriculum

During first cycle studies the student should have the possibility to create their own profile of studies by choosing elective subjects which must constitute a significant percentage of classes in total. Thanks to this the intended outcomes will be achieved of education giving the graduate defined qualifications and preparation for a profession. Relatively brief second cycle studies will lead to particular specializations

It is essential to define the principles for recruitment to second cycle studies particularly where the applicant for such studies is a graduate of first cycle studies in a different field. A conception is being discussed among academics according to which the applicant should have taken for credit not less than 60% of the basic and field specific content defined in the programme requirements for engineering studies in the new (to the applicant) field chosen. The subjects could for example be decided by the departmental committee of the unit conducting the second cycle studies. Another conception is that principles governing vertical mobility between stages of study (change of study field after the first cycle) should be a matter for the individual university to decide.

Full time and part-time programmes must maintain equivalence of input by the student measured in ECTS points, and equality of requirements. The same examinations should be set (and perhaps a common examination be held) and diplomas awarded according to the same principles. Such studies will differ however in terms of the scope of independence of studies and can also differ in terms of content taught and number of contact hours.

Practical placements are an important element of education (especially at the first level of studies). Apart from general guidelines giving their scope character and how credit is to be awarded, they should be adjusted by the university to the level and form of studies. If practical placements last a semester or longer, as demanded by employers without much result, the nominal time of study should be extended appropriately,

Educational standards are defined at three levels [4,6]:

- **General requirements**, referring to all forms, levels and fields of studies, highlighting the primary structure of the graduate's qualifications and defining types of diplomas. There exist three modules in these standards: foreign language (minimum 120 hrs and 5 ECTS credits), information technology (minimum 30 hrs and 2 ECTS credits) and sports (minimum 60 hrs and possibly 2 ECTS credits).
- **Basic requirements**, referring to study area – it is a group of basic courses.
- **Specialist requirements** referring to particular fields of studies within a given study area – it is a group of specialist courses.

At each level requirements are defined through characterising *the knowledge*, i.e. the educational contents specific for a given scientific discipline, and the study outcomes specifying *skills and competences*, i.e. defining the activities that a graduate is able to perform, including the specialist and the universal ones (independent studying, interpersonal communication, team work, etc). Obviously the requirements are formulated so as not to create too-fixed frameworks and not to result in unifying study curricula for a given field offered at different universities. The total number of ECTS credits for courses included in the requirements does not exceed 50% for undergraduate programmes and 40% jointly for both levels. The study contents resulting from the requirements have to be complemented with the elements making a given university unique among others and facilitating realisation of its mission.

6. INTERNAL EDUCATION QUALITY SYSTEMS

A condition of proper implementation of curricula created by universities in accordance with the principles discussed above is introduction of internal systems of education quality assurance. The existence and proper working of such a system is the most important element of quality assurance, but is also an element of external evaluation of quality, and of accreditation.

The Bergen communiqué [5] defined

- standards and guidelines for internal quality assurance within higher education institutions
- standards and guidelines for the external quality assurance of higher education,
- standards and guidelines for external quality assurance agencies.

An Internal quality assurance system is expected to include:

- the institution's strategy for quality and standards,
- monitoring, and periodic review of programmes,
- criteria for assuring equivalence of requirements for different levels and forms of study
- criteria for award of diplomas
- rules of the assessment of students,
- provision of appropriately qualified teaching staff
- quality assurance of teaching staff,
- evaluation of classes by students and graduates
- assurance of the appropriate degree of effectiveness of the teaching process.
- assurance of flexibility and individualization of education
- learning resources,
- criteria for vertical and horizontal mobility
- information systems and public information.

7. TEACHING STANDARDS FOR COMPUTER SCIENCE

7.1 General remarks

In accordance with accepted recommendations educational requirements throughout the second cycle should not exceed 40% of the overall total of hours planned. Engineering studies (first cycle) should last no longer than 7 semesters, the number of class hours

should not be less than 2300 and the number of ECTS points not less than 210. Master's degree studies (second cycle) last no more than 3 semesters, the number of class hours should not be less than 780 and the number of ECTS points not less than 90. The above hours do not include time allocated for the diploma project (final project).

7.2 Qualifications of a graduate

A graduate of engineering studies should possess knowledge and skills in the area of general problems of informatics and additional technical knowledge and skills in the area of informatics systems. He should have a good knowledge of the principles of building contemporary computers and the devices that go with them, operating systems, computer networks and data-bases. He should be able to programme computers and know the engineering principles of programming to an extent allowing effective work in a programming team. He should also have basic knowledge in the area of artificial intelligence, computer graphics, and human /computer interface. He should know how to use his knowledge and skills in professional activity observing legal and ethical principles.

A graduate of first cycle studies should know a foreign language to the B2 level of fluency according to the Council of Europe's Common European Framework of Reference for Languages: Learning, Teaching, Assessment and be able to use specialist language in the area of informatics. A graduate should be ready for work in informatics firms dealing with the building, installation or maintenance of informatics tools and systems, and in other firms and organizations in which such tools and systems are used, as well as in education if he completes the teaching specialization (in accordance with the appropriate decision of the ministry proper to higher education in matters of requirements for teacher education). A graduate should be ready for beginning second cycle studies.

7.3 Framework educational content of first cycle studies

	contact hours	ECTS
GROUP OF GENERAL CONTENT EDUCATION	210	9
A. GROUP OF BASIC CONTENT	255	27
B. GROUP OF FIELD SPECIFIC CONTENT	660	69
Total	1115	105

Components of the topics at particular levels, minimal number of contact hours and minimal number of credit points (ECTS) at the first cycle are as follows:

	contact hours	ECTS
A. BASIC REQUIREMENTS	255	27
Topics in the field of:		
1. Calculus and Linear Algebra	45	
2. Probability and Statistics	60	
3. Discrete Mathematics	60	
4. Physics	45	
5. Technical Subjects	45	

B. SPECIALIST REQUIREMENTS	660	69
Topics in the field of:		
1. Programming Fundamentals		
2. Data Structures, Algorithms		
3. Computer Architecture		
4. Operating Systems		
5. Computer Networks		
6. Languages and Programming Paradigms		
7. Graphics and Human-Computer Interaction		
8. Artificial Intelligence		
9. Database Systems		
10. Systems Engineering		
11. Embedded Systems		
12. Social and Professional Issues		

7.4 Discussion of content and outcomes of education

A1: Calculus and Linear Algebra

Topics:

Sequences, series, power series; Derivatives of function of one and more variables; Definite integral; Differential equations;

Learning outcomes:

Use of computer packages of calculus; Interpretation of results; Solving systems of linear equations.

A2: Probability and Statistics

Topics:

Discrete probability, continuous probability, expectation, stochastic processes, sampling distribution, estimation, hypothesis tests,

Learning outcomes:

Calculate probability of event, mean, variance, and standard deviation; The concept and tools of stochastic processes to analyze the performance of simple hardware and software systems

A3: Discrete Mathematics

Topics:

Fundamentals structures: functions, relations, sets; Introduction to logic and proofs; mathematical induction; Basic of counting, permutations and combinations; Recurrence relations; graphs and trees.

Learning outcomes:

Illustrate by examples the basic terminology of functions, relations and sets; Demonstrate knowledge of formal logic proofs and logical reasoning through solving problems; Apply graphs and trees to problems in a computer engineering setting.

B1: Programming Fundamentals

Topics:

Fundamentals programming constructs, algorithms and problem solving; Fundamental data structures, software development methodology, software testing and validation

Learning outcomes:

Analyze and explain the behaviour of simple programs involving the fundamental programming; Write a program that uses each of the following programming constructs: basic computation, standard conditional and iterative structures, and the definition of procedures and functions.

B2: Data Structures, Algorithms

Topics:

Basic algorithm analysis, algorithmic strategies;: divide-and-conquer, dynamic programming, exhaustive search algorithms, backtracking, heuristics; Basic algorithms: sorting, selection, search; Abstract data types: lists, trees, graph algorithms, hash tables, heaps, queues, priority queues; Fundamental graph algorithms: depth-first and breadth-first search; NP – completeness.

Learning outcomes:

Determine the time complexity of simple algorithms; Design algorithms using basic algorithmic strategy.

B4: Operating Systems

Topics:

Overview of operating systems; Operating systems principles; Introduction to concurrency; Scheduling and dispatch; Processes and threads; Memory management.

Learning outcomes:

Solving classical problems of synchronization; Selection of scheduling algorithm according to application.

B5: Computer Networks

Topics:

Introduction to networking; Network architectures; Network security; Fundamentals of cryptography.

Learning outcomes:

Design and implementation of simple network with two clients and a server using DHCP; Describe the purpose of encryption and the function of public and private keys; Use the PGP package; Design a simple interactive web-based application.

B6: Languages and Programming Paradigms

Topics:

Programming paradigms; Object-oriented programming.

Learning outcomes:

Identify the appropriate paradigm for a given problem; Design code, test and debug simple program in an object-oriented programming language.

B7: Graphics and Human-Computer Interaction

Topics:

Basic techniques in computer graphics; Principles of good human-computer interaction design; Principles of design using graphical user interface (GUIs).

Learning outcomes:

Design, write and debug programs that use API packages; Use of tools supporting design of graphical user interfaces.

B9: Database Systems

Topics:

Databases systems; Data modelling; Relational databases, databases query languages; Relational database design; Transaction processing.

Learning outcomes:

Use of query language SQL to elicit information from a database; Prepare a relational schema from a conceptual model developed using the entity-relationship model; Creating a transaction using SQL; Evaluation of simple strategies for executing a distributer query.

B10: Computer System engineering

Topics:

Overview of software engineering; Frameworks of APIs; Software processes; Software requirements and specifications; Software design, testing and validation; Software evolution; Software project management.

Learning outcomes:

Articulate some of the components of a software process; Use a common non-formal method to model and specify the requirements for a software system (structured analysis or object-oriented analysis). Conduct a review of software requirements, and supporting tools; Demonstrate the application of the different types and levels of testing to software products; Prepare a project plan for a software project; Compare and contrast the different methods and techniques used to assure the quality of software products.

B11: Embedded Systems

Topics:

Embedded digital systems; Microcontrollers; Embedded programs; Real-time operating systems; Design methodologies.

Learning outcomes:

Describe the meaning of embedded system; Program of simple embedded system; Identify strategies to find and minimize errors and system failures; The role of designing verification on reliable system design; Understanding the role of documentation.

B12: Social and Professional Issues

Topics:

Professional and ethical responsibilities; Codes of ethics; conduct and practice; Risk and liabilities; Intellectual property; Patent system; Privacy.

Learning outcomes:

Interpret the social context of computing; Identify ethical issues that arise in software development; Recognize the importance of product safety when designing computer system; describe current computer-base threat to privacy.

8. CONCLUSIONS

Until now in the opinion of many students and employers long cycle studies were considered to be “better” than those divided into two stages, although in many technical universities two cycle studies have already been functioning for some years. In the face of a lack of appropriate legal regulations universities have delayed introduction of recruitment of secondary school leavers exclusively to first cycle studies rather than to long cycle studies. Only with recruitment for the academic year 2007-8 in technical universities will there be the first general recruitment in the two-stage system. This new situation requires

that students, their parents and employers (stakeholders) be shown and have explained to them the principles of the new system of education and also that it be demonstrated that this is not worse than the previous system, but on the contrary favours the gaining of an education giving a greater chance in the demanding employment market of the united Europe.

When creating new programmes it is important to pay particular attention to the fact that the two cycle system of studies is not a mechanical division of five-year studies into 3-year Bachelor's and 2-year Master's studies. The essence of the Bologna Process is that each of the levels constitutes a separate whole, that completion of first-cycle studies gives a complete education allowing the graduate to start professional activity, and that at the same time, in accordance with the principles of vertical mobility it is possible to continue study in the same or in a new field.

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Curriculum Vitae (CV)

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Received her Ph.D. from the Technical University of Lodz in 1986. For the many years she has been involved in the Tempus Projects devoted to the organisation of programmes taught in English, international student exchange, Internal Quality Assurance Systems etc. She participated in the Phare Multi-Country European Pilot Project for Evaluation Quality in Higher Education. She was also involved as an expert in the accreditation process.

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Graduated in 1969 from the Warsaw University of Technology where he currently holds the position of full professor. Currently he is also the Coordinator of the Quality of Education and the Accreditation at the Warsaw University of Technology. Since 1994 he has been involved in several Tempus Projects devoted to organisation of engineering programs taught in English, and the development of the Internal Quality Assurance and Assessment Systems. He is the member of National Accreditation Commission.