Proceedings of the 2013 Federated Conference on
Computer Science and Information Systems pp. 759–765

Concept of competence management system for Polish National Qualification Framework in the Computer Science area

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***Abstract*—This article regards analysing the literature of processing competence in education, as well as competence management systems (CMS) and their role in developing competencies for students of higher education cycle. The Bologna Process and its results are described later in the text, explaining the need for National Qualification Frameworks and the benefits that they can produce when implemented correctly. We focuses on creating the basis for competence management system for Polish National Qualification Framework in Computer Science area, how it should work and how it should be implemented.**

I. Introduction

TECHNOLOGICAL market for jobs related with IT is constantly changing. The reasons for this are constant changes in technology and innovative products that affect the workings of certain services and sites. This results in constant changes in competences required by the IT market [23]. New competencies show up, they have new names and contents. Competencies that are already in existence, change their contents due to technological advancement.

The proposed system got two main roles: to be the Personal Competence Manager (PCM) for each student and to be the Organisational Competence Manager (OCM) for the given faculty. The system is based on competence development lifecycle [18] which includes elements like: creation of a reference competence description, the assessment of existing competences at individual or/and group level, the gap analysis, the definition of competence development programmes, continuous performance monitoring and assessment. Based on the PCM, users can choose their own competence development plans and follow them to built the desired competences. [20]. Based on OCM, the faculty can implement the following scenarios:

1. Knowledge analysis of a student that is trying to begin his second education cycle.
2. Market analysis to estimate how much student's competencies differ from those required by the market.
3. Reporting the level of students' summary competences, for example for accreditation committee.
4. Substantive evaluation of a given curriculum.

The definition of competence can be found in many scientific works [4], [8], [16]. Let us focus on those related with accepted standards. ISO 9000:2005 defines competence as the "demonstrated ability to apply knowledge and skills". ISO 19011 defines competence as "demonstrated personal attributes and demonstrated ability to apply knowledge and skills". ISO/IEC 17021:2011 defines competence as "ability to apply knowledge and skills to achieve intended results".IEEE Standard 1484.20.1-2007 [12] describes competency as "any aspect of competence, such as knowledge, skill, attitude, ability, or learning objective". In addition, there is a running discussion about difference between competence and competency term [8]. The IEEE Standard 1484.20.1-2007 interpreted the competency in the broadest sense to include learningobjectives (those things that are sought) as well as competencies (those things that are achieved).

The discussed competence management system (CMS) is being prepared for faculties related with computer science. Main goal of this system is to help to map the competences of a learner - which will be stored in some kind of a learner profile -with the competences that result from the competence development program[13]. In every higher education curriculum there are many types of different competencies [22]. While designing the concept of our Competence Management System we focused on key competences which we interpreted as Core Qualifications.

IT market is assessed for competencies in many research projects. The [15] is a good example of this practice where the standardisation of ICT job profiles was done and ICT job profiles model was defined. It is based on ontologies principle to describe "Knowledge Objects", "Skills", "Competences" and relations between them.

II. Problem Statement

Analysing main characteristics of a typical curriculum gives us the following mechanisms that develop competencies. Each curriculum consists of courses (subjects) realized in every next semester. On figure 1., an exemplary implementation of a given curriculum is shown, each circle represents a course. Some of them are extended for periods longer than 1 semester (for example 1.1, 2.1 and 2.3, 3.3. 4.3). In the course of studies, elective subjects start to appear from which student got to choose one (for example 4.6, 4.7, 4.8). Another matter are internships that student got to do (4.5). The curriculum ends with an implementation of specialisation courses (5.2-5.6, 6.2, 6.3), which affect the

[1] This work was supported by Project „Platforma Informatyczna TEWI", nr POIG.02.03.00-00-028/09,

overall profile of the student. It must be mentioned that the completion of each course means passing the course with a positive grade. Analysing the above educational path we can distinguish the following mechanisms that develop competencies:

- Competency is developed after completing the given course (e.g. after completing 1.2 or 3.2).
- Competency is developed after completing a certain set of related courses (e.g. 2.3, 3.3, 4.3) which can represent one bigger course divided into many stages (semesters).
- Competency is developed after finishing the internship (4.5).
- Competency is developed after completing a certain group of courses related to a certain technological or scientific aspect (3.1, 3.2, 4.1).
- Competency is developed after completing a specialisation (5.2-5.6, 6.2, 6.3).
- Competency is developed after completing the whole curriculum.

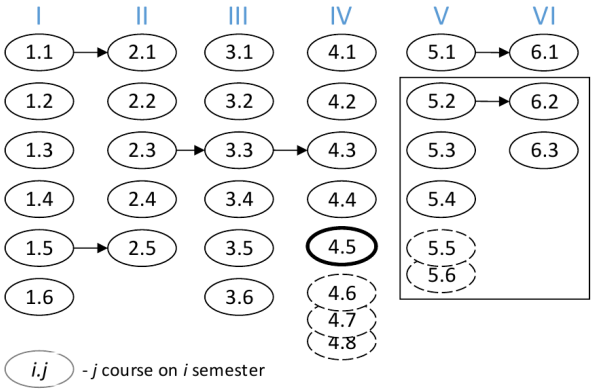

Fig. 1 Schematic representation of university curriculum

III. COMPETENCE MODELING IN IT EDUCATION

For every learning system Bloom's taxonomy is the basis for competencies description. In case of engineering sciences it can be expanded to two dimensions represented by cognitive and knowledge dimensions (Table I). Basic skills and features must be adjusted to the realities of IT's technical field. It seems that expanding skills' base with competencies related with mathematics and system analysis is a must. Typical mathematic-based competencies are[19]: thinking and reasoning, communication, argumentation, representation, modeling, problem posing and solving, symbolic and technical language.

Basing on literature we can define the target set of computer science student's competencies as a total set of knowledge, technology, skills and attitudes which function as action characteristics of an organizational member who can do his or her tasks outstandingly and efficiently in the computing environment [24]. Generally speaking student's computing competency consists of four components [24]:

- The computing mindset (driven from self-concepts and traits).
- The knowledge of computing technology (based on knowledge).
- The capability of computing application (determined from cognitive and behaviour skills).
- The potential of computing capability (driven from personal motives).

Each student upon completion of a given curriculum should posses a set of Core Competencies which are the basis for typical problem solving in the field of IT. The core competence in the literature on education defines a set of learning outcomes (skills or competencies) which each individual should acquire during or demonstrate at the end of a period of learning. It is one of a number of associated con-

TABLE .I
BLOOM TAXONOMY (based on [11])

Cognitive dimension		**Knowledge dimension**	
Remember	Exhibit the memory of previous-learned materials by recognizing or recalling facts, terms, basic concepts and answers.	*Factual Knowledge*	Knowledge about terminology and specification details.
Understand	Understanding of facts and ideas by interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining main ideas.	*Conceptual Knowledge*	Knowledge about generation, classification, and structural modelling of certain concept.
Apply	Using the available knowledge to execute and implement solutions in different ways.	*Procedural Knowledge*	Knowledge about workflows, algorithms, methods, procedures, and events.
Analyze	Differentiating, organizing, and attributing knowledge by manipulating information using certain criteria.	*Meta-Cognitive Knowledge*	Knowledge about strategies and decisional conditions.
Evaluate	Checking and Judgments about information, validity of proposed ideas, or quality of work by certain criteria.		
Create	Generating, planning, and producing information or knowledge together and proposing new solutions.		

cepts, including core skills, core competency, generic skills and key qualifications [10]. According to [21] the core competence applied to education as a whole could be defined as facilitating the empowerment of people, through learning how to acquire information (data), turn it into knowledge and apply that knowledge to solve problems. The example of core competence for network building can be found in [9].

IV. National Qualifications Framework: an overview

A. Bologna Process and Lifelong Learning

Proposed in 1999 by Education Ministers from 29 European Countries, Bologna Process was started to create the European Higher Education Area (EHEA) [16]. After a series of ministerial meetings (Prague 2001, Berlin 2003, Bergen 2003, London 2007, Leuven 2009) and by the year 2013 there are now 47 participating countries in the Bologna Process. The main purpose of it was to create the Qualifications Framework of the EHEA which were greatly influenced by the UK's National Qualifications Framework (NQF) [2]and its later version, the Qualifications and Credit Framework (QCF) [7]. During this process the European Qualifications Framework which acts as a medium to translate national qualifications across European countries, was created. This way, workers and students in European Union gain more mobility between countries allowing them to study or work abroad without the difficulties of complicated analysis of their current competencies, knowledge and skills. Many other countries took prime example of UK and also implemented 8-level NQFs into their education systems. Those national qualifications can be easily translated to EQF and people who moved from one European country to another would not have to repeat what they already learned. The Bologna Process moved on to create the "Bologna qualifications framework".

Another accomplishment of the Bologna Process was creating the idea of Lifelong Learning. Pursuing knowledge for either personal or professional reasons for the individual's entire life rather than only learning "in the classroom". Lifelong Learning focuses on teaching outside schools and universities, using methods like home schooling, education for adults (for individuals that want to develop themselves), continued education (usually extended courses offered by higher education institutions), working with knowledge (using obtained knowledge in professional work) and personal learning (individuals learning using for example online sources of distance education).

B. How NQF works

EQF just like British NQF/QCF is divided into 8 levels, each of them describing what the learner knows, understand and is able to do (where 8th level is the most advanced and 1st level is the most basic). We can already see the similarity to British NQF/QCF which also had 8 levels and the last one was the most advanced[European Communities 2008]. The Bologna qualifications framework states that there are 3 cycles/levels of qualifications framework:

- Cycle 1 - usually correlated to qualifications of bachelor's degree
- Cycle 2 - usually correlated to qualifications of master's degree
- Cycle 3 - usually correlated to qualifications of doctoral degree

Those levels correspond naturally with NQF and thus EQF last 3 levels (6th, 7th and 8th) as they describe the same levels of education cycle. In Bergen 2005 all higher education ministers agreed on EQF levels 6-8 descriptors (as in Table II) to be also the descriptors for the three education cycles of qualification frameworks within European Higher Education Area

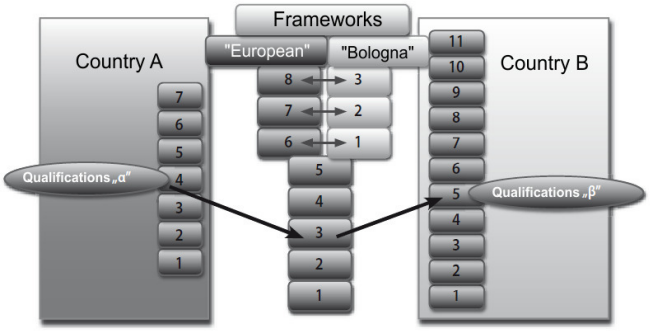

Fig. 2. EQF to NQF translation(based on [3])

Not every NQF easily translates to EQF on a 1:1 level. Different countries have adopted NQF system adjusted to their needs and modified it greatly. Figure 3. is an example of NQFs of France and England compared to EQF.

For example, the last three levels of EQF directly correspond with English and French NQFs but fifth level is different for both countries. This situation is similar with other countries' NQFs. That is one of the reasons Bologna Process focused on the last free cycles of education: bachelor's, master's and doctoral degree (the names for each degree can differ in various countries).

Introduction to European Credit Transfer and Accumulation System (ECTS) was necessary to make the 'translations' between different countries possible. Thus, each cycle referred to certain amount of ECTS credits/points:

- Level 1 - typically 180-240 ECTS credits
- Level 2 - typically 90-120 ECTS credits
- Level 3 - no ECTS

Usually 60 ECTS credits corresponds with 1 academic year which is equivalent to around 1500-1800 hours of study (during classes).

TABLE .II
DESCRIPTORS DEFINING LEVELS IN THE EUROPEAN QUALIFICATIONS FRAMEWORK (based on[8])

Level	Knowledge	Skill	Competence
1	Basic general knowledge	basic skills required to carry out simple tasks	work or study under direct supervision in a structured context
2	Basic factual knowledge of a field of work or study	basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	work or study under supervision with some autonomy
3	Knowledge of facts, principles, processes and general concepts, in a field of work or study	a range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems
4	Factual and theoretical knowledge in broad contexts within a field of work or study	a range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
5	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	a comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
6* Cycle 1	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups
7* Cycle 2	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research Critical awareness of knowledge issues in a field and at the interface between different fields	specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
8* Cycle 3	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	the most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

C. Learning outcomes

Obtaining given knowledge, skill and competency means that student has reached the 'learning outcomes' planned to achieve after completing his education [1]. Whether we refer to only one lesson, learning module or the whole education cycle it does not matter, learning outcomes can correspond to all of these.

Learning outcomes can be divided into three groups: generic (outcomes that are general for a certain cycle of education, e.g. for outcomes for each bachelor's degree studies), field (outcomes that are specific for a certain type of studies, e.g. technical university), specific (outcomes that are specific for a certain learning module curriculum, major etc.). The general learning outcomes defined by NQF Work Group are also defined and incorporated into the first group. They can be defined by both Ministry of Education and the university as well, though they are distinguished which are which.

V. COMPETENCE (QUALIFICATION) MANAGEMENT SYSTEM

Student while completing the courses on studies achieve learning outcomes defined for the course, thus achieving learning outcomes for his/her major, and those learning outcomes correspond with learning outcomes by the Ministry of Higher Education. Achieving learning outcomes for a specific course means that the student posses a set of knowledge, skills and competencies. Each of those three can corre-

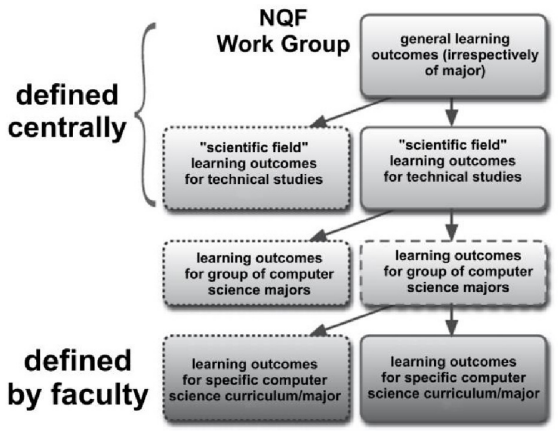

Fig.3 Defining learning outcomes in Poland (based on [3])

spond to a different learning outcome. The problem lies in finding an easy method to name and manage the key competencies we want to use in our management system, it is also essential for processing those sets in the system. That is when Core Qualifications (to correspond with the NQF name) term come in. Core Qualifications are combinations of knowledge, skills and competence, all of them contributing in the European Qualifications Framework. Using the same set of learning outcomes (knowledge, skill competence) as in the EQF makes it possible to easily process and compare Polish NQF with EQF but to make it even more adaptable Core Qualification (QF) must be implemented. In the future this system will be able compute the CQs of students from different Universities based exactly on learning outcomes and this knowledge, skill, competence sets.

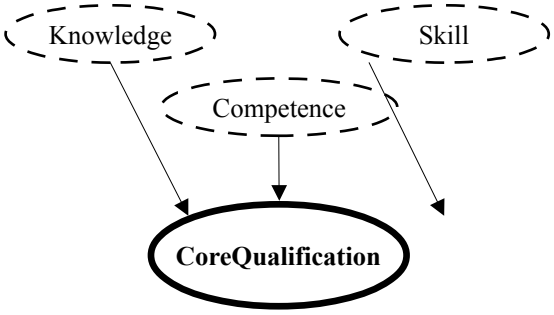

Fig. 4 Core Qualification components

Figure 6. presents the class diagram of NQF based on Computer Science Faculty at West Pomeranian University of Technology in Szczecin. The courses are created accordingly to EQF standards designed by the Bologna Process. The diagram clearly shows 3 distinctive learning outcomes groups like mentioned before. Although the 'specific learning outcomes' in the system are shown to more correspond with the specialisation instead of major, they mostly refer to the same learning outcomes designed for the major (or rather scientific field). The difference between this diagram relations and the learning outcomes mentioned before comes from the University-specific preferences. Sets of Knowledge, Skills and Competence visible from learning outcomes for specialisation and course will be the basis to create the Core Qualification.

The proposed system is using the Competence Object Library (COL) [17] for competence modelling. The COL based on the TENCompetence Domain Model (TCDM) for competence structure modelling and the competence set theory for fuzzy competence set expansion cost analysis [14]. The COL on one hand enables to model different kind of competence content, on the other hand the system can perform quantitative analysis of competence. The COL defines following classes [17]:

- Competency : any form of knowledge, skill, attitude, ability or learning objective that can be described in a context of learning, education, training or any specific business context.
- Competence: effective performance of a person within a context at a specific level of proficiency.
- Context: circumstances and conditions surrounding actions performed by a person.
- Category: indicates the relative level in a taxonomic hierarchy.
- Proficiency Level: indicates the level at which the activity of a person is considered.
- Relation: arbitrary association of competencies within a context and at specific proficiency level.
- Element of Competence: entity derived from competence that can form a set.
- Competence Set: collection of elements of competence. The system has to support the function CompetenceSet.CompareSet() with quantity outcome.
- Competence Profile: collection of competence sets. There is a relented function Competence-Profile.CompareProfile() for different profiles comparison.
- Required Competence Profile: requirements in terms of competence to be fulfilled by a person.
- Acquired Competence Profile : description of competencies possessed by a person.
- Learning outcomes: activity, job, skill, attitude, ability or learning objective for which competence requirements can be specified.
- Person (Student): competent actor performing activities.

VI. CONCLUSION

In this article, we focused on showing the complexity of the issue of competence management in university. The main area of study was computer science, because it is possible to use multiple reference models showing areas of expertise in the field (e.g. 2012 ACM Computing Classification System). Such knowledge-base enables in the future to decide on the level of student's competence and knowledge using the automatic ontology processing methods.

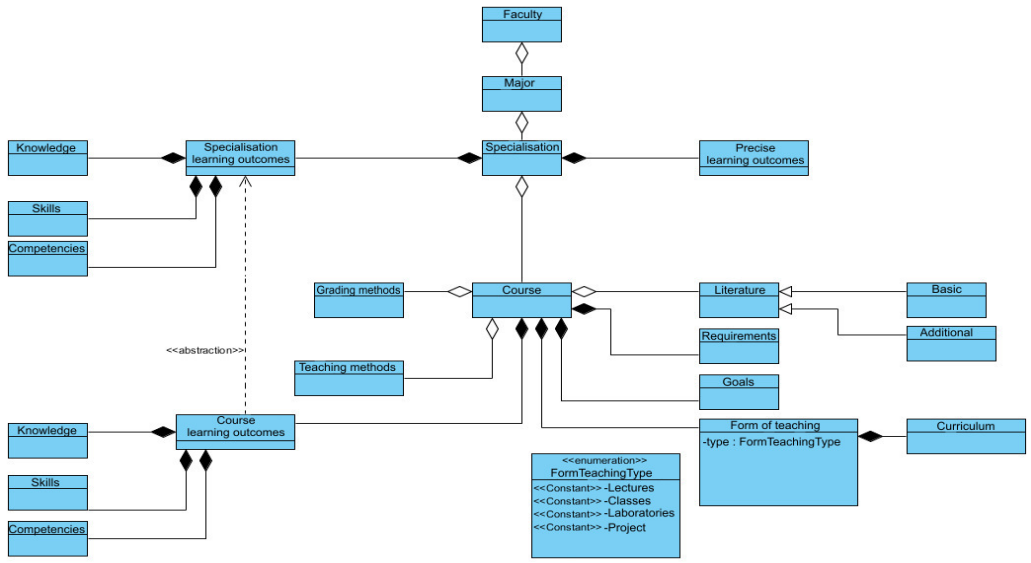

Fig. 5 Class diagram of the NQF at West Pomeranian University of Technology

The Bologna Process is a social and organizational program that includes a set of activities. Among them the qualification framework is one of the most important. The competence management system increasing the possibility of changing qualifications of the student depending on the market requirements.

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