Towards a domain model for integrating competence frameworks into learning platforms

Matthias Then, FernUniversität in Hagen, Germany
Benjamin Wallenborn, FernUniversität in Hagen, Germany
Michael Fuchs, Wilhelm Büchner University of Applied Sciences, Pfungstadt, Germany
Matthias Hemmje, FernUniversität in Hagen, Germany

ABSTRACT. Since adoption of the Europe-wide university-reform called Bologna Process, each accredited study path, module, or course has to be provided with a summary of the conveyed competences. Until now, this additional information had little effect on the comparability of learning content, because competences are usually described in form of free text. This leaves too much room for interpretation and misunderstandings. Standardized, machine-readable taxonomies are promising alternatives, especially in combination with so-called Competence Frameworks (CFs). In this article, we introduce the Competence Based Learning Model (CBLM). Its development starts with a specific solution for the European e-Competence Framework (e-CF) and arrives to the creation of a generalized e-CF-independent version. The resulting CBLM is the basis for our two prototypical implementations – an extension for the learning platform Ecosystem Portal (EP) and a plugin for the Learning Management System (LMS) Moodle which extends its CBE-functionality introduced with release v3.1. A short summary and an outlook on future development conclude this article which succeeds our conference paper presented at the IX International GUIDE Conference.

KEYWORDS: Competence Based Learning, Competency Based Education, Competence Model, Competence Frameworks, Distributed Online Courses, Moodle Extensions

1. Introduction and motivation

Nowadays each Higher-Education Institution (HEI) is expected to provide a comprehensive online presence. Besides extensive functionalities for general information and administrative purposes, this includes
a complex infrastructure for creating, organizing and executing virtual courses which consists of various components. A *Learning Platform* and systems for campus and examination management are obligatory. In many cases this basic equipment is complemented by separate solutions for course authoring, resource management, and other tools supporting advanced e-learning concepts. To achieve best possible usability, a clearly arranged course catalog with capable features for identifying and comparing available learning resources should be displayed to students, faculty and staff; the distribution of course-related meta-data over different systems should be hidden as far as possible. No matter how much effort is spent on user interface and search functionality – comparing learning content remains a tedious and error-prone process, especially if the resources belong to different study paths and institutions. A typical cause for disaccords is the acknowledgement of examinations and certificates gained during semesters abroad. Participation at *Massive Open Online Courses (MOOCs)* raises the same question: will the certificate be accepted or not and who is competent to make a decision? Along with the Europe-wide university-reform called *Bologna Process (BP)* ([Ehea.info, 2016](http://ehea.info)), the member countries of the European Union made some agreements concerning the comparability and quality of higher-education study programs, modules, and courses. As a consequence, each *Study Program, Module or Course (SMC)* has to be provided with academic credit points according to the *European Credit Transfer System (ECTS)* ([European Commission, 2016a](http://ec.europa.eu)). Furthermore, the conveyed qualifications have to be stated and categorized in a determined way by assigning so-called *Competences*. A binding accreditation process which every SMC provided by a European university or college has to pass ensures compliance of these criteria. The fact that every SMC has to provide a so-called *Learning Goal (LG)* description containing a summary of all conveyed competences, on first sight seems to enable students to integrate a greater flexibility into their curricula. Unfortunately, that expectation did not fulfill; the comparability of learning content has not increased in the degree originally aimed by the BP. As the development of standardized qualifications catalogues is still at an early stage, competences are usually described in form of free text and every faculty in every university uses its own formulations. This leaves too much scope for interpretation and misunderstandings.

In September 2016, the *University of Hagen* ([German Fern-Universität Hagen, in short FernUni or FUH](http://fernuni-hagen.de), [2016](http://fernuni-hagen.de)) initiated the preparation of an interdisciplinary research cluster which is concerned with the effects of diversity, lifelong learning and digitalization on higher education ([Pellert, 2016](http://fernuni-hagen.de)). In this context, progressive approaches for representing competences in a comparable and BP-conform way are of major interest, for example the use standardized terms from so-called *Competence Frameworks (CFs)* instead of free text. The *Chair of Multimedia and Internet Applications (CoMMIA)* ([Lgmmia.fernuni-hagen.de, 2016](http://fernuni-hagen.de)) at FUH’s Department for Mathematics and Computer Science, a participant in this research cluster, is currently working on this topic ([Then et al., 2016a and 2016b; Wallenborn et al., 2015](http://fernuni-hagen.de)).

Research projects like *EDISON* ([Edison-project.eu, 2016](http://edinova.eu)), a 2-year project which started in September 2015 with the purpose of accelerating the creation of the Data Science profession, already perceive CF-based competence specifications as an integral part of a profession profile and corresponding study programs. FUH’s CoMMIA through its associated *Research Institute for Telecommunication and Cooperation (FTK)* ([Ftk.de, 2016](http://fernuni-hagen.de)) is a participant of the EDISON project which has several thematic intersections with the above-mentioned research cluster. In the remainder of this paper we will outline the starting points for our work by means of a problem statement, corresponding objectives as well as our research questions and approach. Furthermore,
we will introduce the relevant state of the art in science and technology as well as our overall conceptual and architectural approach towards implementing an initial prototype. The paper will conclude with some reflections and conclusions as well as an outlook onto the remaining future work.

2. Problem statement, objectives, research questions and approach

Replacing free-text LG specifications with competences from standardized, generally admitted CFs or taxonomies can be a relief for those faculty members who are responsible for acknowledgement procedures and decisions about equivalence of examinations passed in different study programs and institutions. From a student’s perspective, such LG-descriptions offer a reliable fundament for identifying and comparing suitable SMCs. Therefore, they contribute to increased flexibility and a greater scope of design for personal study programs and Learning Plans (LPs). Consequently, a progressive, BP-compliant learning concept has to include a strategy for equipping SMCs with LGs which consist of selected qualifications from widely applicable, machine-readable competence catalogues. Software solutions concerned with creation, management, organization, and execution of SMCs are therefore required to offer capable and user-friendly support for such approaches.

An HEI’s IT-infrastructure is distributed over various components, which are responsible for different tasks. Authoring tools are concerned with the creation of SMCs, a campus management system is used for administrative issues, and the execution process is organized by a Learning Management System (LMS) which cooperates with further e-learning tools, digital libraries and media archive portals. Last but not least, the students’ performance data inclusive of achieved competences have to be archived in an examination management system. It can be stated that competence data have to be processed by and shared between diverse software systems, so the introduction of competences has a significant impact on the entire architecture.

For better understanding of our research objectives, we briefly introduce our Competence Based Learning (CBL) concept; for detailed information see (Then et al., 2016a and 2016b; Wallenborn et al., 2015). Primarily, some fundamental terms and criteria for competence based course authoring and management have to be described. An online-course is usually composed of Learning Activities (LAs) and Knowledge Resources (KRs); each of these elements contributes to the course’s LG. Our CBL-concept perceives LAs and KRs as independent resources which can convey their own competences; in other words: they are equipped with separate LGs and can be used in multiple courses. In the following, the term CRLE is used for a Competence-Relevant Learning Element, which can either be an SMC, an LA or a KR. LGs and personal user profiles are represented by so-called Competence Profiles (CPs); each CP contains a set of competences taken from a CF. From a technical point of view, competence information is added to a CRLE by assigning a CP. Furthermore, every user has a personal CP; the gap to his individual LG (again a CP) can be bridged by an LP. The course creation process ideally is attended by a competence- and taxonomy-based Recommender System (RS) which scans the data inventory for appropriate learning (raw) material and makes suggestions to the author.

This article is concerned with some important research aspects which have not been covered in adequate detail by our former publications. The central question is, if a general, framework-independent domain model for representing CFs and their relations to CRLEs and personal user profiles is realistic. Although all CFs have a common ground and similar structures, there might be
significant differences in the details.
An HEI’s IT-infrastructure is distributed over various software components which exchange CRLEs and information about students’ learning performance. Introduction of CBL means that new data structures have to be established, and diverse systems are involved into creation, processing, and transfer of competences; thus high interoperability is a key requirement for CBL-approaches. This includes a suitable exchange format, appropriate interfaces, and capable application logic. Which components definitely have to be modified depends on the architecture and the division of tasks. Obviously, the LMS is affected, because it is responsible for the execution of online courses, and in many cases, it has to import these courses from specific authoring tools or a campus management system. Furthermore, the LMS collects performance data about course participants’ attempts at LAs like quizzes, assignments, and tests; in the case of a competence based course, the achieved competences have to be transferred to and processed by the HEI’s examination management system. It can be concluded that a comprehensive strategy is required which regulates distribution, lifecycle, and versioning of all competence-related information.

Besides internal processes concerned with data management and exchange, Graphical User Interfaces (GUIs) have to be developed, for example a competence editor, an improved Course Authoring Tool (CAT) and utilities for managing LGs and LPs. The course authoring process should be supported by competence- and taxonomy-based Content Syndication functionality and Recommender Systems (RS) – this topic area is being researched at the moment and will be presented in a future paper. Once a target competence or a CRLE is selected, related elements will automatically be detected and suggested to the student, teacher, or author. An additional RS could support creation and modification of individual learning plans and study programs: depending on the gap between a student’s existing CP and his personal LG, the system can be scanned for appropriate learning content. If the available CRLEs are distributed over multiple software infrastructures and institutions, cross-system operation is necessary.

With regard to the above-mentioned research questions, the Competence Based Learning Model (CBLM) has been developed, which can both be used for direct implementation and for serialization into an xml-based exchange format. The CBLM closes the gap to our former publications where competences have been described on a more conceptual level and concrete data structures have not yet been specified. Based on the CBLM, advanced search- and comparison-algorithms can be implemented, followed by RSs for supporting course creation and the development of personal learning plans. Besides competence frameworks, other types of standardized qualification representations, in the following introduced as an application of domain-oriented Taxonomies, are considered. For best possible content syndication going beyond the level of a single CF, the CBLM supports connections between elements from different frameworks and corresponding domain taxonomies. The development of the CBLM is the main topic of this article.
3. State of the art and technology

The CBLM and the underlying CBL-concepts are inspired by results of former research projects which had already worked on related problems and offer interesting thoughts or even partial solutions for our objectives. They are introduced within the following thematic sections:

- Competences and Learning Goals;
- Standardization of Qualifications;
- CBL-support in existing software systems.

3.1 Competence and learning goals

This chapter is concerned with the origins of progressive CBL-concepts:

- The Bologna Process (BP) (Ehea.info, 2016; Bmbf.de, 2015; Luther, 2005; Magna-charta.org 2016);

3.3.1 Bologna process

The Europe-wide university reform called Bologna Process has been adopted in 1999 with the intention to establish a more comparable, compatible and coherent system of higher education in Europe. The main pillars of these improvements are:

- The Three Cycle System (bachelor/master/doctorate);
- Modular structured study programs: study programs consist of modules and modules consist of lectures, respectively courses;
- Introduction of academic credit points according to the European Credit Transfer System (ECTS) (European Commission, 2016a). The ECTS-points assigned to a course are a benchmark for its range and the time required for participation;
- Capable quality control. European universities and colleges participating in the BP have to go through an accreditation process for each study program, module and course;
- Summaries describing learning goals and the conveyed competences are obligatory for courses, modules, and study programs.

These new guidelines raised the students' hope for greater flexibility and location-independent planning of their individual curricula, but unfortunately it did not fulfill; the article in (Uni-leipzig.de, 2016) expresses the frustration about the BP. Faculty members are disappointed as well, especially those who are responsible for acceptance procedures and therefore have to judge about equivalence of certificates issued by different educational institutions. The main reasons are of political and administrative nature. Furthermore, it is hardly possible to keep an overview of the rapidly growing number of accredited bachelor and master programs – according to Stiftung zur Akkreditierung von Studiengaengen in Deutschland (2016) more than 10,000 in Germany at the beginning of 2016.
However, there are also technical deficits, particularly in the context of learning goals and competences: they are usually specified in form of free text and leave a large scope for interpretation and misunderstandings, because every faculty or institution uses its own words. As a consequence, the European Qualifications Framework (EQF) (see section 3.2.1) has been designed which defines a raster for classifying qualifications into types (competence, skill, knowledge) and difficulty levels. The EQF can be regarded as a milestone for the development of standardized, machine-readable Competence Frameworks (CFs) which could be the key for significant improvements regarding comparability. Although the development of CFs is still at an early stage, in section 3.2.2 an interesting representation is covered in more detail.

3.1.2 Competency based education

Conventional study programs are determined by the providing institutions and associated with an academic or non-academic degree, a timeline and a sequence of courses. Each course includes its own schedule regulating the access to resources, exercises and assessments. Competency Based Education (CBE) (Johnstone, Soares, 2014; Hickey 2015; Educause, 2014; Luminafoundation.org, 2014), an idea which originally emerged within the context of continuing education and lifelong learning, proposes a more flexible way to create individual study programs which incorporate a user’s curriculum vitae and previous knowledge. The terms CBL (Competence Based Learning) and CBE are often used synonymously.

For each learner, a summary of proven competences is added to his personal profile; it does not matter, if these qualifications have been achieved at school, at university or in professional life. As soon as a learning goal consisting of aspired competences is determined, an individual learning plan can be created which bridges the gap between the existing profile and the LG. In CBE, every course has to specify the conveyed qualifications, so appropriate learning content can be identified on this base. The learner then can make his own choice and schedule a reasonable sequence of processing. CBE intends to offer maximum flexibility for integrating continuing education into the students’ free time, so tight schedules in courses should be avoided. A competence can be added to the learner’s personal profile after providing a proof of performance; the learning goal is achieved as soon as all included competences are verified.

CBE has been adapted for higher education in some prototypical projects in the American region, but until now the use of competences for improving the comparability of SMCs beyond the scope of a single institution has, if at all, been a side issue. Standardized, machine-readable competences therefore are not a major topic for current CBE-approaches. Furthermore, it remains ambiguous, if difficulty levels should be assigned to competences and which role grades on assessments should play.

The key for increased comparability beyond the level of a single institution or nation could consist in a combination of CBE and European CFs like the European Qualifications Framework (EQF) and the European e-Competence Framework (e-CF) which are described in section 3.2. At the moment, software support for such approaches is limited. Some promising research projects and software systems, namely the TENCept Project (TCP), the Ecosystem Portal (EP) and the LMS Moodle with its lately developed CBE-Plugin, will be covered in section 3.3.
3.2 Standardization of qualifications

Subsequent to the BP, some promising approaches have been made to define qualification standards in the European region:

- The European Qualifications Framework for Lifelong Learning (EQF) (European Commission, 2008 and 2016b);
- The European e-Competence Framework (e-CF) (Profiletool.ecompetences.eu, 2016; Ecompetences.eu, 2016);

3.2.1 European qualifications framework

The Europe-wide established EQF has been initiated as a follow-up project to the BP with the goal to further improve the comparability of qualifications and to incorporate non-academic graduations and continuing education. It has been adopted in 2008 as a “Recommendation of the European Parliament and of the Council of the European Union”, see (European Union, 2008). The EQF defines a raster for classifying qualifications into types (competence, skill, knowledge) and difficulty levels; an extract is shown in Table 1. It can be regarded as a common reference framework, to which national qualification systems can be mapped. Based on these classifications, students, faculty members and employers will be able to better understand, appraise, and compare the qualifications and levels of different countries and education systems. As stated in (European Union, 2008), the EQF is compatible with the Qualifications Framework in the European Higher Education Area (QF-EHEA), the BP’s basic structure which classifies SMCs into three degrees: bachelor, master and PhD. They are equivalent to the EQF-levels 6-8, see Table 1.
Table 1. EQF-cutout (European Commission, 2016c)

<table>
<thead>
<tr>
<th>Level</th>
<th>Equivalent</th>
<th>Knowledge</th>
<th>Skill</th>
<th>Competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Bachelor Degree, Graduate Certificate, Graduate Diploma, City and Guilds Graduateship (GCGI), German Fachwirt/ Fachkaufmann, German Meister, ...</td>
<td>Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles</td>
<td>Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study</td>
<td>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</td>
</tr>
<tr>
<td>7</td>
<td>Master, Postgraduate Certificate, Postgraduate Diploma, vocational university (Fachhochschule) Master, City and Guilds (MCGI)</td>
<td>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 issue in a field and at the interface between different fields</td>
<td>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</td>
<td>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</td>
</tr>
<tr>
<td>8</td>
<td>Doctorate, PhD, Professional Doctorate, City and Guilds Senior Awards - Fellowship</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

For each combination of EQF-level and qualification type, a descriptor is available which characterizes the corresponding learning outcome. According to the European Parliament and Council:

- “knowledge means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual”;
- “skills means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments)”;
- “competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy” (European Union, 2008).

In recent years, a large number of EQF-compatible National Qualifications Frameworks (NQFs) has been developed and mapped to the structure and difficulty levels of the EQF; for example the German DQR (Dqr.de, 2016). NQFs can be compared by using the EQF as a kind of middleware.
or mediator; a tool for comparing 14 EQF-compliant NQFs is available in (European Commission, 2016d). On this basis, national graduations and learning programs, academic and non-academic, can be compared Europe-wide.

### 3.2.2 European e-competence framework

As stated above, the EQF defines a raster for classifying learning outcomes; it does not describe or grade any concrete competences or study programs. The development of a qualifications catalogue, for example a Competence Framework (CF), is a big challenge both from a technical and a political point of view; it is a task for national and EU-wide research projects in cooperation with educational institutions, universities, and employers. A promising approach of international dimension is the European e-Competence Framework (e-CF) (Ecompetences.eu, 2016) which concentrates on the domain of Information and Communication Technology (ICT) and is regarded as the first sector-specific implementation of the EQF. Its development started in 2005 and is a continuous process until today; an overview of the recent version v3.0, which has been released in 2013, is provided by the e-CF profile tool (Profiletool.ecompetences.eu, 2016 - Figure 1 and 2).

<table>
<thead>
<tr>
<th>Dimension 1</th>
<th>Dimension 2</th>
<th>Dimension 3</th>
<th>e-Competence proficiency levels e-1 to e-5, related to EQF levels 3–8</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 e-CF areas (A – E)</td>
<td>40 e-Competences identified</td>
<td>e-1</td>
<td>e-2</td>
</tr>
<tr>
<td>A. PLAN</td>
<td>A.1. IS and Business Strategy Alignment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.2. Service Level Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.3. Business Plan Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.4. Product/Service Planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.5. Architecture Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.6. Application Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.7. Technology Trend Monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.8. Sustainable Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.9. Innovating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. BUILD</td>
<td>B.1. Application Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.2. Component Integration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.3. Testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.4. Solution Deployment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.5. Documentation Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.6. Systems Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. RUN</td>
<td>C.1. User Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C.2. Change Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C.3. Service Delivery</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C.4. Problem Management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1.** European e-competence framework 3.0; cutout (Profiletool.ecompetences.eu, 2016)
The e-CF is divided into four so-called dimensions; the excerpts in Figure 1 and Figure 2 provide an overview of the e-CF’s structure. Dimension 1 defines five main ICT business areas: Plan, Build, Run, Enable and Manage. Each of the 40 competences from dimension 2 is assigned to one of these fields; Figure 2 displays the competence Architecture Design which belongs to the Plan-area. Most competences can be provided with different Proficiency Levels (PLs) from dimension 3. In Figure 1 and Figure 2, all possible combinations are highlighted; in the case of our sample competence Architecture Design, the PLs e-3, e-4 and e-5 are available. Dimension 4 defines a set of Skills and Knowledge Examples (SKEs) for each competence, see Figure 2. SKEs are not intended to be exhaustive, so users can add further examples if required. The hierarchical relation between competences and SKEs is a special characteristic of the e-CF but it is not a contradiction to the EQF, which the e-CF claims to implement. Terms like competence, skill, and knowledge are interpreted in an EQF-compliant way and furthermore, relationships between the PLs and EQF-levels have been specified.
Figure 3. Screenshot e-CF - ICT profile “Database Administrator”

The e-CF v3.0 provides a collection of ICT profiles consisting of selected competences on preassigned proficiency levels. The profiles themselves are not graduated, but individual instances can differ in their competences’ PLs; for example, the Database Administrator profile displayed in Figure 3 can include the competence Component Integration on level e-2 or e-3. SKEs are not considered within ICT profiles.

3.2.3 The 2012 ACM Computing Classification System

The ACM Computing Classification System (ACM CCS) is a de-facto standard for representing knowledge from the domain of Computer Science and is, e.g., heavily used in semantic web applications. It is available at no extra cost for educational and research purposes. The first version was published in 1964, the last one in 2012. It represents a poly-hierarchical taxonomy with over 2000 terms; Figure 4 shows the 13 main categories.
The ACM CSS is available in the XML-based SKOS (Simple Knowledge Organization System) format (see Figure 5) (W3.org, 2015b), a standard for describing knowledge organization systems in the field of the semantic web, which has been published in 2009 by the W3C (W3.org, 2015b).

**Figure 4.** The main categories of the ACM CSS (DI.acm.org, 2015)

<table>
<thead>
<tr>
<th>General and reference</th>
<th>Hardware</th>
<th>Computer systems organization</th>
<th>Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software and its engineering</td>
<td>Theory of computation</td>
<td>Mathematics of computing</td>
<td>Information systems</td>
</tr>
<tr>
<td>Security and privacy</td>
<td>Human-centered computing</td>
<td>Computing methodologies</td>
<td>Applied computing</td>
</tr>
<tr>
<td>Social and professional topics</td>
<td>What is the CCS?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5.** ACM CCS in SKOS-format
3.3 CBL-support in existing software systems

A few software systems already offer basic support for CBL/CBE-approaches, but not with the functional range demanded by our concept. Open-source solutions which offer partial solutions for our objectives might be appropriate starting points for prototypical implementations. Of special interest are:

- The TENCompetence Project (TCP) (Tencompetence.org, 2016a and 2016c) with its TENCompetence Personal Competence Domain Model (PCDM) (Vogten et. al., 2009);
- The Ecosystem Portal (EP) (Globit.com, 2016);
- The LMS Moodle (Moodle.org, 2016) with its lately developed CBE-Plugin (Docs.moodle.org, 2016a-2016e).

3.3.1 TENCompetence project

According to (Tencompetence.org, 2016c) “… the aim of the TENCompetence Project is to develop a technical and organisational infrastructure, which is both open source and standards based, to support lifelong learning in Europe, to serve the needs of individuals, groups, and organisations. The project runs from December 2005 to December 2009, and is funded by the European commission through the Framework 6 IST Technology Enhanced Learning programme, with 15 partners from throughout Europe.” The TCP has been inspired by the idea of CBE as well as by the BP, which has been in progress roughly at the same time.

Figure 6 displays an excerpt of the Personal Competence Domain Model (PCDM) which has been developed within the scope of the TENCompetence Project as a basic domain class model for a prototypical open-source software system called Personal Competence Manager (PCM) (Tencompetence.org, 2016a; Kluijfhout, Koper, 2010; Vogten et. al., 2010; Tencompetence.org, 2016b). The PCM is based on the Liferay Portal (Liferay.com, 2016).

The “blue classes” on the left side of Figure 6 represent learning content like courses, activities and resources. They are widely compatible with IMS Learning Design (IMS LD), a common specification with has been developed at the Open University of the Netherlands (OUNL); the first version was published in February 2003 (Koper, 2003). IMS is a shortcut for the IMS Global Learning Consortium (Imsglobal.org, 2016b). LD bundles a wide range of existing e-learning standards and allows the modeling of different learning strategies by using just a single language (Imsglobal.org, 2016a). IMS LD and thus the PCDM use the metaphor of a stage-play – also called Unit of Learning (UOL) – to model learning designs. A UOL represents an enclosed educational part like a course, module or lesson with pre-defined Learning Goals (LGs), and consists of one or more Learning Acts (LActs). An act on its part contains different Learning Activities (LAs) as reading texts or discussing the subject with peers. Learning Resources (LRs) (in PCDM-context Knowledge Resources) and their files represent the requisites of the stage-play.
The data structures specified by IMS LD do not offer support for competences and CBE-approaches. The “grey classes” on the right side of Figure 6, which can be regarded as the PCDM’s competence model, close this gap. With the classes Competence, Proficiency Level (PL) and Competence Profile (CP), it contains some elements which are semantically equivalent to the correspondent items introduced in previous chapters. The PCDM interprets a competence as the acquired or perceived skill of a person, group, or an organization to handle critical events, problems, or tasks in certain situations; for a detailed discussion see (Tencompetence.org, 2016d). Connections between learning content and elements of the competence model can be established by the association Objective/Prerequisite. In the PCDM, the idea of assigning difficulty levels is not limited to competences; the class Competence Profile Level (CPL) introduces PLs for CPs. The following example demonstrates the benefit: a competence profile “software developer in java” is available for bachelor and master programs as well as for vocational training. On the CPL correlating with the bachelor degree, it includes several competences on different PLs: expert skills in java programming, solid knowledge about object-
oriented programming concepts, as well as basic skills in relational databases and modeling languages. When a CP is chosen as a personal learning goal, an appropriate Learning Plan (LP) consisting of a sequence of UOLs, usually courses, has to be created. The selected UOLs have to provide suitable activities and knowledge resources for achieving the associated competences.

In our former publications (Then et al., 2016a; Wallenborn et al., 2015), the PCDM and the PCM are analyzed in more detail. Some essential elements of our CBL-concept cannot be realized with the PCDM, but it is regarded as an excellent fundament for the Competence Based Learning Model (CBLM) which provides the required modifications and extensions.

3.3.2 Ecosystem Portal

The Ecosystem Portal (EP) is an advancement of the Educational Portal toolkit, a Typo3-based (Typo3.org, 2016) learning platform originally developed by the software company GLOBIT (Globit.com, 2016). The further development is conducted by the Research Institute for Telecommunication and Cooperation (FTK) (Ftk.de, 2016) in the Horizon 2020 Research and Innovation Action RAGE (RAGE, 2016). For a more detailed introduction and discussion of the EP see (Then et al., 2016a).

![Figure 7. Screenshots of the EP](image)

A wide variety of useful course- and knowledge-management features is already provided by EP until now, including a web-based, user-friendly course authoring tool called EP-CAT. At the moment, FTK is working on improved content syndication functionality which is used for recommending suitable knowledge resources during course creation. Before relations between courses and resources can automatically be identified, they have to be tagged with additional meta-data from so-called Taxonomies. The EP already provides a Taxonomy Plugin (TP) which, for example, has been used for integrating the 2012 ACM CCS into the EP; a screenshot of this tool is displayed on the left side of Figure 7. Taxonomy elements from the domain of Computer Science are represented and organized by so-called Categories which can be created manually with the TP’s taxonomy management tool or via XML-import from standardized taxonomies. On the right side of Figure 7, the user interface for assigning categories to a content object is displayed – in this case the taxonomy itself is a knowledge resource as well as the semantically tagged content object. The TP has been integrated into the EP within the RAGE (RAGE, 2016) project; extensions for SKOS import and version management are
scheduled for the future. Competence Frameworks differ from taxonomies in objectives and structure. Therefore, the concept described above has to be modified for CBL-support. A prototypical implementation is in progress and will soon be published in a separate paper.

3.3.3 Moodle’s CBE-plugin

With release v3.1, the open-source LMS Moodle (Moodle.org, 2016) introduced the CBE-Plugin (Docs.moodle.org, 2016a-2016e) which widely supports the ideas described in chapter 3.1.2. It provides capable tools for managing and applying typical CBE-elements like competences, their relations to courses and activities, learning plans, and personal competence profiles. Even competence frameworks can be represented; a screenshot of our evaluation scenario, the integration of the e-CF (see chapter 3.2.2), is displayed in Figure 8.

Figure 8. Representing the e-CF with Moodle’s CBE-plugin

In Moodle, a CF is regarded as a collection of competences which is hierarchically structured in up to five layers. Each competence, apart from those on the lowest layer, can contain sub-competences. The root node of the resulting tree is the CF; the elements on layer five are leafs. In our evaluation scenario, we interpret the e-CF’s four dimensions as layers, so we receive the structure in Figure 8: framework => business areas => competences => skill-knowledge-examples. As Moodle does not support the concept of proficiency levels, dimension 3 cannot be represented.

After choosing the edit-option in Figure 8, the selected competence, in this case the skill modeling technologies and languages, can be modified; see Figure 9. Most entries are self-explanatory. The
ID number has to be unique and is used to clearly identify a competence within a competence framework. Scales are used as grading schemes for rating the students’ attempts to achieve a competence; attempts can be made in form of rated activities like quizzes, assignments and tests.

![Figure 9: Editing a competence in Moodle](image)

Scales should not be confused with the proficiency levels from the e-CF and the PCDM: a PL determines the difficulty level of a competence, respectively a course or activity to which the competence has been assigned, and not the quality of a student’s attempt. Although PLs are essential parts of CFs, they are not supported. As a consequence, a competence like “Programming in Java” cannot be provided on beginner, advanced and expert level; three separate competences have to be created.

Describing the entire CBE-Plugin with its broad variety of capable features would go too far here. Therefore, we concentrate on the functionality which is relevant for our CBL-concept and point out limitations regarding our requirements. In addition to the lack of PLs, Moodle does not provide a specific data structure for competence profiles. A course’s learning goal therefore is described by a list of competences; a learning plan consists of competences and selected courses; a student’s personal profile is represented by a summary of all assigned LPs and status information about progress and performance. These LPs cannot be merged to a personal user profile in the meaning of our CBL-concept; they are just listed and treated as independent units. The creation of LPs is restricted to owners of the competence manager role; it is not intended that students create their individual LPs. Furthermore, defining competence-based preconditions for participating in a course or attempting an activity is not possible.

Moodle by default offers a lot of configuration options which can help teachers keeping an overview of their running courses and the participants’ performances. For example, availability periods can be configured for resources and activities like quizzes, assignments and tests; furthermore, evaluation
processes can be initiated after the expiry of a given deadline. The CBE-Plugin introduces an additional evaluation feature which enables teachers to attest competences to course participants. The process of granting competences and registering them in the students’ LPs to a certain extent can be configured to run automatically, but there still remains a lot of manual work to do for teachers and competence managers.

In many cases there are multiple dependencies between competences and their sub-competences. For instance, a competence C1 with the sub-competences SC1-SC6 might be automatically granted, as soon as a certain number of sub-competences has been attested or the key sub-competences SC2 and SC4 have been achieved. In Moodle, such dependencies can be expressed by so-called Competency Rules. Another way to define relations between competences within the same CF are so-called Cross-References; our idea of connecting elements beyond the scope of a single CF by semantic tagging would require an extended cross-reference feature.

In summary, it can be stated that Moodle’s CBE-Plugin already supports some integral parts of our CBL-approach by now, but the realization of the entire concept requires several extensions and modifications. Moodle as an open-source software with a plugin-architecture can be regarded as a perfect fundament for our prototypical implementation. The CBE-Plugin prevents us from re-implementing basic functionality like management tools for competences, learning plans, and much more; the effort for accomplishing the upcoming tasks seems to be maintainable.

3.4 Remaining challenges

Motivated by the BP, an innovative strategy for improving the comparability of CRLEs on the basis of standardized competences has been developed. An integral part of this concept is the Competence Based Learning Model (CBLM), a domain class model for representing competence-related information which is intended as a further development of the PCDM. The CBLM, our fundament for prototypical software solutions, will be implemented in form of extensions for common open-source tools.

A major deficit of the BP and existing CBE-approaches is the fact that competences are usually specified in form of free text. Each faculty or institution uses its own words, so this leaves too much scope for interpretation and misunderstandings. Providing support for standardized qualifications catalogues like competence frameworks is regarded as a significant improvement and a major goal of the CBLM; a core requirement is the representation of the European e-Competence Framework (e-CF) described in section 3.2.2, which concentrates on the field of Information and Communication Technology (ICT). In the near future, hopefully further CFs will be available for disciplines like humanities, engineering sciences, economy, law and others, so the CBLM is not intended to remain e-CF-specific. A general solution for EQF-compatible (see 3.2.1) CFs is required which moreover includes structures for connecting qualifications from different CFs and taxonomies like the ACM CCS (section 3.2.3).

As stated in section 3.3.1, designing a completely new domain class model from scratch is not necessary, because the Personal Competence Domain Model (PCDM) which has been developed in the context of the TENCompetence Project offers an excellent fundament. In addition to basic CBE-structures, it provides suitable classes for representing IMS-LD-conform learning content, assessments, and personal performance data; in our former publications, we already proposed some extensions concerning these aspects and the data exchange in distributed architectures. By combining the CBLM and the PCDM, we continue the strategy of developing PCDM-based solutions. With Moodle’s CBE-extension and the Ecosystem Portal (EP), two appropriate open-source basis
systems for prototypical implementations have been identified, see sections 3.3.2 and 3.3.3. Both systems already offer a broad variety of capable CBE-features which in the case of a standalone-solution for our CBL-concept would have to be re-implemented at a considerable expense. In comparison, the effort for implementing plugins for the above-mentioned systems seems to be significantly lower, although in the case of Moodle, the elements of the CBLM have to be mapped to existing data structures.

In an HEI’s IT-infrastructure, competence information is distributed over various components and has to be shared between different software systems which either directly implement the CBLM or use it as a kind of middleware, exchange format, or mediator. A learning platform is an essential part of such an infrastructure and at the University of Hagen, especially the LMS Moodle plays an important role. Therefore, a mapping between CBLM-elements and Moodle’s data structures has to be defined in any case. In addition to this mapping, the following extensions are necessary to realize our CBL-concept with Moodle:

- Support of Proficiency Levels (PLs);
- Competence Profiles (CPs) have to be introduced and used in the context of personal user profiles and Learning Plans (LPs);
- Personal profiles represented by a summary of assigned LPs are not informative enough and therefore have to be redesigned;
- It should be possible to specify competence-based preconditions for participating in a course or activity;
- The Cross-Reference-Feature has to be extended for connections between elements from different CFs or taxonomies;
- The concept of Competency Rules has to be extended for PLs.

Like Moodle, the EP offers capable authoring and management tools for courses, learning content and knowledge resources. Some basic functionality for semantic tagging is already provided: knowledge resources can be tagged with elements from taxonomies, for example the ACM CCS described in section 3.2.3. To suffice our CBL-concept, this tool has to be adapted for supporting relations between CRLEs and competences from CFs.

4. Conceptual design of the CBLM

The development process of the Competence Based Learning Model (CBLM), a CBL-optimized domain model offering best possible support for CFs, starts with the technical analysis of a typical representative – the European e-Competence Framework (e-CF). The insight into structure and properties of CFs reveals diverse aspects and constraints which have to be considered; most of them are not e-CF-specific and can be generalized. The resulting requirements on a competence model go beyond the possibilities of the PCDM. Therefore, the CBLM as a PCDM-based solution (see chapter 3.4) has to provide suitable extensions. Our first milestone consists of a domain model which is able to fully represent the elements and relations defined by the e-CF. As the CBLM is not intended to support just a single CF, it later has to be revised for EQF-compatible CFs in general. Besides competence frameworks, further standardized, machine-readable, hierarchically structured
qualification representations are available in the form of taxonomies, as for instance, the ACM CSS is already existing for the domain of Computer Science. These diverge from CFs in content and structure, so they cannot be mapped to a competence model in an adequate way. To increase the informative value of CFs represented with the CBLM and to offer best possible conditions for content syndication functionality and recommender systems, the CBLM has to be provided with elements for enabling connections between competences and qualifications described in taxonomies. This approach can easily be transferred to relations between qualifications from different CFs: Competence frameworks are usually orientated on specific subject areas, so each faculty will use another CF for characterizing its Competence-Relevant Learning Elements (CRLEs). In many cases, study paths have thematic intersections which can be represented by connections of the above-mentioned type. This contributes to increase the comparability of CRLEs, which results in a greater flexibility regarding acceptance procedures and individual learning plans. The CBLM will be developed in six steps; this article covers steps 1-3. Steps 4-6 can be processed in parallel.

- Step 1: PCDM-based domain class model for representing the e-CF;
- Step 2: Connections between competences and elements from taxonomies;
- Step 3: Generalized solution for EQF-compatible competence frameworks;
- Step 4: Tools for competence managers, course authors and students;
- Step 5: Version management for competences and CFs;
- Step 6: Competence- and taxonomy-based recommender systems.

4.1 Technical aspects for representing competence frameworks

The technical analysis of the e-CF revealed an important fact: the term Competence is used in two different meanings. Both aspects are demonstrated in Figure 2, which shows the competence A.5-Architecture-Design in form of a screenshot created with the e-CF-Profiletool (Profiletool.ecompetences.eu, 2016).

- The “maximum competence”, in the following called the Competence Scope (CS), specifies a fixed pool of available Proficiency Levels (PLs) and Skills and Knowledge Examples (SKEs). The CS of our sample-competence A.5-Architecture-Design consists of PL3-PL5, K1-K5 and S1-S5,
- A Competence Instance (CI) contains a subset of the SKEs and PLs which are available within the corresponding CS. CIs are the elements which in the meaning of our CBL-concept have to be connected with Competence-Relevant Learning Elements (CRLEs) and personal user profiles. A sample CI of the CS A.5-Architecture-Design could contain PL3, K2, K4, S1 and S4.

This leads to a revised interpretation of the e-CF: dimension 2 consists of 40 competence scopes; a competence instance is created by choosing a CS and making a selection from the available PLs and SKEs. In the e-CF-Profiletool this can easily be done by opening a CS (see Figure 2) and marking the elements which shall be assigned to the CI. The option to create individual CIs offers great flexibility for equipping CRLEs with competence information.

The e-CF does not make any statements about the dependency relations between competence instances and SKEs. What does a proof of performance for a competence have to include – demonstration of certain key skills, a predefined number of SKEs, or should CIs and SKEs by default...
be treated independent of each other with dependency relations as optional features? This question
is not e-CF-specific; it concerns every hierarchically structured CF consisting of competences and
sub-competences or -qualifications. The evaluation process for granting competences on the basis of
dependency rules should run automatically; the CBLM has to provide appropriate structures.
As already stated in section 3.2.2, the e-CF does not intend to determine exhaustive lists of SKEs;
this is pointed out by the term “example” in SKE (Skills and Knowledge Example). It might happen
that the available choice of SKEs provided by a CS is not sufficient to characterize the competence
instance for a CRLE in an adequate way: for the course Basic-Concepts-of-Object-Oriented-Programming-
FC123, the knowledge B.1.KS-Programming-Languages contained in the CS B.1-Application-Development
might be too general. At educational institutions like the University of Hagen, many courses are
concerned with programming technologies and differ in paradigm and language, so how should
B.1.KS-Programming-Languages be handled in practical use? The following approaches could solve the
problem:

- Extending CSs with additional SKEs: This would result in university-specific versions of the
e-CF with the advantage of best possible adaption to its own CRLEs. The disadvantage is a
decrease of comparability regarding CRLEs provided by external institutions. The influence of
additional SKEs on the above-mentioned dependency rules has to be considered;
- Adding metadata to CIs and CSs: If an SKE is perceived as too general, further information
could be added by a simple keyword or a link to an element from a taxonomy (e.g. the ACM
CSS, see section 3.2.3) or a qualification from another CF. Enabling connections between
competences and taxonomy-elements is one of the CBLM’s major goals anyway;
- Additional SKEs and sub-SKEs: This approach adopts the idea of university-specific SKEs and
extends it with a hierarchical SKE-structure which allows concretizing indistinct SKEs like
B.1.KS-Programming-Languages. However, this would modify the structure of the e-CF, because
SKE-hierarchies are not intended.

Some of these possibilities require writing access to the competence framework. As course authors
should not be authorized to modify competence scopes, an appropriate workflow between authors
and competence managers has to be defined.

In our understanding of Competence Based Learning (CBL), the Learning Goal (LG) of a
Competence-Relevant Learning Element (CRLE) – a CRLE can be a study program, module, course,
learning activity (LA) or knowledge resource (KR) – is specified by a so-called Competence Profile
(CP), which consists of diverse competence instances (CIs). This is demonstrated by the following
example: A module M1 which is part of a study path P1 consists of the two courses Software-
Engineering-FC987 and Software-Architectures-FC543. Both courses have to define their LGs in form of
CPs, which means that appropriate CIs have to be determined. We start with course FC987 which
among other things conveys basic knowledge in architecture design; consequently, a CI of type A.5-
Architecture-Design (see Figure 2) is added to FC987’s learning goal and named CI-FC987-A.5.PL3. As
the course is addressed to beginners, the proficiency level A.5.PL3 is selected, which is the lowest
and A.5.PL3.S4 are chosen and assigned to CI-FC987-A.5.PL3. (see Figure 10).
An important characteristic of our CBL-concept is that the hierarchical structure of CRLEs has a significant impact on relations between CIs. Study programs are composed of modules; modules consist of courses; courses provide learning activities (such as forums, wikis, quizzes, assignments and tests) and knowledge resources (for instance pdf-files and videos). The consequence is demonstrated in Figure 10 which displays the example from above in form of an object diagram. Assumed, the courses FC987 and FC543 – both are integral parts of module M1 – convey the competence A.5 with different key topics: FC543’s LG then has to be equipped with a competence instance CI-FC543-A.5.PL3 which differs from CI-FC987-A.5.PL3 regarding the selected SKEs; we choose A.5.PL3.K3, A.5.PL3.K4 and A.5.PL3.S2. The resulting CI for M1 at least has to include the union of all SKEs contained by CI-FC987-A.5.PL3 and CI-FC543-A.5.PL3, so the LG for M1 automatically receives an according competence instance CI-M1-A.5.PL3. In addition to the inherited SKEs, further elements can be selected manually, for example the skill A.5.PL3.S5.

The merging process for CIs induced by the CRLE-hierarchies is straightforward, as long as the
involved CIs and SKEs do not differ in their proficiency levels. At this stage of development some decisions have to be made:

- The PL of a CI and its SKEs has to be identical, otherwise SKEs would have to be equipped with their own PLs. Although this is not intended by the e-CF, it has to be kept in mind with regard to a more flexible, e-CF-independent solution;
- CIs of the same CS can only be merged, if their PLs are identical. If, for example, A.5.PL4 was assigned to FC543’s CI, it would not be compatible with CI-FC987-A.5.PL3. Module M1 would inherit two separate competence instances CI-M1-A.5.PL3 and CI-MI-A.5.PL4.

The initial version of the CBLM, displayed in Figure 11, consists of a PCDM-based domain model which allows representing typical object constellations like the one from Figure 10.

![Diagram](image-url)

**Figure 11.** The CBLM, steps 1+2

The class *Competence* already exists in the PCDM which does not distinguish between CI and CS; from the perspective of our CBL-approach the name *CompetenceInstance* would be more precise. In technical terms, a CS is a CI with some additional properties, so a separate class *CompetenceScope* is introduced and equipped with a generalization relationship to *Competence*. The association *Scope* ensures the constraint that each CI belongs to exactly one CS.

As stated in the technical analysis (section 4.1), the hierarchical structure of CRLEs causes dependencies between the associated CIs; Figure 10 shows the relations between the sample CIs belonging to module M1, course FC987 and course FCS43. In the CBLM, such connections can be represented by the association *CRLE-Hierarchy*.

In the meaning of the EQF and the e-CF, competences as well as skills and knowledge are regarded as qualification types, so they share some common properties, which are summarized in the class *Qualification*. Their semantic differences are considered by the subclasses *Competence* and *SkillKnowledgeExample*.

In the PCDM, the class *Competence* is equipped with a reflexive association for assigning sub-
competences. This relation is the basis for defining competence hierarchies and should not be confused with the CBLM’s association CRLE-Hierarchy. As the e-CF combines different types of qualifications, the CBLM requires a more general solution which enables hierarchical relations between CIs and SKEs. This has been achieved by moving the reflexive association to the class Qualification; its name has been changed to Sub-Qualification.

The PCDM contains an association between the classes Competence and ProficiencyLevel. As the CBLM considers enabling PLs for both CIs and SKEs, we shift the Competence-sided endpoint of this association to the class Qualification. Although the e-CF does not make any statements, when a competence can be regarded as granted to a learner, a solution for defining appropriate dependency rules between competences and SKEs has to be found. Such dependency relations are located in the class CompetenceScope, which is indicated by the attribute CompletionCriteria. It specifies conditions for granting the competence, for example key SKEs or a minimum number of achieved SKEs.

Competence frameworks and subcategories like the e-CF’s competence areas can be represented by the class CompetenceCollection, a simple container for organizing competences. If it turns out that competence frameworks require a more complex structure, a separate class CompetenceFramework has to be introduced.

4.3 Step 2: Extensions for tags and taxonomies

The informative value of qualifications can easily be increased by adding secondary data, for example simple keywords. In the CBLM, this basic way of semantic tagging is supported by the class SimpleTag, see Figure 11. As connections between elements from different CFs and taxonomies cannot be adequately specified by keywords, the class SemanticTaggingObject is introduced, which provides all necessary attributes for referencing clearly identifiable taxonomy elements. From a technical point of view, a SemanticTaggingObject (STO) can be regarded as an extended SimpleTag, which is considered by a generalization relationship. The attribute Identifier contains a link, an object-id or any other distinct key; for instance, the ACM CSS supports identifiers consisting of the highest category and the name of the selected element (example: Software-and-its-engineering => Memory-Management). The ACM CCS uses specific difficulty levels (low, medium, high); a mapping to the e-CF-/EQF-levels might be useful.

The benefit of SemanticTaggingObjects largely depends on a software system’s support for taxonomies, which usually diverge from CFs in content and structure and therefore cannot be mapped to a competence model. For example, the Ecosystem Portal (EP) already includes a representation of the entire ACM CCS, based on its own taxonomy model. This offers best possible conditions for content syndication, search algorithms, and recommender systems. The LMS Moodle does not provide extensions for taxonomy-support. Therefore, the use of SemanticTaggingObjects would be limited to connections between qualifications from different CFs at the moment. For the future, we plan to equip our EP-based prototype with services which enable external applications like Moodle to use the EP’s taxonomy-features from outside.
4.4 Step 3: Generalized version

The CBLM-version in Figure 11 is able to represent the e-CF in a way that matches our CBL-concept, but it is not yet applicable for competence frameworks in general and thus has to be accordingly modified. The generalized version is displayed in Figure 12.

![Diagram of the generalized CBLM version]

The most significant change is that there are no more distinct classes for competences and SKEs, from now on all types of qualifications are represented by the class Qualification. Regarding the e-CF, this causes no loss of performance, which could not be caught by appropriate constraints. The intuitive relation between e-CF-elements and CBLM-classes has dropped away to some degree, but this disadvantage is more than offset by the increased flexibility achieved by the framework-independent structure. Furthermore, by replacing the CompetenceScope with a QualificationScope, the possibility of defining dependency rules has been opened for all qualification types and their sub-qualifications.

5. Initial implementation approach

In a university’s distributed IT-architecture, diverse software components are involved into the lifecycle of a competence-based online-course. Authoring tools are concerned with creation and modification, a campus management system is used for administrative issues, and the execution process is organized by an LMS which cooperates with further e-learning tools. As a consequence, competence data have to be processed by and shared between various software systems which either directly implement the CBLM or use it as a kind of middleware or exchange format.

Currently, our prototypical implementation concentrates on the two established open-source learning platforms Moodle and Ecosystem Portal (EP), which have been described in the sections 3.3.3 and 3.3.2. Besides fundamental CBL-support, the scheduled extensions will provide appropriate interfaces for exchanging CBLM-based courses and learning activities. In the described constellation,
the EP’s Course Authoring Tool (EP-CAT) is designated for creation and modification of CRLEs which have to be transferred to and executed by the LMS Moodle. Our former publications (Then et al., 2016a and 2016b) discuss this task-sharing in more detail and propose the platform-specific architecture displayed in Figure 13.

Figure 13. Use case scenario FernUni – Software Integration Architecture (Then et al., 2016a and 2016b)

Until now, the EP focused on course authoring, knowledge management and taxonomy-based content syndication; this functionality has to be extended for CBL. As the EP does not yet provide any data structures intersecting with the CBLM, our EP-based prototype can introduce the CBLM as it is. Our solution will soon be presented in a separate paper.

The fundament of our Moodle-extension is the CBE-Plugin (see Section 3.3.3) which contains its own database tables for representing competences; in the following, these data structures will be called the Moodle Competence Model (MCM). As it is not intended to re-implement existing functionality and modification of the core code shall be avoided as far as possible, the CBLM has to be adapted to the MCM which means that some elements of the CBLM have to be mapped to existing data structures. CBLM-elements with no counterpart in Moodle, like the classes CompetenceScope, ProficiencyLevel, CompetenceProfile and SemanticTaggingObject, are not concerned and can be introduced as they are. Other CBLM-elements, like Competence or CompetenceCollection, have to be mapped to Moodle’s database tables; this merging process results in a Moodle-Specific CBLM (MoCBLM).

Before the CBE-Plugin has been released, we already outlined a strategy for mapping PCDM-classes to Moodle database tables, see (Then et al., 2016a and 2016b). CBL-data have been treated in a quite general way, because neither the CBLM nor the MCM existed at that time, so our prototypical implementation has to concretize this mapping with a view to these competence models. The development of our Moodle-extension is in progress and will be presented in a separate article.
6. Summary and future work

The Competence Based Learning Model (CBLM) presented in this article has been developed within the context of the CBL-concept published in (Then et al., 2016a and 2016b; Wallenborn et al., 2015) and provides appropriate data structures for representing and exchanging competence data. Motivated by the Bologna Process and the lack of comparability regarding verbally described competences, our CBL-approach proposes to equip courses and learning activities with standardized, machine-readable information about the conveyed qualifications. These data can be used for competence based search- and comparison-algorithms as well as for advanced recommender systems, provided that the underlying domain class model is able to represent multiple CFs and connect their elements with CRLEs; this is ensured by the CBLM.

In the state-of-the-art-section, existing competence frameworks and domain taxonomies have been analyzed. The European e-Competence Framework (e-CF) has been identified as an important representative with all typical properties of a qualifications collection, so it has been chosen as a reference framework for the development process, which has been divided into three steps:

- Design of a PCDM-based domain class model which is able to represent the e-CF;
- Extending the e-CF-specific solution with structures for connecting elements from different CFs and domain taxonomies;

The open-source learning platforms Moodle and Ecosystem Portal (EP) have been identified as perfect fundaments for prototypical implementations, because they already include partial solutions for our objectives and have plugin architectures which offer suitable connection points. Developing extensions for these systems instead of creating project-specific standalone solutions is obvious. At the moment, the implementation process is in progress; the prototypes will be presented in a future paper.

Currently, we assume that proficiency levels for competence instances and their sub-qualifications are identical; furthermore, only CIs with the same PL and competence scope are merged. The CBLM would allow a more flexible structure, but the consequences of loosening these restrictions have not been fully researched yet. The increase of complexity regarding CRLE authoring, dependency rules and merging procedures within the context of personal competence profiles and learning goals might discourage potential users from applying our CBL-concept.

Finally, it has to be stated that, with regard to the Bologna Process, the capability of CBL- and CBE-approaches strongly depends on political decisions which have to be made on Europe-wide, national, and institutional level. As demonstrated in this paper, the arising challenges are manageable from a technical point of view, but who is qualified and authorized to make fundamental decisions about equivalence of learning content from different study paths and educational institutions? How far can a competence conveyed by a bachelor course or resource be acknowledged for a master program? The difficulty level of CRLEs is not consistent inside of a study path. The program for the first semester consists of basic skills and knowledge, in contrary the bachelor thesis demands expert knowledge in a particular subject. How far can that be considered, what is the maximal permitted proficiency level for a bachelor CRLE? Does that result in an additional bureaucratic effort during accreditation processes? Such questions also concern competences, which have been achieved in non-academic programs, for example in the context of vocational training and lifelong learning.
Acknowledgement

This publication has been produced in the context of the RAGE project. The project has received funding from the European Union’s Horizon 2020 Research and Innovation Action under grant agreement No 644187. However, this paper reflects only the authors’ views and the European Commission is not responsible for any use that may be made of the information it contains.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM CCS</td>
<td>ACM Computing Classification System</td>
</tr>
<tr>
<td>BP</td>
<td>Bologna Process</td>
</tr>
<tr>
<td>CAT</td>
<td>Course Authoring Tool</td>
</tr>
<tr>
<td>CBE</td>
<td>Competency Based Education</td>
</tr>
<tr>
<td>CBL</td>
<td>Competence Based Learning</td>
</tr>
<tr>
<td>CBLM</td>
<td>Competence Based Learning Model</td>
</tr>
<tr>
<td>CF</td>
<td>Competence Framework</td>
</tr>
<tr>
<td>CI</td>
<td>Competence Instance</td>
</tr>
<tr>
<td>CoMMIA</td>
<td>Chair of Multimedia and Internet Applications at FUH</td>
</tr>
<tr>
<td>CP</td>
<td>Competence Profile</td>
</tr>
<tr>
<td>CPL</td>
<td>Competence Profile Level</td>
</tr>
<tr>
<td>CRLE</td>
<td>Competence-Relevant Learning Element</td>
</tr>
<tr>
<td>CS</td>
<td>Competence Scope</td>
</tr>
<tr>
<td>ECTS</td>
<td>European Credit Transfer System</td>
</tr>
<tr>
<td>EP</td>
<td>Ecosystem Portal</td>
</tr>
<tr>
<td>EP-CAT</td>
<td>EP’s Course Authoring Tool</td>
</tr>
<tr>
<td>EQF</td>
<td>European Qualifications Framework for Lifelong Learning</td>
</tr>
<tr>
<td>e-CF</td>
<td>European e-Competence Framework</td>
</tr>
<tr>
<td>FTK</td>
<td>Research Institute for Telecommunication and Cooperation</td>
</tr>
<tr>
<td>FUH</td>
<td>University of Hagen (FernUni)</td>
</tr>
<tr>
<td>HEI</td>
<td>Higher-Education Institution</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
</tr>
<tr>
<td>IMS</td>
<td>IMS Global Learning Consortium</td>
</tr>
<tr>
<td>IMS LD</td>
<td>IMS Learning Design</td>
</tr>
<tr>
<td>KR</td>
<td>Knowledge Resource</td>
</tr>
<tr>
<td>LA</td>
<td>Learning Activity</td>
</tr>
<tr>
<td>LG</td>
<td>Learning Goal</td>
</tr>
<tr>
<td>LMS</td>
<td>Learning Management System</td>
</tr>
<tr>
<td>LP</td>
<td>Learning Plan</td>
</tr>
<tr>
<td>LR</td>
<td>Learning Resource</td>
</tr>
<tr>
<td>MCM</td>
<td>Moodle Competence Model</td>
</tr>
<tr>
<td>MoCBLM</td>
<td>Moodle-Specific CBLM</td>
</tr>
<tr>
<td>MOOC</td>
<td>Massive Open Online Course</td>
</tr>
<tr>
<td>NQF</td>
<td>National Qualifications Framework</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>OUNL</td>
<td>Open University of the Netherlands</td>
</tr>
<tr>
<td>PCDM</td>
<td>Personal Competence Domain Model</td>
</tr>
<tr>
<td>PL</td>
<td>Proficiency Level</td>
</tr>
<tr>
<td>QF-EHEA</td>
<td>Qualifications Framework in the European Higher Education Area</td>
</tr>
<tr>
<td>RS</td>
<td>Recommender System</td>
</tr>
<tr>
<td>SKE</td>
<td>Skill-Knowledge-Example</td>
</tr>
<tr>
<td>SKOS</td>
<td>Simple Knowledge Organization System</td>
</tr>
<tr>
<td>SMC</td>
<td>Study Program, Module or Course</td>
</tr>
<tr>
<td>STO</td>
<td>Semantic Tagging Object</td>
</tr>
<tr>
<td>TCP</td>
<td>TENCompetence Project</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
<tr>
<td>UOL</td>
<td>Unit of Learning</td>
</tr>
</tbody>
</table>
References

ACM.org (2016), The 2012 ACM Computing Classification System (CCS)
http://www.acm.org/about/class/class/2012


Dqr.de (2016), Deutscher Qualifikationsrahmen (2016)
http://www.dqr.de

DL.acm.org (2016), CCS 2012
http://dl.acm.org/ccs/ccs.cfm

Docs.moodle.org (2016a), Competencies – MoodleDocs
https://docs.moodle.org/31/en/Competencies

Docs.moodle.org (2016b), Competencies FAQ – MoodleDocs
https://docs.moodle.org/31/en/Competencies_FAQ

Docs.moodle.org (2016c), Competency frameworks – MoodleDocs
https://docs.moodle.org/31/en/CompetencyFrameworks

Docs.moodle.org (2016d), Learning plans – MoodleDocs
https://docs.moodle.org/31/en/Learning_plans

Docs.moodle.org (2016e), Competency Based Education – MoodleDocs
https://docs.moodle.org/dev/Competency_Based_Education

Ecompetences.eu (2016), European e-Competence Framework,
http://www.ecompetences.eu/

Edison-project.eu (2016), EDISON: building the data science profession|Edison Project
http://edison-project.eu/

Educause (2014), 7 Things you should know about Competency-Based Education

Ehea.info (2016), European Higher Education Area website 2010-2020| EHEA
http://www.ehea.info/
European Commission (2008), Explaining the European Qualifications Framework for Lifelong Learning

European Commission (2016a), European Credit Transfer and Accumulation System (ECTS) - European Commission
http://ec.europa.eu/education/tools/ects_en.htm

European Commission (2016b), Learning Opportunities and Qualifications in Europe - European Commission
https://ec.europa.eu/ploteus/search/site?f[0]=im_field_entity_type%3A97#

European Commission (2016c), Descriptors defining levels in the European Qualifications Framework (EQF) - Learning Opportunities and Qualifications in Europe - European Commission
https://ec.europa.eu/ploteus/en/content/descriptors-page

European Commission (2016d), Learning Opportunities and Qualifications in Europe - European Commission


Fernuni-hagen.de (2016), FernUniversität in Hagen: Fernstudium | Weiterbildung | Akademiestudien
http://www.fernuni-hagen.de/

Ftk.de (2016), FTK e.V. Forschungsinstitut fuer Telekommunikation und Kooperation
http://www.ftk.de/

Globit.com (2016), Ecosystem Portal | Globit

Hickey Daniel (2015), A Framework for Interactivity in Competency-Based Courses
http://er.educause.edu/articles/2015/8/a-framework-for-interactivity-in-competency-based-courses

Imsglobal.org (2016a), IMS GLC: Learning Design Specification
http://www.imsglobal.org/learningdesign/

Imsglobal.org (2016b), IMS GLC: Background
http://www.imsglobal.org/background.html
Johnstone Sally, Soares Louis (2014), *Principles for Developing Competency-Based Education Programs*, “Change Magazine”, March-April
http://www.changemag.org/Archives/Back Issues/2014/March-April 2014/Principles_full.html

Kluifhout Eric, Koper Rob (2010), *Building the technical and organisational infrastructure for lifelong competence development*, “Dspace.ou.nl”, 5 February

Koper Rob (2003), *IMS Learning Design*, Presentation at OU seminar, Milton Keynes, 24 September, Dspace.ou.nl
http://dspace.ou.nl/handle/1820/72

Lgmmia.fernuni-hagen.de (2016), http://www.lgmmia.fernuni-hagen.de/

Liferay.com (2016), *Liferay - Enterprise open source portal and collaboration software* - Liferay.com
http://www.liferay.com

Luminafoundation.org (2014), *Degree Qualifications Profile*

Luther Gaby (2005), *Der Bologna-Prozess und die Modularisierung*

Magna-charta.org (2016), *The Bologna Declaration of 19 June 1999 - Joint declaration of the European Ministers of Education*
http://www.magna-charta.org/resources/files/text-of-the-bologna-declaration

http://www.imsglobal.org/lti/ltilImplMGv2p0.html

Moodle.org (2016), *Moodle - Open-source learning platform* | Moodle.org
https://moodle.org/

Pellert Ada (2016), *Diversität, Lebenslanges Lernen und Digitalisierung - Konsequenzen für die Hochschulbildung. Konzeptentwurf zur Etablierung eines Forschungsschwerpunktes an der FernUniversität in Hagen*

Profiletool.ecompetences.eu (2016), *European eCompetence Framework*
http://profiletool.ecompetences.eu/
RAGE (2016), RAGE - Realising an Applied Gaming Eco-system  

Stiftung zur Akkreditierung von Studiengängen in Deutschland (2016), Akkreditierte Studiengänge – Zentrale Datenbank  
http://www.hs-kompass2.de/kompass/xml/akkr/maske.html

Tencompetence.org (2016a), TENCompetence | Building The European Network for Lifelong Competence Development  
http://tencompetence-project.bolton.ac.uk/

Tencompetence.org (2016b), The Personal Competence Manager v 2.0 | TENCompetence  
http://tencompetence-project.bolton.ac.uk/node/182/index.html

Tencompetence.org (2016c), TENCompetence Overview | TENCompetence  
http://tencompetence-project.bolton.ac.uk/node/181/index.html

Tencompetence.org (2016d), The TENCompetence Personal Competence Manager V1.0 | TENCompetence  
http://tencompetence-project.bolton.ac.uk/node/96/index.html


http://online-journals.org/index.php/i-jet/article/view/5108

Typo3.org (2016), TYPO3 - The Enterprise Open Source CMS  
https://typo3.org

Uml.org (2016), Unified Modeling Language (UML)  
http://www.uml.org/

Uni-leipzig.de (2016), UNCOVER: Mobil im Studium – Wie Bologna wechselwilligen Studenten den Weg versperrt  
http://www.unileipzig.de/journalistik2/index.php?id=143&tx_ttnews%5Btt_news%5D=436&cHash=c0ceb6b24a
Vogten Hubert, et. al. (2009), ID3.18 - Architecture Design Document, “Dspace.ou.nl”, 10 July
http://dspace.ou.nl/handle/1820/1983

Vogten Hubert, et. al. (2010), ID3.24 - Updated design for release 6.0 of the TENCompetence software, “Dspace.ou.nl”, 5 January
http://dspace.ou.nl/handle/1820/2258

W3.org (2015a), World Wide Web Consortium (W3C)
http://www.w3.org/

W3.org (2015b), SKOS Simple Knowledge Organization System - home page
http://www.w3.org/2004/02/skos

Oggi siamo abituati a sentir parlare di globalizzazione e di aperture tra i paesi, e tutti ci siamo adattati a pensare cittadini di una grande ma eterogenea nazione. Queste considerazioni spaziano tra tutti i settori coprendo, ovviamente, anche quello dell’educazione. Programmi di scambio durante gli anni universitari o una mobilità post laurea e lavorativa sono accessibili a tutti. Ancora oggi, però, una limitazione si incontra quando si confrontano programmi o curriculum anche dello stesso corso di studio, ma erogato in paesi diversi. Ancora più difficile è mettere in relazione un titolo di studio conseguito in un paese con quello di un altro. 

A porre rimedio a queste differenze è intervenuto il processo di Bologna che, tra le altre cose, mirava a definire una serie di parole chiave atte a identificare i corsi e a creare quello che si chiama il “Competence Based Learning”.

A distanza di anni, però, uno standard per le parole chiave ancora non esiste e, ancor peggio, questi identificatori vengono scritti in forma di testo libero non catalogabile da algoritmi informatici. Il lavoro qui presentato, evoluzione di un precedente pubblicato sempre su questa rivista, mira proprio a definire gli standard di un “Competence Based Learning Model” e di tutta l’architettura informatica che lo gestisce e lo rende utilizzabile. Inoltre, e a riprova della maturità della proposta, una prima versione di questo algoritmo è stata implementata su una piattaforma di Distance Learning proprio per testare, in un caso applicativo, vantaggi, svantaggi e problemi che dovrebbero, in un futuro vicino, contribuire ad abbattere le “frontiere della conoscenza”.