Ontology literature review as guidelines for improving Croatian Qualification Framework

K. Klarin*, I. Nazor* and S. Celar**

* University of Split/University Department of Professional Studies, Split, Croatia
** FESB, Split, Croatia

karmen.klarin@oss.unist.hr, igor.nazor@oss.unist.hr, stipe.celar@fesb.hr

Abstract – Development of information systems dealing with education and labour market using web and grid service architecture enables their modularity, expandability and interoperability. Application of ontologies to the web helps with collecting and selecting the knowledge about a certain field in a generic way, thus enabling different applications to understand, use, reuse and share the knowledge among them. A necessary step before publishing computer-interpretable data on the public web is the implementation of common standards that will ensure the exchange of information. Croatian Qualification Framework (CROQF) is a project of standardization of occupations for the labour market, as well as standardization of sets of qualifications, skills and competences and their mutual relations. This paper analysis a respectable amount of research dealing with application of ontologies to information systems in education during the last decade. The main goal is to compare achieved results according to: 1) phases of development/classifications of education-related ontologies; 2) areas of education and 3) standards and structures of metadata for educational systems. Collected information is used to provide insight into building blocks of CROQF, both the ones well supported by experience and best practices, and the ones that are not, together with guidelines for development of own standards using ontological structures.

Keywords – ontology, education, e-learning, Croatian Qualification Framework

I. INTRODUCTION

Communication between two or more dislocated information systems via web implies their ability to automatically interpret exchanged information. Use of ontology enables clear and unambiguous access to structured knowledge, while allowing enough freedom in conceptualizing and creating the final software product. [1] analyses the role of ontologies in the semantic web and the corresponding data structures, such as Linked data and Big data. Authors investigate advantages and problems of development of ontologies, their sharing and reuse, and analyze tools and techniques that enable their development and use. In general, ontologies are still not widely implemented in practical applications. Although there are differing opinions on the need to further implement them, there is a common agreement about the need for unanimous semantic, understanding and formal representation with the aim of connecting heterogeneous systems with large amounts of data.

CROQF (Croatian Qualification Framework) is based on EQF (European Qualifications Framework) and on QF-EHEA (Qualifications Frameworks in the European Higher Education Area). Main task of CROQF is to classify qualifications based on the criteria set for certain levels of learning achievements. The purpose is to integrate and coordinate national qualification systems and to improve transparency, accessibility, mobility, and quality of qualifications in relation to the market labor and civil society. It should allow effective integration of education programs and labor market requirements. One of the ways of linking labor markets and education systems is to provide support by a common language called ESCO (European Skills, Competences, Qualifications and Occupations taxonomy) standard [2], shown on Fig. 1.

ESCO should improve the exchange of information and enable cooperation between education systems, public and private job search platforms, as well as among different countries. ESCO standards should enrich and upgrade tools and applications so that they provide better options for compatibility, up-skilling and information exchange. A detailed breakdown and description of ESCO taxonomies are shown in the Chapter II and on Fig. 3.

This paper analyses the research done in the last decade in the area of application of ontologies to e-learning and education systems. Analyzed papers were identified among publicly available resources by keywords: ontology, e-learning and education. A total of 33 publications and papers (30 in journals and 3 conference papers) were analyzed. From the overview of analyzed papers by year, shown on Fig. 2, one can conclude that the subject of ontologies in education has been continuously researched.

Chapter II describes the three dimensions used for classification of papers: purpose and coverage with basic
functionality of education system, ontology content for education system and application scenarios of ontology implementation. An overview of all papers with a summarized description of ontology content with purpose and coverage of these ontology in education systems is shown in Chapter III. An overview of papers according to application scenarios of ontology implementation, as well as purpose and coverage of these ontologies in education is given in Chapter IV. Chapter V concludes our analysis and emphasizes the problem of lack of basic concepts, such as learning outcomes, which connect the labor market system with the education system.

II. CLASSIFICATION

Our domain of interest is the education ontology cluster (shown on the left-side of Fig. 1). The analysis of papers was performed over the following dimensions (main topics): Purpose and coverage, Content and Application scenarios [3] [4] [5] [6].

A. Purpose and coverage

What is it for? The purpose of ontologies covering e-learning systems can be classified according to the following characteristics [3]:

- **Curriculum modelling and management** covers institution’s processes and organization for development, design, and implementation of each degree program’s organization, structure, content, assessment of outcomes, and pedagogy.

- **Describing learning domains** incorporate subject-domain ontologies (providing substance for learning process) and task ontologies (activities, exercises, case studies, projects, simulations, and assessment items).

- **Describing learner data** is related to an individual learner (learning profile, completed content and performance data).

- **Describing e-learning services** - collaboration between heterogeneous e-learning systems. Ontologies are used for searchable, accessible, and sharable learning resources (services such as IEEE LOM, Dublin Core, and SCORM).

B. Content

What is in it? Fig. 3 shows detailed set of ontologies from Fig. 1, their connections and applied standards (taxonomies). According to ESCO interoperability map [4] and main relationships and classifications from [5] the following domains were identified:

- **Education Ontology** includes information about levels and fields of education. Fields of education are based on FOET (Fields of Education and Training) taxonomy and level of education on standard ISCED (International Standard Classification of Education).

- **Competency Ontology** defines the proven ability to use knowledge, skills and personal, social and methodological abilities. ESCO defines DigComp (Digital Competence Framework) which provides a vocabulary of digital competences at the European level.

- **Knowledge Ontology** contains the body of facts, principles, theories and practices that is related to a field of work or study (e.g. CS2013 – Computer Science Curricula 2013, from [https://dl.acm.org/citation.cfm?id=2534860](https://dl.acm.org/citation.cfm?id=2534860)).

- **Skills Ontology** defines the ability to apply knowledge and use know-how to complete tasks and solve problems. The task of CROQF is to define the National skills classification.

- **Qualification Ontology** is described in terms of knowledge, skills, responsibility and autonomy and should be attainable though a variety of educational and career paths.

- **Occupation Ontology** includes information about occupations and workplaces. An integral part of this ontology is ISCO (International Standard Classification of Occupations). Occupation ontology is outside of this paper’s scope.
C. Application scenarios

How do ontologies help? Four main categories of ontology application scenarios are given in [6], showing a wide range of ontology representations, from semantically lightweight to semantically rich ones, such as:

- Neutral ontology for authoring, where individuals develop their own ontologies for authoring operational data with different applications. Individual organizations or companies use ontologies as translators for various proprietary software systems.

- Ontology as specification, domain-specific ontology created to be implemented manually or by partially-automated software tools. This level of ontology application automates documentation, maintenance, reliability, knowledge use and reuse.

- Common access to information, where ontology information is used by multiple agents, as a mutually agreed basic standard for information conversion and mapping, thus facilitating interoperability and effective knowledge (re)use.

- Ontology-based search, where an ontology is used by a structuring device (e.g. search engine) as information repository allowing better access to information. This ontology application scenario allows using the same ontology for multiple systems as a way of concept-based structuring of information.

D. Two types of analyses

The analysis is performed by grouping the available literature according to the topics covered, in relation to the topics (dimensions) of interest:

1. Purpose and coverage in relation to Content (Chapter III with Table 1), and
2. Purpose and coverage in relation to Application scenarios (Chapter IV with Table 2).

During the both analysis a special focus was placed on Curriculum modelling and management, and Describing e-learning services, which are parts of Purpose and coverage dimension, as well as the main functionalities of processes implemented within the CROQF.

Skills, Competences and Qualifications ontologies, which belong to dimension Content, are integral parts of both the ESCO and the CROQF standards, so the research results that include these ontologies are a valuable asset that can be used for development of CROQF.

Furthermore, the knowledge about Application scenarios of ontology implementation obtained from researched papers can be used to provide insight into the building blocks of CROQF.

III. Purpose and coverage vs content

Table 1 show frequency of articles according to the two main topics covered (dimensions), each shown as a hierarchy of characteristics. The hierarchies contain a relatively large number of characteristics in order of their influence to be quantified as precisely as possible during the phase of analysis. One paper’s scope may cover more than one characteristic, therefore the same reference may be found in more than one place within a single table.

As shown in Table 1, ontologies Knowledge and Education are mentioned in a large number of papers (30 of 33 papers analyzed), as opposed to Skills, Competences and Qualifications, mentioned in only 11 papers, and consequently researched to a lesser extent.

Ontology-based system for educational and Curriculum modelling and management [22] [36] with semantic repository and predefined semantic queries. An approach to achieve optimal sequence of learning the contents of a course and taking tests is researched in [19]. In [25] a technique for developing an individualized learning path that meets user’s requirements is described. It uses revised Bloom’s taxonomy to specify concepts of a domain ontology: courses, lessons and their sequences. Besides development process of an educational ontology [32] emphasizes the importance of specifying competences in terms of learning outcomes. A semantic web-based system, Gescur [22] [24], is used for managing the education curriculum, data about institutions, knowledge areas and subjects.

A Java ontology integrated toolkit, used to create an ontology-based application that specifies the Describing learning domain is described in [26]. Development of an ontology-based e-learning support system [7] [30] [35] includes specification of curriculum, syllabus and subject ontologies, as well as discovery and sharing of knowledge based on subjects’ ontology (teachers and students). [24] demonstrates the use of semantic web system Gescur for improvement of education process quality. An intelligent approach to compose optimal learning groups with members having different domain backgrounds is described in [13]. [34] deals with interoperability problem and ontology mapping between educational domains elements (syllabus, courses, materials, exams) and pedagogical resources. Modeling of a particular knowledge area with concept maps was created by experts and with the guidance of teacher judgment in [39]. In [8] and [27] authors define the main knowledge domain concepts and relations in form of graphs, maps or

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<td>Skills Ontology</td>
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<td>Qualification Ontology</td>
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An ontological representation of cognitive skills is described in [10].

Educational domain modelling and Describing learner data in [8] are a basis for personalized e-learning. A method for tracking students’ active learning and self-leading learning is proposed in [7] and [12]. Ontology-based e-learning systems [16] [28] make adaptations and improvements to the learning process by analyzing students’ learning performance and courses’ ontology. Knowledge-based systems which assists learners in achieving desired knowledge and goals are described in [13] [15] and [19]. A domain ontology offers learners a personalized choice of registered courses and materials [21] [25] [37], in order to achieve personalized competences. To improve the content and structure of personalized course knowledge [14] [23] use ontology-based metadata for describing both the entire domain and specific learning objects.

Metadata standards of the Describing e-learning services domain, such as LOM, Dublin Core and SCORM, are used to develop different educational systems: PASER system [9] supporting educational process; GrEd [17] used for education in Greece; LO management model [18] used to find correlation between learning styles and LO characteristics; SMILE system [20] enabling semantic ontology mapping for interoperability of learning resource systems, and a framework for building an adaptive Learning Management System [21]. MOODLE system is used in [33] to classify learning objects and to develop modern semantic learning management system. Education objective metadata repository in [9] provides a system-wide consistent competency vocabulary. [11] and [23] describes e-learning at the workplace and link between learning and work performance, as well as the communication between individuals.

An overview of papers frequency across the Content dimension hierarchy (shown on the left side of Fig. 4) shows that a large number of papers cover the Knowledge and Education ontologies, specifically their following elements: syllabus, courses, materials, exams, and pedagogical resources. On the other hand, Competency, Skills and Qualification ontologies, relevant to CROQF, are covered in a small number of papers. The breakdown across functionalities Curriculum modeling and management and Describing e-learning services, which are relevant to CROQF (right side of Fig. 4), shows the same trend.

The experiences gathered from the current research on the education systems are a valuable reference for the task of designing basic concepts of CROQF. The ontologies that not adequately researched should be developed from the beginning, from conceptualization to formal application.

### IV. PURPOSE AND COVERAGE VS APPLICATION SCENARIOS

Regarding different application scenarios, which can be divided according to the level of maturity of implementation of ontologies, lower levels of maturity have received a greater focus. As shown in Table 2, scenarios Neutral ontology for authoring and Ontology as specification, representing lower levels of maturity, have been researched in 22 papers, as opposed to Common access to information and Ontology-based search, which were mentioned in 14 papers.

Curriculum modeling and management is presented in [22] [25] [32] [36] as conceptualization of education ontology. In [24] ontology structure is used by Gescur web–based system to execute semantic queries. [33] presents the design of curriculum ontology and syllabus ontology in detail with implementation of mapping rules with the aim of connecting different entities that contain different formats of syllabi. Web applications in [17] and [19] use ontologies to: define vocabularies, share common

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understanding of information structure among people or software agents, and enable reuse of domain knowledge.

Describing learning domains by conceptualizing educational knowledge structure, resulting in concept maps, is given in [32] [35] and [39]. Domain-specific ontology is created for adaptive learning path implementation [7] or for multidisciplinary learning group composition [13] [14] and [34]. Knowledge and content structuring, using collaborative ontology design methods, is presented in [27]. In [25] and [26] the ontology of student activities is designed to store information about their learning process and results. An agent platform, described in [12], supports various personalization levels by using machine-understandable representations of educational domains and learners’ characteristics.

An approach to learning where learning objects are based on students' specific needs results in them developing a unique learning style. Describing learner data [23] [25] [39] deals with determining, managing and monitoring such learning objects, as well as tracking students' time spent learning different content. In [13] authors propose a flexible e-learning self-evolving system, so that enrolled trainees can become trainers at the end of the process. [10] [19] and [28] describe different ontology-supported methods of processing contents of e-learning systems. Improved methods of student assessment during learning process used by educators are described in [12] [14] [16] and [37]. Results of assessment can be used to adjust syllabus concepts, such as body of knowledge and area/unit of knowledge taxonomies.

Describing e-learning services using [23] ontology and LOM standard to create a concept tree of learning objects and detect the student’s previous knowledge level. Application of semantic web techniques to services of e-learning system, such as searching context relevant learning resources by means of decision trees and ontology mapping, are described in [18] and [33]. An ontology-based learning management system was used to manage e-learning knowledge in [31], [9] and [21] present intelligent systems with ontologies, metadata repositories and knowledge-based modules that use queries and reasoning on learning metadata.

An overview of papers frequency across the Application scenarios dimension hierarchy (shown on the left side of Fig. 5) shows that a large number of papers cover Neutral ontology for authoring and Ontology as specification, which shows that the current research is focused on specification and conceptualization of subject-domain ontology. From the perspective of CROQF-related ontologies, such results are encouraging, because they constitute a solid basis for their development. A small number of papers that covered Common access to information and Ontology based search, points out the complex task of ontology development, implementation, use and reuse. The breakdown across functionalities Curriculum modeling and management and Describing e-learning services, which are relevant to CROQF (right side of Fig. 5), shows the same trend. Consequently, work on the CROQF will be a demanding and long-lasting job.

V. CONCLUSION

The main recommendation for the process of establishment of EQF and national qualifications, CROQF in our case, is for them to be related to learning outcomes. Development of a methodology for description, use and application of learning outcomes has the aim of increasing transparency, understanding and comparability of qualifications. Web technology and ontology-based systems can ensure semantic interoperability between characteristics used to describe learning outcomes, such as skills, competences and qualifications, which would help to reduce the communication gap between EU countries and between domains of employment, education and training.

The research described in this paper is focused on ontology-based systems in education. Literature is analyzed with respect to two aims: representation of ontologies relevant to CROQF (Skills, Competences and Qualifications), and maturity of ontology-based software implementation.

Analyzed papers, as expected, contain many references to the Education and Knowledge ontology which support the learning process. However, the most important aim of the education process, learning and learning outcomes, and the appurtenant ontologies Skills, Competences and Qualifications, are researched to a much lesser extent. They represent an upgrade of the e-learning process and a connection with learning outcomes and qualifications. Their further analysis is recommended, as well as research into the possibilities of their implementation in both the CROQF and EQF.

For maturity of ontology-based software implementation, majority research is focusing on low-level ontology implementations, such as modelling of interest domains, and less on a holistic approach aimed at integrating heterogeneous systems and achieving their interoperability. In addition to further research ontology-based systems and their application to CROQF, additional

Figure 5. Frequency of articles for Purpose and coverage dimension in relation to Application scenarios dimension

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work should be done developing web services and applications for facilitating interoperability and effective knowledge use and reuse.

REFERENCES


