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Julia V. Rogushina
Ph.D. in Information Technology, Associate Professor, Senior Researcher
Institute of Software Systems of the National Academy of Sciences of Ukraine, Kyiv, Ukraine
ORCID ID 0000-0001-7958-2557
ladamandraka2010@gmail.com

Serhii M. Pryima
Doctor of Pedagogical Sciences,
Associate Professor, Professor at Department of Pedagogy and Pedagogical Skills
Melitopol Bohdan Khmelnytsky State Pedagogical University, Melitopol, Ukraine
ORCID ID 0000-0002-2654-5610
pryima.serhii@gmail.com

DEVELOPMENT OF METHODS FOR SUPPORT OF QUALIFICATION FRAMEWORKS TRANSPARENCY BASED ON SEMANTIC TECHNOLOGIES

Abstract. The urgency of the integration of national and European qualification frameworks for the comparing of learning outcomes for different countries is grounded. Theoretical research in this area and the tools that are built on them are analyzed. The approaches to harmonization of the National qualification framework of Ukraine with the European qualification frameworks and problems dealing with their practical use are considered. The necessity of the development of software tools oriented on comparison of these qualification frameworks based on the Semantic Web technologies is reasoned. In this work the use of ontologies for representation of learning outcomes and the Semantic Wiki technologies for structuring of the relevant information resources is proposed. A theoretical model and an algorithm for matching ontologies with Wiki-resources that enable dynamic replenishment of these ontologies and comparison of various information objects are developed. A software implementation of the proposed approach is realized.

Keywords: Qualification Framework; ontology; Wiki.

1. INTRODUCTION

Eurointegration aspirations of Ukraine, balancing of national interests, the education market and the labor market, improving the quality and effectiveness of training, on the one hand, and globalization processes dealing with technology and economy, labor mobility, on the other hand, require the development and implementation of a national system of qualifications. Based on the results of learning, National qualification system will not only provide the transparency of education documents but will become a catalyst for modernization of education and expand an access to qualifications. National qualification system presupposes implementation of the National Qualifications Framework (NQF) [1] harmonized with the European Qualifications Framework (EQF) - a reference tool for comparison of qualification levels of various national qualification frameworks. NQF will facilitate understanding of national qualifications in a diversity of national education systems.

NQF of Ukraine becomes an instrument for three major goals:

– rise of relevance of qualifications to labor market needs;
– integrity and harmonization of the qualification system;
– transparency of qualifications.

In addition, NQF offers the set of descriptors of learning outcomes used to develop / upgrade qualifications.

NQF needs the mechanisms to compare the development of its qualification levels with the EQF levels for understanding and common vision of transparency.

NQF as well as EQF is oriented towards formalized descriptions of something that person knows, understands and is able to do. These properties can be represented by learning outcomes. NQF includes four categories: *knowledge*, *skills*, *communication*, *autonomy* and *responsibility* that deal with learning outcomes and are divided into 10 levels.

Each of these levels is characterized by description of "integrated competence" – combination of knowledge, skills, communication, autonomy and responsibility that describes the degree of ability to act in various situations of study or work.

Descriptions of levels can be used as a common reference framework for comparison, classification, recognition and development of qualifications. In the context of qualification frameworks such descriptions can be used for development of the standards of person's abilities as an outcome of learning.

The research of modern tools for representation and analysis of knowledge that can be used to ensure the transparency of the NQF shows that development of models and methods for integration of these tools with existing formalized descriptions of qualifications is a topical and timely research task.

Analysis of recent research in the scope of comparison of qualification systems. Now problems of analysis and comparison of learning outcomes and comparison of different qualification systems have considerable theoretical basis. These problems attract great attention of domestic and foreign researchers. Such interest is explained by the diversity of approaches to creating and approving qualification frameworks of different countries oriented towards the transition to the knowledge society [2]. Theoretical aspects of NQF implementation are now being actively discussed by the academic community of Ukraine [3-6]. It is advisable to take into account the experience of the European and national qualification frameworks and use their learning outcomes and competencies [7]. The purpose of this analysis is the development and implementation of new educational standards as the basis for transformation of learning programs and other system components of educational process by integration of learning and research activities [8].

Partial implementation of NQF levels comparing and matching methods is proposed in [9]. A tool developed by DISCO II project (the European DIctionary of Skills and COmpetences) EC (http://disco-tools.eu/) provides a comparison of learning outcomes and matching of documents deal with qualifications, but it is focused on a limited list of domains only, and the continuation of this project is restricted by code secrecy. Interactive tables from the portal of the European Commission (http://ec.europa.eu/eqf/ compare_en.htm) help to match levels of the European and national qualification framework but do not allow to analyze the semantics of the qualification levels and to match educational and professional qualifications.

The project TRACE (TRAnsporentCompetenceinEurope) is also aimed at transparency of EQF and national frameworks of EU countries: computer ontologies connect information objects (IOs) related to educational and professional qualifications. However, educational qualifications are based on the curriculums while the national educational qualifications are based on industry education standards that complicate determining of qualifications.

Another promising direction of matching qualification levels to ensure the transparency of European and national qualification frameworks uses the standards of competence description RCD (Reusable Competency Definition) and SRCM (Simple Reusable Competency Mapping). But these standards do not process the semantics of competencies.

All above-mentioned approaches are oriented on processing of NQF and EQF for particular cases and specific needs but are not suitable as a universal competence matching instrument for transparency of the European and national qualification frameworks.

The main problem of these approaches lies in the impossibility of automated processing of natural language descriptions of qualifications and learning outcomes even within a single framework of qualifications. If these descriptions belong to different frameworks, their comparison is complicated further because of terminological and classification differences. Therefore, we need a data representation model that formalizes the semantics of these categories for their automated analysis and retrieval by intelligent information systems [10].

Problem statement. The purpose of this study consists in creation of methods of application of modern semantic technologies to support the transparency of qualification frameworks. On the basis of analysis of task specifics we select ontological knowledge representation that formalizes semantics of learning outcomes and related IOs. Ontological analysis ensures the sufficient expressiveness and reuse of knowledge. Ontologies are accompanied by various tools for knowledge analysis and acquisition. Wiki-technology is used for representation and processing of information resources (IRs) that contain information about these IOs because Wiki provides open and distributed processing of the natural language IRs.

We transform the transparency problem to matching of IOs dealing with learning outcomes and competencies that are represented by Wiki pages semantically marked by the elements of domain ontology. Therefore, we need methods and software tools for such matching.

This task solving requires:

- developing a reference ontological model of national and European qualification frameworks that formalizes knowledge about basic IOs and the relationship between them;
- proposing the appropriate theoretical apparatus for comparison of IOs represented by this ontology;
- researching the ways of converting natural language documents related to different qualification frameworks into the semi-structured IRs based on semantic Wiki-technologies;
- developing the method that matches elements of Wiki-resource with elements of the ontological model of qualification frameworks.

2. METHODS OF RESEARCH

To achieve the goal of this research the theoretical and practical methods were used. Theoretical methods relating to intelligent information technologies include the ontological analysis, elements of systems analysis, set theory, elements of mathematical modeling, linguistic analysis, and mathematical logic. These methods are used for domain knowledge processing. Practical methods involve the use of modern information technologies - standards and languages of knowledge representation developed by the Semantic Web project.

3. RESULTS

Semantic Web as a tool for research of qualification frameworks. Semantic Web offers a powerful practical approach to management of knowledge and information services [11]. It offers a lot of open information standards, methods and software for these purposes [12]. The main components of the Semantic Web are *ontologies* [13], *services* and *software agents*. Today the Semantic Web project is in progress, new language and standards of distributed knowledge processing and improving of existing ones are generated. Therefore, it seems reasonable to focus on these Semantic Web results and to create intelligent methods and software that can effectively use the benefits of the new semantically enriched information environment.

Now researchers consider ontologies to be the effective means for modeling that provide formal representation of their domain semantics. A formal ontology model contains concepts that are subdivided into classes and instances, relations between them and interpretation functions of these concepts and relationships. Such models are widely used for interoperable distributed knowledge representation, allowing to reflect different aspects of the real world [12] but can be defined more exactly according to specifics of domain and/or task.

Fundamental domain concepts correspond to classes of ontology. Ontological instance can be determined by declaration as a member of a class. The properties of instances enable to assert general facts and relations. The properties as well as classes can be arranged hierarchically.

For the goals of this research work we propose the following formal model:

$$O = \langle X, R, F, T \rangle \tag{1}$$

This model consists of the following elements:

- ✓ $X = X_{cl} \cup X_{ind}$ is a set of concepts of ontology, where
  - – X_{cl} is a set of classes,
  - – X_{ind} is a set of classes such as $\forall a \in X_{ind} \exists A \in X_{cl}, a \in A$;
- ✓ $R = r_{ier\_cl} \cup \{r_i\} \cup \{p_j\}$ is a set of relations between elements of ontology, where
  - – r_{ier_cl} - the hierarchical relations that can be established between ontology classes and class properties and is characterized by such properties as transitivity and antisymmetry, $r_{ier\_cl} : X_{cl} \to X_{cl}$;
  - – $\{r_i\}$ is a set of object properties that establish the relationship between instances of classes: $r_i(a, a \in X_{ind}) = b, b \in X_{ind}$, $r_i : X_{ind} \to X_{ind}$;
  - – $\{p_j\}$ is a set of the properties of the data that define relations between instances of classes and values: $p_i(a, a \in X_{ind}) = t, t \in T$, $p_i : X_{ind} \to Const$ such that within the set of object properties and properties of relations the specific hierarchical relations also can exist r_{ier_obj}, $r_{ier\_obj} : \{r_i\} \to \{r_i\}$ and r_{ier_data}, $r_{ier\_data} : \{p_j\} \to \{p_j\}$;
- ✓ F is a set of characteristics of ontology classes, instances and their properties that can be used for inference (equivalence, difference, disjointness, domain and range);
- ✓ T is a set of data types (string, integer).

The choice of such ontology model for this task is due to the following reasons. First, this model has sufficient expressiveness to solve problems dealing with learning outcomes and competencies. Second, it corresponds to the intuitive notion about ontologies represented by the user interface of Protégé ontology editor and therefore this model is easily combined with visualization of ontology elements in this software product. Thirdly, integration of this model with a variety of intelligent applications that support semantic processing of information (for example, with semantic Wiki-resources and with lexical ontologies) is quite simple.

Semantic Wiki is one of promising technologies of the Semantic Web. It is based on the famous Wiki-technology that provides distributed and open processing of the Web information resources and allows users to edit content pages [13]. The information in Wiki has a non-linear navigation structure and contains hyperlinks to other resources. There are many different platforms for creation and maintaining of the Wiki-resources that provide information semantization. For example, Semantic MediaWiki (SMW) is an intelligent extension of MediaWiki. It allows users to add semantic annotations to the Wiki-pages and transform MediaWiki into the semantic resource. This software uses the markup elements as semantic properties (for data creating) and semantic queries (for data usage). Semantic Wiki-resources are easily integrated with relevant domain ontologies: elements of ontology can be used as a basis for the hierarchy of categories in the Wiki, and advanced ontology can be generated by the knowledge of semantic markup of the Wiki-pages set.

Wiki-ontology is an ontology constructed on the basis of semantically marked Wiki-resource. Knowledge contained in this ontology is directly obtained from semantic markup of Wiki pages. Therefore, this ontology does not contain, for example, such characteristics of classes and properties as equivalence or disjointness. Formal model of Wiki-ontology is a special case of formal model (1):

$$T_{wiki} = \langle X, R, \varnothing, T \rangle \quad (2).$$

In this model, a set of concepts is constructed as a combination of such Wiki elements as the pages and categories $X = X_{wiki\_categor} \cup X_{wiki\_page}$ related by various types of relations from $R = \{r_{ier\_cl}\} \cup \{r_{link}\} \cup \{r_{sem\_prop}\}$:

- ✓ a set of ontology classes is a set of Wiki categories $X_{wiki\_categor}$ and these categories are linked by hierarchical relations;
- ✓ a set of instances is a set of Wiki-pages connected by links r_{link} and by semantic properties $r_{sem\_prop_i}, i = \overline{0, m}$;
- ✓ a set of data types is complemented by the specific class – "Wiki-page."

This model can be upgraded with such Wiki elements as templates, forms, special pages etc.

Matching of ontologies and semantic Wiki-resources. Transparency of qualification frameworks requires semantic matching of such IOs as competencies and learning outcomes represented by various terms, natural language descriptions and classification systems.

The solution of this problem includes the matching of relevant domain ontologies and semantic Wiki-resources. Content of Wiki-resources and ontologies that reflect the same domain use formalisms with different expressiveness. These formalisms strongly vary one from another by user intelligibility. Ontology is a much more powerful instrument of knowledge representation, analysis and processing based on descriptive logic supported by a variety of tools and standards. However, ontological analysis can be executed only by users with sufficient qualification in knowledge management. Semantic Wiki-technologies support markup of information at the knowledge level and the creation of complex semantic queries (with limited expressiveness) [15] accessible for a wide range of users. Semantically marked Wiki-resources are much more dynamic and relevant compared to ontologies because their improvement and restoration is realized by many people, so information in Wiki can be useful to improve the relevant domain ontology. Therefore, it is advisable to integrate both approaches to effectively use their advantages to solve practical problems.

Before creating semantically enriched Wiki-resources we need to form the complete and noncontradictory system of categories and semantic properties. But built-in tools of the Semantic MediaWiki do not allow to analyze this information. Therefore, we propose first to build ontology of domain displayed in Semantic MediaWiki (with the help of Protégé or any other ontology editor), and then use this ontology (in this case - a reference ontology of competencies) as a basis for semantic markup of Wiki-pages.

If we want to use the domain ontology for markup of the Wiki pages then we need the matching of correspondence between elements of this ontology and elements of the Semantic MediaWiki pages. Some of these matchings are mutually unambiguous and can be detected automatically, bur some other require additional clarification from the user. For more rigorous description of these correspondences we use formal models (1) and (2).

Domain ontology class corresponds to category of the Semantic MediaWiki $P_{categ} \to X_{cl}$. But ontology class can also correspond to templates and forms. So, this mapping is single-valued from Wiki to ontology but multivalued from ontology to Wiki.

The hierarchy of categories of Semantic MediaWiki is associated with hierarchy in the domain ontology. For example, if the Semantic MediaWiki has a special page called "Category: Competence_management», then it corresponds into the domain ontology to class «Competence_management».

Wiki-page corresponds to ontology individual but the same page can be associated with several different individuals of ontology (usually of different classes), so that in many cases an individual of ontology is associated directly with a particular part of Wiki-page. Therefore, we have multivalued matching $P_{user} \to X_{ind}$ from ontology to Wiki and single-valued mapping from Wiki to ontology $X_{ind} \to P_{user}$. For example, if the Wiki page description contains the text [[Category: competence_management]] then this page corresponds to ontology instance from class «competence_management».

Links to other Wiki-pages are single-valued and uniquely correspond to the object properties with a fixed ontology name: $L = \{"link"\} \to R$; $R \to L = \{"link"\}$. For example, if the description of the Wiki page contains the text [[Atomic competence]] (link to the "Atomic competence" without specifying the link semantics) then the relevant ontology individual has object property with type "link" and value "Atomic competence".

Semantic properties of the "page" type in Semantic MediaWiki have single-valued correspondence to object properties of ontology with appropriate names: $P_{sem\_prop\_page} \to \{r_i\}$; $\{r_i\} \to P_{sem\_prop\_page}$. For example, if the page description contains the text [[competence_management :: Eqf | EQF]] (link to page «Eqf» which semantically relates to this page as «competence_management») then the ontology instance relevant to this page has the object property with type «competence_management» and value «Eqf».

Semantic properties of any other type of Semantic MediaWiki map one-to-one to appropriate data properties in the ontology: $P_{template} \to X_{cl}$; $X_{cl} \to P_{categ} \cup P_{template}$.

Thus, if we have OWL domain ontology it can be easily used for Semantic MediaWiki building. But the reverse process cannot be fully automated. Moreover, the automatic generation of ontologies on the basis of the Semantic MediaWiki causes the loss of information about the characteristics of classes and properties contained in OWL-ontology. It deals with ontology elements that have non-Wiki analogs (especially on the equivalence of classes and properties, presence or absence of intersection, domain and range). At the same time, some part of the Semantic MediaWiki content cannot be directly transformed into ontology. For example, the fact that the pages use the same pattern indicates that these pages describe the IOs of the same type but ontology can show it only by creation of the specific class associated with these pages. In this case we cannot understand by this ontology what we need to create into the Wiki - pattern or category: this choice depends on the user because we create templates for IOs with specific and well formalized structure, and we create Wiki pages assigned to relevant category for IOs of all other cases. In addition, we can associate with a ontology class the entire page only and not its specific fragment.

Because of the nature of the analyzed problem of competence management [14] we need to develop ontological Reference Model of Qualification Framework (RMQF) and to mark up semantically relevant Wiki-resource, and then implement the knowledge exchange between them.

Ontological Reference Model of Qualification Framework. In order to build RMQF we analyzed natural language descriptions of national and European frameworks to identify those IOs and their properties that are typical for most of these approaches and to take into account experience of ontology use for competence analysis [16].

RMQF determines the semantic properties and relations of IOs related to learning outcomes (pic.1). RMQF classes match with IO classes of this domain. RMQF formalizes the relationship between IOs and establishes their hierarchy. This model is described by OWL Light language and can be visualized by means of ontology editor Protégé. OWL Lite (as well as OWL DL and OWL 2.0) is based on descriptive logic ALC (Attributive Language with Complements) which guarantees the finite logical conclusion on this ontology. RMQF describes properties of these classes (object properties and data properties) and the relations between the basic domain terms and their subclasses. Classes in the model data are combined into groups and subgroups of different levels depending on the domain specifics [10]. Individuals of different RMQF classes are linked by different object properties. Object property of association does not have additional restrictions (such as transitivity, symmetry, etc.) and therefore does not reflect the additional semantics allowing its representation by OWL Light. In addition, RMQF uses semantically loaded object properties such as "requires preliminary study", "based on the level of education" and others that may have additional restrictions.

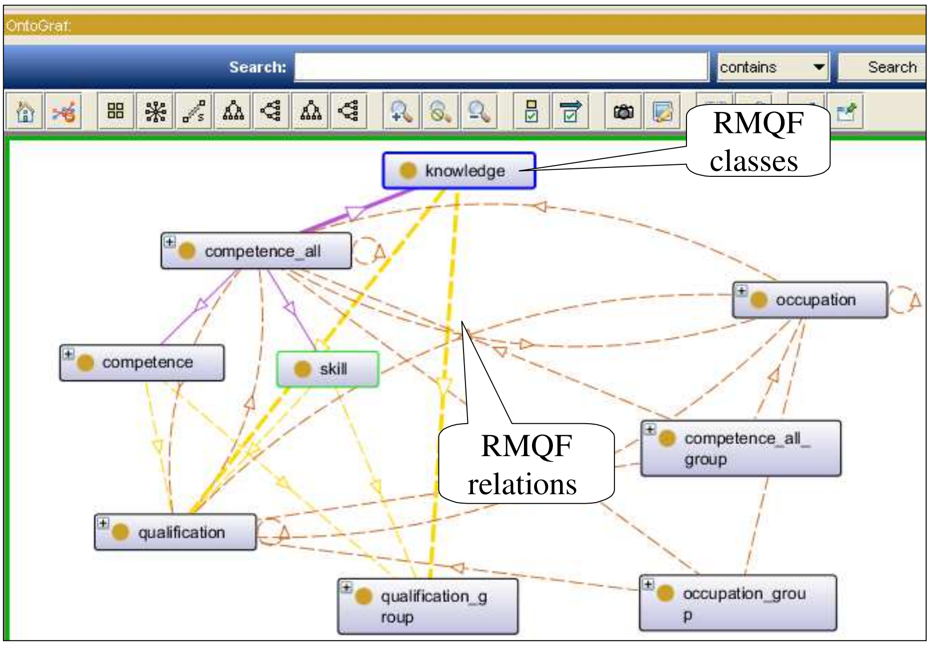

Figure 1. RMQF main classes and relations visualized by Protégé plugin Ontograf

Each IO instance $x \in X$ can be represented as $\left\langle \left(r_{obj_i}, \{x_k\}\right), \left(r_{data_j}, \{d_m\}\right) \right\rangle$, where

– r_{obj_i} – object properties of domain ontology;

– r_{obj_i} – data properties of domain ontology;

– x_k – instances of IO classes;

– d_m – constants of different types.

Each r_{obj_i} can be considered as $r_{obj_i} : \{X_{in_{i_1}}, ..., X_{in_{i_k}}\} \to \{X_{out_{i_1}}, ..., X_{out_{i_m}}\}$: domain and range are defined for all object properties as the IO subsets.

Besides IOs which are traditional for qualifications frameworks we suggest using an additional IO class – *atomic competence* [17] that is appointed for matching individuals of different IO classes by estimation of their semantic proximity. Each competency can be represented as a union of atomic competencies $\forall c \in C \exists a_i \in C_{atomic}, i = \overline{1, n}, k = \bigcup_{i=1}^{n} a_i$; and every atomic competence is not a subset of another atomic competence $\forall a, b \in C, a \subseteq b \Rightarrow b \notin C_{atomic}$. For each competency $c \in C$ there is one and only one set of atomic competencies.

Object properties of different classes RMQF belong to class "atomic competence", and it allows to match semantically their instances.

RMQF use automates the processing of information related to learning outcomes by integrating competence knowledge. This ontology helps to make and perform appropriate queries. RMQF ontology population by information about new IO instances requires specific skills from the sphere of ontological analysis. This problem can be solved with the help of Wiki resources that are semantically labeled by RMQF elements and methods of their analysis described above.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

As a result of this research the following results are obtained:

– on the basis of the analysis of national and European qualification frameworks ontological reference model of qualification framework that formally defines the basic domain concepts and the relations between them was built;

– theoretical basis for matching of IOs related to learning outcomes and associated with different sets of atomic competencies is developed;

– the method of integration of ontological model of qualification frameworks with the technological platform of Semantic MediaWiki is proposed.

Prospects for further research in selected sphere are associated with the implementation of prototype information system of intelligent and cognitive support of qualification framework transparency. This system would promote national and international recognition of qualifications acquired in Ukraine and establish effective interaction in the sphere of educational services and the labor market. This work requires improving the ontological basis of the system and replenishing of relevant Wiki-resources.

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РОЗРОБКА МЕТОДІВ ПІДТРИМКИ ПРОЗОРОСТІ РАМОК КВАЛІФІКАЦІЙ НА ОСНОВІ СЕМАНТИЧНИХ ТЕХНОЛОГІЙ

Рогушина Юлія Віталіївна
кандидат фізико-математичних наук, доцент, старший науковий співробітник
Інститут програмних систем НАН України, м. Київ, Україна
ORCID ID 0000-0001-7958-2557
ladamandraka2010@gmail.com

Прийма Сергій Миколайович
доктор педагогічних наук, доцент, професор кафедри педагогіки і педагогічної майстерності
Мелітопольський державний педагогічний університет імені Богдана Хмельницького,
м. Мелітополь, Україна
ORCID ID 0000-0002-2654-5610
pryima.serhii@gmail.com

Анотація. Обґрунтовується актуальність інтеграції національних і Європейської рамок кваліфікацій для співставлення результатів навчання у різних країнах. Проаналізовано теоретичні дослідження у цій сфері й інструментальні засоби, що побудовані на їх основі. Розглянуто підходи, за якими Національна рамка кваліфікацій України має узгоджуватися з Європейською рамкою кваліфікацій, і проблеми, що виникають в процесі її використання на практиці. Обґрунтована необхідність створення інструментальних засобів, що базуються на технологіях Semantic Web, для зіставлення рамок кваліфікацій. У публікації запропоновано використовувати онтології для представлення результатів навчання і семантичні Wiki-технології для структурування відповідних інформаційних ресурсів. Розроблена теоретична модель й алгоритм співставлення онтологій і Wiki-ресурсів, які дозволяють динамічно поповнювати онтології і зіставляти інформаційні об'єкті, що описані в них. Створено програмну реалізацію запропонованого підходу.

Ключові слова: рамка кваліфікацій; онтологія; Wiki.

РАЗРАБОТКА МЕТОДОВ ПОДДЕРЖКИ ПРОЗРАЧНОСТИ РАМОК КВАЛИФИКАЦИЙ НА ОСНОВЕ СЕМАНТИЧЕСКИХ ТЕХНОЛОГИЙ

Рогушина Юлия Витальевна
кандидат физико-математических наук, доцент, старший научный сотрудник
Институт программных систем НАН Украины, г. Киев, Украина
ORCID 0000-0001-7958-2557
ladamandraka2010@gmail.com

Прийма Сергей Николаевич
доктор педагогических наук, доцент, профессор кафедры педагогики и педагогического мастерства
Мелитопольский государственный педагогический университет имени Богдана Хмельницкого,
г. Мелитополь, Украина
ORCID ID 0000-0002-2654-5610
pryima.serhii@gmail.com

Аннотация. Обосновывается актуальность интеграции национальных и Европейской рамок квалификаций для сопоставления результатов обучения в разных странах. Проанализированы теоретические исследования в этой сфере и инструментальные средства, построенные на их основе. Рассмотрены подходы, по которым Национальная рамка квалификаций Украины должна согласовываться с Европейской рамкой квалификаций, и проблемы, возникающие в процессе ее использования на практике. Обоснована необходимость создания инструментальных средств, основанных на технологиях Semantic Web, для сравнения рамок квалификаций. В публикации предложено использовать онтологии для представления результатов обучения и семантические Wiki-технологии для структурирования соответствующих информационных ресурсов. Разработана теоретическая модель и алгоритм сопоставления онтологий и Wiki-ресурсов, которые позволяют динамично пополнять онтологии и сопоставлять описанные в них информационные объекте. Создано программную реализацию предложенного подхода.

Ключевые слова: рамка квалификаций; онтология; Wiki.