Use of Semantic Technologies for Validation of e-Learning Outcomes

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Abstract

The paper offers means, sources and methods for semantic validation of learning outcomes (including non-formal and informal distant learning) based on the ESCO ontological model and matching of its main concepts. Atomic competencies are used for representation of different components of ontological model that formalizes relations between main subjects and objects of learning process.

We analyze specifics of the Web-oriented semantic technologies used for support of e-learning. Ontological analysis provides representation of distributed background knowledge about users, their professions, competencies, lifelong learning outcomes, etc., and standards of the Semantic Web project provide the technological foundation for creation of intelligent advisory applications. Validation of learning outcomes of informal and non-formal learning needs in semantic matching of user profiles with classifications of professions and qualifications.

Advantages of proposed approach are demonstrated on example of applied information system AdvisOnt developed to combine the market of educational services with the labor market that can use validation of the informal and non-formal learning outcomes.

Keywords

Learning outcomes, validation, ontology, competencies, ESCO, Semantic Web.

1. Introduction

Now the Semantic Web and associated semantic technologies become standards of the mainstream industry dealt with a huge number of the Web-oriented intelligent information systems (IISs). Such IISs migrate from the processing and storage of large amounts of data to processing and storage of more compact knowledge with a much more complex structure. They apply semantization for different steps of information processing and try to take into account meaning of data and relations with domain knowledge. One of the prospective spheres of IISs is e-learning and such it`s subdomain as validation and formalization of learning outcomes. Now this research direction is very actual because of COVID pandemia and transition to distant forms of lifelong learning and online estimations of received skills and competencies. Lifelong learning [1] is a key factor in personal and professional development that needs in cooperation of industry leaders with educational organizations and non-formal learning courses and services. The accession of Ukraine to the European educational space [2] causes important changes in the structure and semantics of the educational process.

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The concept of lifelong learning, which was not only invoked with reference to education and schooling, but also as a way to solve the problems of unemployment and preparation for the job market. Labor market change, reflecting evolutions in technologies, markets and organizations, requires that skills and competences can be transferred within a new working environment.

Recognition of learning outcomes (knowledge, skills, abilities and competencies) achieved through non-formal and informal (spontaneous) learning, including through open educational resources, is necessary for access to the labor market and lifelong learning. Employer organizations, trade unions, chambers of commerce and industry, national bodies involved in the recognition of professional qualifications, employment services, youth organizations, education providers, and civil society organizations are the most interested parties in providing opportunities for the recognition of non-formal and informal learning. All stakeholders contribute to more systematic approach to the recognition of non-formal and informal learning outcomes [3]. Now lifetime employment becomes an exception because the majority of employees change job several times in their work lifespan.

Successful implementation of this task facilitates the development of vertical mobility of citizens in vocational education and labor market, and horizontal mobility from one professional trajectory to another through the mechanism of official recognition of partial qualifications acquired in formal, non-formal and informal learning. Subjects of the labor market have possibilities to describe their proposals and requirements through various informal characteristics which are often intangible (e.g. team spirit, social skills, leadership skills). Use of different terms to describe such characteristics actualizes the problem of comparing the semantics of such descriptions.

Semantic technologies (STs) that are aimed at knowledge-level processing of information can solve this problem because they are able to formalize, analyze and process the content of information resources (IRs) and personal data dealt with learning process and learning outcomes. STs are based on the application of domain knowledge and knowledge about the users of these information technologies, providing automated analysis of information on the Web. One of the results of such processing is an achievement of semantic compatibility of open educational resources that allows to use and integrate information about results of non-formal and informal learning from different sources and databases in various information systems (IS). Thus, the implementation of ISs of semantic identification and documentation of the results of non-formal and informal learning is an urgent and timely scientific task. The materials presented in our article are structured as follows. The first section points out the relevance of the development and implementation of IIS to create an advisory system based on the ontological presentation of knowledge about the subject area.

The second section presents the structure and functionality of the European classifier ESCO. The ESCO contains a description of the professions, skills, and competencies required to obtain a particular job or position. The third section explains the essence of semantic technologies and the effectiveness of ontological models for creating IIS. It was considered the questions of knowledge management based on Semantic Web technology. As the basic tool it was used ontological knowledge modeling. The fourth section explains that tools for semantic identification and documentation of learning outcomes (including non-formal and informal ones) should be quite dynamic. We actively use software agents and semantic Web-services to improve the functions of our system. There are analyzing of the methods of obtaining knowledge from Web-resources, Wiki-resources and natural language documents. The means of intellectualization of software agents, search engines and Web-services was demonstrated. The fifth section presents the ontological model of competencies that represents the structure of relations between learning outcomes and professions, jobs, knowledge, skills, competencies and qualifications. The sixth section presents the architecture and description of the functionality of IIS AdvisOnt Advisory System.

2. Multilingual classifier of European skills, abilities, qualifications and professions

In order to support the process of recognition of learning outcomes in formal and non-formal and informal learning, the European Commission has developed free Internet portal ESCO [4]. ESCO (European Skills, Competencies, Qualifications and Occupations) is a multilingual classifier of European skills, abilities, qualifications and professions.

ESCO classifier is published in the Linked Open Data format. This conception provides the ability to create a system that easily adapts to domain and allows developers to use it as a building block in services for job search, career guidance and self-assessment. ESCO classifier is available in various formats (SKOS-RDF, CSV), so that users can integrate it into their services and other types of software. In addition, ESCO provides local API and API of Web Services so that applications and Web services can request real-time information from the classifier.

ESCO classification identifies and classifies skills, competencies, qualifications and occupations important to the European labor market, education and training. Use of ESCO classifier provides consolidation of the labor market and the market of educational services, because, on the one hand, it helps education providers better understand the needs of the labor market and adapt curricula to these needs, and on the other hand – helps employers in understanding of the learning outcomes acquired by professionals looking for work.

ESCO classifier contains three main elements: occupations; skills and competencies; qualifications. All these elements are interconnected and allow ESCO to organize common and transparent terminology for the European labor market and education sector.

Profession element is a description of all professions that are important for the European labor market. Today, ESCO classifier contains description of 2,942 occupations. Each concept of the Profession describes its meaning, as well as provides useful information about the profession (metadata). The main element that defines professions in ESCO is the basic idea or understanding of what it is and how it differs from other professions. They are fixed in the description and the note area. ESCO description is a text field that contains a brief explanation of the meaning of the profession and its understanding. Most importantly, it explains the semantic boundaries of the profession. For this reason, a description is always provided for each ESCO employment.

Each Profession in ESCO is associated with basic and additional skills and competencies:

- main skills and competencies are usually relevant to the profession, regardless of the work context, employer or country;
- additional skills and competencies may be actual or arise when in the profession working dependently on the employer, work context or country.

Professions in ESCO are structured by comparing them with the International Standard Classification of Occupations (ISCO-08) developed by the International Labor Organization. ESCO employments and their ISCO-08 hierarchy compose the ESCO Profession element. ISCO-08 provides four upper levels, while the professions at ESCO provide fifth and lower levels. Each ESCO employment is assigned to one group of ISCO-08 elements (even if they are not directly related to it, for example, if they are at the sixth or seventh level).

The Skills and Competence element (often abbreviated as Skills) of ESCO provides a complete list of skills relevant to the European labor market:

- *knowledge*: a set of facts, principles, theories and practices that are related to the field of work or study. Knowledge is described as theoretical and / or factual and is the result of information gaining through learning;
- *skills*: the ability to apply knowledge and use know-how to perform tasks and solve problems. Skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving the use of manual dexterity and the application of methods, materials, tools and equipment);
- *competencies*: the ability to use knowledge, skills and personal, social and methodological abilities in work or study, as well as in professional and personal development.

The concepts of "skill" and "competence" differ semantically because "skill" refers to the use of methods or tools in specific settings and tasks, and "competence" refers to a person's ability to face new situations and unforeseen problems, the use and application of knowledge and skills in new areas of activity. However, these ESCO elements have similar structure.

ESCO provides metadata from the Skills group for each profession Such metadata include: preferred term; non-core terms (synonyms, spelling variants, abbreviations, etc.); hidden terms (for example, outdated ones); sphere of the semantic boundaries of the concept; relations with ESCO professions etc. This information can be used for identifying and documenting learning outcomes and, as a result, maintaining professional mobility.

Qualifications element contains information about the full list of qualifications that are important for European labor market. This ESCO information is obtained from national databases on the qualifications of EU member states and from other qualifications provided directly by the awarding bodies.

ESCO classifier ontology consists of three elements – professions, skills and qualifications, as well as two additional registers: bodies that award qualifications and bodies that award the context of work, and usually refer to ESCO qualifications.

However, different subjects on the labor market describe their proposals or requirements through different informal characteristics. Different terms can be used to describe such characteristics, and it causes problems of their semantic comparing. Such problems can be solved by knowledge processing and use of IISs and appropriate models, methods and ontologies that support formalization of learning process and learning outcomes.

3. Semantic technologies

STs aimed at knowledge-level information processing can solve validation problem because they are able to formalize, analyze and process the content of IRs that describe results of learning.

Semantics allows to define explicitly meanings and relations between domain concepts represented by data (words, phrases, symbols, etc.) that depends on context. For the same piece of information, semantics can be defined differently depending on ontology used to formalize the user's view of the world. Ontologies can be used as a formal, explicit specification of conceptualization of terms at a certain level of details.

Semantic processing of information includes: methods and means of integration and unified representation of heterogeneous distributed knowledge and data; retrieval and processing the Web resources as an universal knowledge source of about meaning of information objects.

STs in general can be described through a combination of three main components [5]: ontologies; semantic resources; models of semantics of natural language (NL) entities. This approach is concentrated on NL processing. In our study we take into account more wide classes of IOs with various structure defined by appropriate ontologies. For example, advisory systems analyze people, organizations, vacancies, learning courses, etc. that cam contain NL definitions, multimedia elements and structured data.

Therefore from the point of view of creating semantic applications, these three basic components form a hierarchy where: 1. ontologies and other knowledge bases (KBs) are the upper level of abstraction of the knowledge structure; 2. IO models represent the intermediary level that allows to distinguish typical IOs and their properties and characteristics; 3. semantic IRs are the lower level that provides information about individuals of classes.

Semantic IRs can have links between content elements (IOs of various types and structure) and with elements of IO models (for example, links with other Wiki pages or with data). Meaning of links is provided by means specific for IR representation and markup. For example, Semantic MediaWiki uses semantic properties.

Semantic Wiki resources are both a provider of knowledge for building ontologies and users of such ontologies. They are closely connected with various means of acquiring and presenting knowledge, with Semantic Web technologies. The integration of data mining tools with semantically annotated Web resources provides promising opportunities to effectively meet the information needs of users in current and dynamic information about the world around them.

The ontological representation of knowledge about the domain can be automatically processed by intelligent software agents representing the interests of students in the IAS, designed for e-learning. One of the goals of such personal software agents in e-learning is that each student can find the course he needs (on the one hand, that meets his information needs, and on the other hand - based on the courses previously studied by this student and submitted to him in the most easy to learn form).

The use of agent-oriented technologies in e-learning allows you to take into account personalized information about students and teachers and saves all users from routine operations (for example, once determining the type of interface or the most convenient form of control, the student will always receive a default course in in this form).

4.Semantic identification of learning outcomes

Tools for semantic identification and documentation of learning outcomes (including non-formal and informal ones) should be quite dynamic. They have to take into account changes in the world around them, use background knowledge and ensure the retrieval of new information from the Web resources. This requires the use of technologies oriented on intelligent processing of distributed information.

Recently, developers of distributed IISs exhibit a tendency to transition from the use of relational databases to ontological knowledge bases (KBs). This is due to the development of the Semantic Web conception [6] that is based on tree main elements – ontologies [7], Web-services [8] and software agents [9]. The ground of ontological KBs is ontology – a formalized, explicit description of domain, and Web-services used by software agent need in knowledge represented by these ontologies. Ontological KBs include the set of classes (concepts) and descriptions of the various relations between them, as well as the set of class individuals. Semantics of data is defined by connection with element of description of domain knowledge and meaning of this connection.

For example, if domain ontology describes learning outcomes then semantics of resume of potential employee can be defined formally by some elements of this ontology [10]. Now domain ontologies are usually represented by the OWL [11] language developed by the Semantic Web initiative that is an add-on to the RDF language [12].

The Semantic Web technologies can be exploited for development of the Web-oriented tools for semantic identification and documentation of non-formal and informal learning outcomes:

- software agents are used for personified and unified representation of specific needs and interaction of various subjects of learning process and labor market;
- semantic Web-services support various functions dealt with validation of learning outcomes and their use in matching of vacancies and resumes at the semantic level;
- ontology represented relations between learning outcomes and professions, jobs, knowledge, skills, competencies, qualifications etc. and various external ontologies represent domain knowledge.

5.Ontological model of competencies

Ontological model that represents structure of relations between learning outcomes and professions, jobs, knowledge, skills, competencies and qualifications is an important element of IS for validation the learning results of is development. This model provides processing of non-formal and informal learning outcomes on semantic level and can be used for their unification and matching with existing standards and taxonomies such as ESCO. Ontologies allow to describe formally any concepts, groups of classes, relations between objects and types, elements of classes, etc. Formal model of ontology defines main elements of ontological analysis: concepts, relations and rules their interpretation [13]. For example, ontologies can be used for representation of various learning courses [14] and their characteristics, sequence of learning, links with professions and specialties.

In this work we use the enhanced formal model of ontology [15]: $O = \langle X, R, F, T \rangle$, that consists of the following elements:

- $X = X_{cl} \cup X_{ind}$ is a finite set of basic concepts of ontology where X_{cl} is s set of classes, X_{ind} is a set of instances of these classes, such that $\forall a \in X_{ind} \exists A \in X_{cl}, a \in A$;
- $R = r_{ier\_cl} \cup \{r_i\} \cup \{p_j\}$ is a finite set of relations between classes and instances of ontology classes where r_{ier_cl} is a hierarchical relation between ontology classes and properties of classes characterized by properties such as antisymmetry and transitivity, $r_{ier\_cl} : X_{cl} \to X_{cl}$; $\{r_i\}$ is a set of object properties that establish the relation 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 data properties that establish 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 sets of object properties and

relation properties may also be hierarchical relations $r_{ier\_obj} : \{r_i\} \to \{r_i\}$, and r_{ier_data}, $r_{ier\_data} : \{p_j\} \to \{p_j\}$;

- F is a finite set of characteristics of ontology classes, instances of classes and their properties;
- T is a finite set of data types (for example, string, integer).

The basic classes of learning validation are competence; profession; qualification; knowledge; as well as subjects associated with these classes: owners (potential employees with certain knowledge and skills), customers (employers) and providers (persons and organizations that provide educational services that allow for professional development) [16].

O_{learn} is realized by OWL Light dialect of OWL and describes the properties of classes (both object properties and data properties) and relation between basic terms and their subclasses. It contains the following classes (the list of classes is arranged alphabetically, not by relevance): knowledge, candidate, qualification, competence, country, course, skill, education passport, concept, course provider, profession, job, employer, term.

O_{learn} is used for competence management [17] for matching of individuals of these classes. Values of their properties are defined by non-empty sets of atomic competencies [18].

Atomic competence a is defined as follows:

- $a \in C$ where C is the set of information objects of the class "Competence" of O_{learn}, and C_{atomic} is the set of atomic competencies, $C_{atom} \subseteq C$;
- each competence is a union of a non-empty set of atomic competencies $\forall c \in C \exists a_i \in C_{atomic}, i = \overline{1,n}, k = \bigcup_{i=1}^{n} a_i$;
- any atomic competence can not be a subset of any other atomic competence $\forall a, b \in C, a \subseteq b \Rightarrow b \notin C_{atomic}$.

$a \in C$ are defined by individuals of relevant domain ontology: concepts $x_i \in X, i = \overline{1,n}, n \geq 1$ and relations $r_j \in R, j = \overline{1,m}, m \geq 1$ such that $x_{i_a} = r_j(x_{i_b})$. Thus, matching of user competencies with vacancy at the semantic level is reduced to comparison of finite sets of atomic competencies of individual user with competence set of tasks [19]. This approach guarantees the comparison for a time proportional to the number of atomic competencies.

6. Advisory system AdvisOnt

Advisory system AdvisOnt (see Fig.1) defines relations between main subjects of advisory activities – applicants (persons needed in some work based on relevant competencies and skills), employers (persons or organizations needed in employees for execution of some task or work on some position) and providers of learning services (organizations that propose various formal, non-formal and informal learning means for expansion of personal competencies). System is oriented on agricultural domain but it validation services based on the Semantic Web standards can be integrated with any other learning software.

AdvisOnt is a as semantic application because it provides:

- personified user interaction based on use of personal intelligent agents;
- semantic analysis for unified representation of vacancies and resume based on NL processing and ESCO terminology;
- comparison of resumes and vacancies at the semantic level with use of semantic similarity of domain terms semantic relations between professions, skills, competencies and qualifications defined by ESCO ontology.

We distinguish the following parameters: user profile – non-formalized representation of main features values of user proposed by applicant; formalized user profile – formalized representation (according to selected ontological structure) of main features values of user with pre-defined data types such as demography, skills, qualification, background, cognitive style, restrictions, etc. expressed by the non-empty finite set of competencies; NILO (non-formal and informal learning outcomes) – non-formalized set of additional competences and skills of user that need in formalization and adaptation with user profile model; formalized NILO – formalized set of additional competences and skills of

user expressed by the non-empty finite set of competencies; task – non-formalized representation of employer needs for work execution that can be covered by one or more vacancies; vacancy – non-formalized representation of employer needs and demands to employees; formalized vacancy – formalized representation of employer needs (according to selected onto-logical structure) and demands to employees expressed by the finite set of competencies.

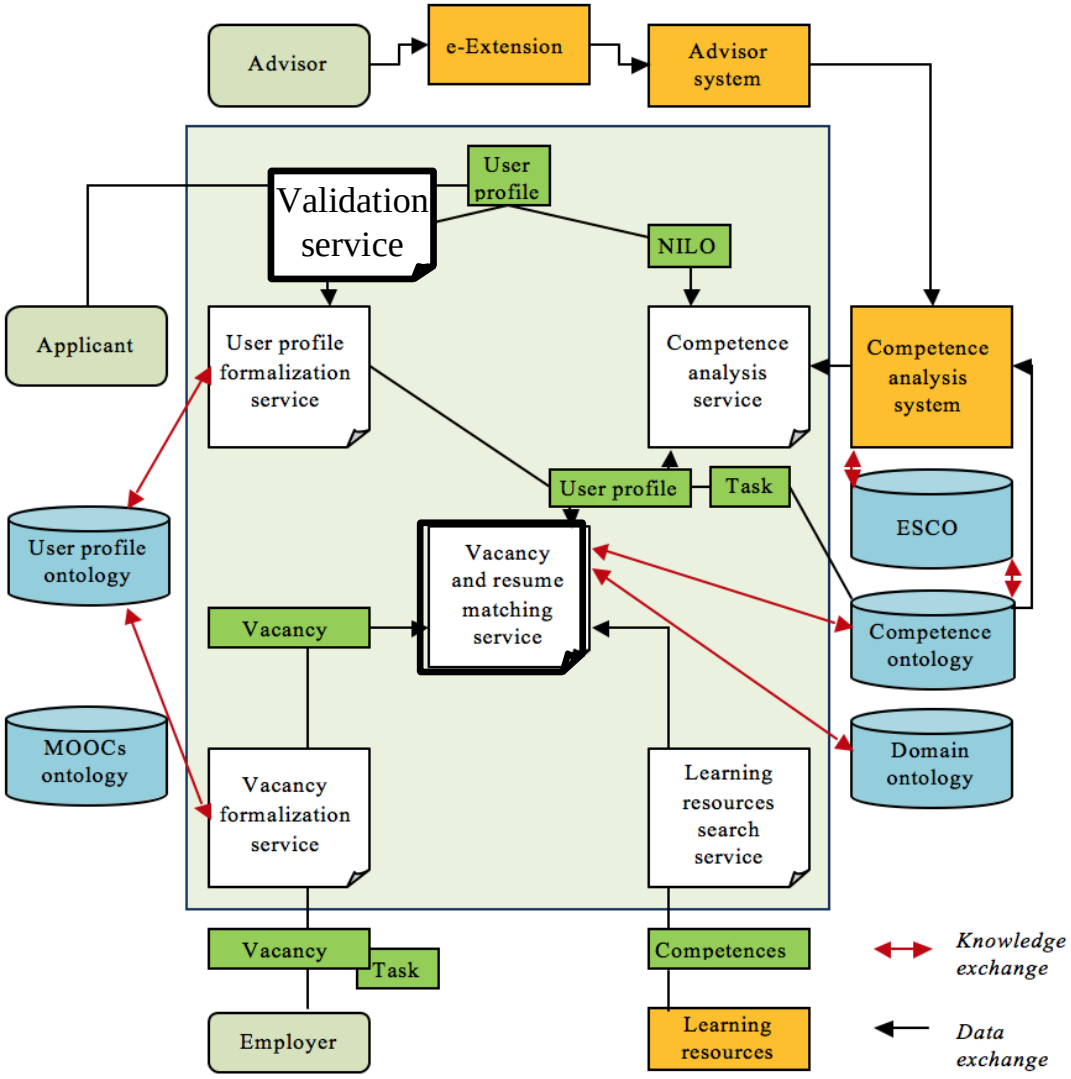

Figure 1: General architecture of AdvisOnt advisory system

In this work we use definitions of agro-advisory services based on Service-oriented architecture (SOA) paradigm terms and its semantic extension defined by OWL-S ontology. Functionality of AdvisOnt system is defined by the set of services: service for vacancy formalization; service for user profile formalization; service for learning course formalization; service for learning course retrieval; service for matching of vacancies and resumes. Data types of input and output of these services are defined with the help of external ontologies: ontology of user pro-files, ESCO and ontology of agricultural domain. These ontologies define the structure of analyzed data and contain information about types of their attributes, restrictions and conditions of their use. An important feature of SOA-based system is it`s interoperability – we can select other external ontologies instead of these ones for other subject domain or for other view on system tasks and goals without changing of services.

We consider advisory systems used by various countries and regions, their specifics and aims, and knowledge bases that can be used as bedrock for agro-advisory applications – the European Multilingual Classifier of Skills, Competences, Qualifications and Occupations ESCO ontology, ontologies of learning resources (on example of MOOCs - Massive Open Online Courses), user profile ontologies.

Analyses of the intelligent Web-oriented informational technologies shows an expedience of advisory development based on the Semantic Web standards of knowledge representation and processing.

An important factor of advisory efficiency deals with semantic documentation and validation of non-formal and informal learning outcomes typical for agriculture. We propose semantic advisory system AdvisOnt based on ontological representation of knowledge about competencies, vacancies, training courses, user profiles, employers and companies. AdvisOnt services match available vacancies and applicant profiles to recommend employment or further learning of wanting competences by analysis of their formal, non-formal and informal learning outcomes [19].

7. Conclusions

We analyze modern approaches to the interaction of the educational services market with the labor market through recognition of non-formal and informal learning outcomes. The authors prove the expediency of semantic technologies used for information processing at the knowledge level, analyze the Semantic Web standards and specifics of their use for education and labor market applications. ESCO classifier that combines services of the labor market and the educational market is examined in detail. This classifier allows jobseekers and employers from different EU member states to handle information on learning outcomes more efficiently. The analyzes of practical ESCO classifier usage on example of the European Employment Service (EURES) demonstrates that this approach provides all necessary information for jobseekers abroad.

The ontological analysis is an efficient way to model the ideas of various domains that allows to represent formally their semantics. Hence, the research analyzes the ontological model for this information system and its components; in particular, the authors provide the described content of the ESCO ontological model which consists of three elements – occupations, skills and qualifications. Original method of semantic identification and documentation of non-formal and informal learning outcomes based on competence analysis is proposed. Main element of this method is atomic competence. Enhanced formal model of domain ontology that provides representation of competence matching is developed. Labor market participants usually describe their proposals or requirements through various informal characteristics; therefore, this research work is aimed on problem of comparing the semantics of such descriptions on base of semantic ontologies. Analysis of publications on the topic of the study concluded that the Multilingual Classifier of European Skills, Competencies, Qualifications and Professions ESCO can be used as an effective tool to combine the market of educational services with the labor market. ESCO Classification identifies and classifies skills, competencies, qualifications and occupations that are relevant to the European labor market, education and training. Proposed approach is used efficiently in applied intelligent system that provides competence management for agro-advisory.

Information system of recognition of results of non-formal and informal training represented in this work is oriented on the Semantic Web technologies and uses conception of the Web services and RDF-based repositories of ontologies. The developed architecture and user interface of this system allow semantic identification and documentation of non-formal and informal learning outcomes, thereby increasing the efficiency of handling information about these outcomes.

In the future, we plan to use Data Mining and Inductive Inference techniques to develop the most appropriate personal learning strategies for each student by summarizing the background of student interaction with the e-learning system (for example, some students prefer theoretical materials and others prefer learning on practical examples). someone prefers a graphic or textual representation of information, etc.).

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