

**A.YA. GLADUN**, PhD (Eng.), Senior research associate, International Research and Training Centre of Information Technologies and Systems of the NAS and MES of Ukraine, Glushkov ave., 40, Kyiv, 03187, Ukraine, glanat@yahoo.com

**YU.V. ROGUSHINA**, PhD (Eng.), Senior research associate, Institute of Software systems of National Academy of Sciences of Ukraine, Glushkov ave., 40, k.5, Kyiv, 03187, Ukraine, Ladamandraka2010@gmail.com

**K.O. KHALA**, Junior research associate, International Research and Training Centre of Information Technologies and Systems of the NAS and MES of Ukraine, Glushkov ave., 40, Kyiv, 03187, Ukraine, cecerongreat@ukr.net

## **APPLICATION OF SEMANTIC MODELING TO FORMALIZED KNOWLEDGE ASSESSMENT BASED ON OPEN ENCYCLOPEDIA RESOURCES**

*It is suggested to use semantically markup open encyclopedic resources as a source of knowledge for validation of distance learning outcomes. Evaluation of the results of distance learning is based on the creation of a personal ontology by students of the discipline, which includes the basic concepts and relationships between them. These concepts can be obtained from relevant encyclopedic resources and perform an automatic comparison of the student's ontology of knowledge with the standard ontology of the subject. The results of this comparison allow us to identify errors in the understanding of parts of domain knowledge (discipline, subject) and to improve the standard ontological model of the discipline as a whole.*

**Keywords:** semantic markup, electronic encyclopedia, ontology, thesaurus, non-formal and informal learning, competence.

### **The urgency of the problem**

Dynamic European integration processes in Ukraine and balancing of national interests in the educational services and labor market require improving the quality of training. In addition, recognition of learning outcomes (formal, non-formal and informal) – the knowledge, skills and competences that link the educational services market to the labor market is required. All these complex learning processes in our country need to enhance the role of formally assessing students knowledge and developing a mechanism for the formal recognition of partial qualifications acquired through formal, non-formal and informal learning.

One of the sources of such knowledge can be a variety of encyclopedic resources, dictionar-

ies, which are available electronically and provide an automated processing of the information they submit.

The development of national procedures for the recognition of non-formal and informal learning should be based on national encyclopedic resources (for example, the Great Ukrainian Encyclopedia – a multi-volume encyclopedic publication of a universal nature containing a portal version created on the basis of modern semantic technologies – e-VUE [1]).

### **Literature review**

Computer technology has significantly changed the content and practice of teaching. Multimedia

applications, modeling, computer data sharing, social media communities, as well as support for individual and distance learning – all these have the potential for large-scale education improvement [2]. In recent years, *e*-learning has become widespread, causing standardization of learning technologies [3]. There are now many *e*-learning tools with different functionality and purpose [4].

An important component of *e*-learning is testing of the students' skills and knowledge. The Ministry of Education and Science of Ukraine is currently implementing the Online Education Development Program, which envisages the development of projects for standards of the systems, methods and technologies of online education in educational institutions, taking into account international standards [5,6]. But there are serious problems with the semantics of testing. Learning control requires a means of comparing a student's knowledge base, which is formed (and modified) in the learning process, with the knowledge base of the course domain. This requires powerful interoperable tools for knowledge representation and analysis. The domain ontologies [7] are used as a resource that structures the learning content [8].

### Problem statement

The basic idea behind the proposed approach is that the domain ontology is not only a learning tool but also a semantic model for validating its results. We invite students to consistently build an ontology of passed sections of the discipline to compare it with the standard ontology of the subject. The results of this comparison show errors in understanding parts of domain knowledge (discipline, subject matter) and help the tutor to improve the distance course. Practical experiments show that this approach is much more effective than regular tests, when some errors may be associated with ambiguous question and error, but the correct answers can be obtained intuitively or randomly, which unfortunately does not reflect the true concept of students' knowledge of the domain. Using semantically markup encyclopedic resources as a source of knowledge to build a reference ontology provides the objectivity of this approach.

### Using ontologies to represent the knowledge of the subject area

In modern systems of distance learning is important to focus on the means of presenting knowledge, which has become the standard for Intelligent Information Systems (IIS) and focused on functioning in the Web – ontologies [9]. In IT ontology is a specification of conceptualizations that are used to help programmes and users share knowledge.

Ontologies offer a shared understanding of a domain that people and applications can communicate with. Knowledge of ontologies is formalized through five types of components: classes, relationships, functions, axioms, and instances. The formal model of the *O* ontology is an ordered triplet of finite sets  $O = \langle T, R, F \rangle$  [12], where *T* is the terms of the subject area, which is described by the *O* ontology; *R* is the finite set of relations between the terms of the subject area; *F* is a function of domain interpretation on ontology terms and relationships. An ontology in informatics should have a formalized representation language that computer is capable of processing without direct human involvement [10 – 13].

### The main stages of building the ontology of the subject area

Building an ontology based on IDEF5 methodology [14] requires students to complete the following steps:

- 1) Build a set of domain terms;
- 2) Fix restrictions that govern how these terms can be used to make descriptive domain claims;
- 3) Build an ontological model that, when given a specific descriptive statement, can generate "appropriate" additional descriptive statements.

The students (as well as tutor, who is building a reference domain ontology) must fulfill four basic steps to developing an domain ontology [15] (Fig. 1):

1. Identify the main classes and terms of the subject area and describe their meaning:
  - define a set of class names *T*;
  - define a set of names of relations *R*;
  - define for each class name a set of attribute names *A*;

- for each attribute name  $a \in A, t \in T$ , define its type – INT, STRING, NUMBER, etc. or another ontology class.

2. To build a taxonomy of the terms of the subject area: identify all pairs of classes  $\langle t_1, t_2 \rangle, t_1 \in T, t_2 \in T, t_2 \in T, r(t_1, t_2) \rightarrow t_1 \text{ IS\_A\_Subclass\_Of } t_2, r \in R$ .

3. Define synonymy and other relationships between these terms:

- define all pairs of classes;

$\langle t_1, t_2 \rangle, t_1 \in T, t_2 \in T, r(t_1, t_2) \rightarrow t_1$

"IS\_Synonyme\_Of"  $t_2, r \in R$ ;

- define all pairs of classes associated with the specific relations of the subject area;

$\langle t_1, t_2 \rangle, t_1 \in T, t_2 \in T, r_{domain_i}(t_1, t_2), r_{domain_i} \in R$ .

4. Describe instances of built classes:

- define the names of instances  $a$ ;

determine the value of all attributes of the instances of the class  $\forall a \in t, t \in T$ .

### Comparing ontology of the subject area, built by students, with reference ontology

Students' domain ontologies should be compared to the reference ontology that was created by the tutor. It should be noted that the problem of comparing arbitrary ontologies of subject areas is very complex, but we consider it a separate case with many limitations: it is a light ontology terminology or light ontology with an empty set of axioms, with a fixed set of relationships and with sets of concepts which must be subsets of the set of concepts of a reference ontology.

We use the original algorithm [16] for automatically compare ontologies, which ensures that hierarchical levels are consistent in terms of taxonomy (if class  $A$  is a subclass of  $B$  in the reference taxonomy and  $B$  – subclass  $A$  in the taxonomy student, then this is an error) and controls the affiliation of the instances to the classes (if the instance belongs to class  $A$  in the reference taxonomy and the student describes the instance to that belongs to class  $B$ , then this is an error).

This algorithm is based on some specific conditions and therefore cannot be used to compare arbitrary ontologies:

- the student must use ontological terms for classes and subclasses only from a fixed set of terms

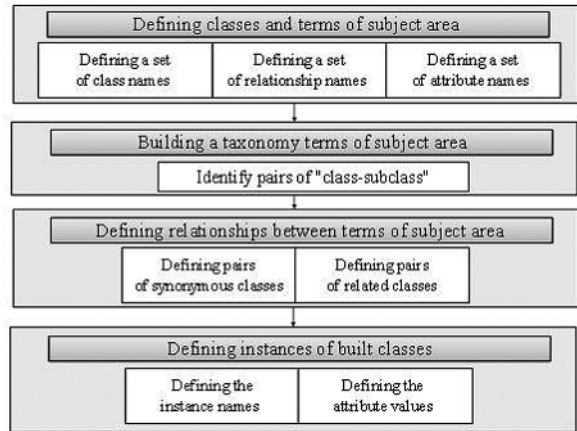


Fig. 1. The main stages of building the ontology of the subject area

that correspond to the standard ontology, other terms are considered errors;

- the student has used the relations between classes only from a fixed set corresponding to the relations of the reference ontology other attitude is also regarded as an error;

- if a student still uses a term that does not exist in the reference ontology, then that term must correspond to some term of the reference ontology (the student may use an incorrect name by mistake).

The main steps of the algorithm comparison student ontology  $O_s$  with reference ontology  $O_e$ , which has developed a tutor (Fig. 2):

1. Define the set of ontological terms:

- $T_s$  is the set of terms of the student's ontology,
- $T_e$  is the set of terms of a reference ontology.

2. Divide terms from  $T_s$  into three categories:  $T_n$ ,  $T_u$  and  $T_w$ ,  $T_s = T_n \cup T_u \cup T_w$  where

- $T_n$  – correctly defined terms  $T_n \subseteq T_e$ ;
- $T_u$  – inaccurately defined terms,  $T_u \not\subseteq T_e$  but  $\forall t_i \in T_n \exists t_{j_1} \in T_e, \dots, t_{j_m} \in T_e, t_{j_k} \in T_e, m = 1, k$ ;
- $T_w$  – incorrectly defined terms,  $T_w \not\subseteq T_e$  and  $\forall t_i \notin T_n \neg \exists t_j \in T_e$ .

3. Define the set of ontological terms:

- $R_s$  is the set of terms of the student's ontology,
- $R_e$  is the set of terms of a reference ontology.

4. Classify the ratio of  $R_s$  for the three categories that do not intersect:  $R_n$ ,  $R_u$  and  $R_w$ ,  $R_s = R_n \cup R_u \cup R_w$  where

- $R_n$  – correctly defined relations,  $R_n \subseteq R_e$ ;
- $R_u$  – inaccurately defined relationships,  $R_u \not\subseteq R_e$  but

$\forall r_i \in R_n \exists r_{j_1} \in R_e, \dots, r_{j_m} \in R_e, r_{j_k} \in R_e, m = \overline{1, k}$ ;  
 ■  $R_w$  – incorrectly defined relations,  $R_w \not\subset R_e$  and  $\forall r_i \notin R_n \neg \exists r_j \in R_e$ .

5. Analyze the use of ontology terms and relationships. We distinguish the errors of different gravity. If a student uses the wrong attitude but with a group of hierarchical relationships (for example,  $A$  is part of  $B$ , and  $A$  is a subclass of  $B$ ), it is not as important as if he used a hierarchical relationship instead synonymic relationship. A more serious mistake is the misdirection of hierarchical relationships (for example,  $A$  is part  $B$  instead of  $B$  is part  $A$ ).

Fig. 3 presents the results of the estimation of correctness when comparing the student ontology

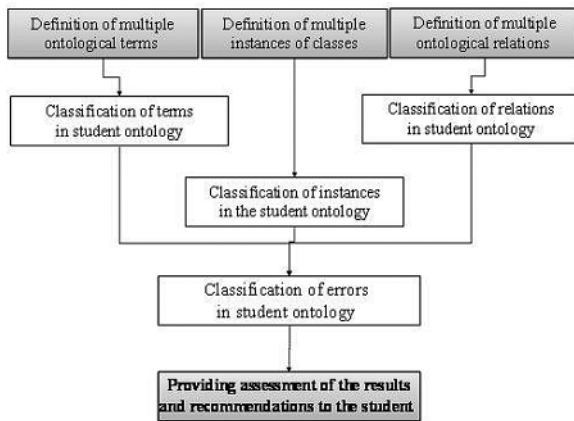


Fig. 2. The main stages of comparing a student's domain ontology with a reference ontological discipline

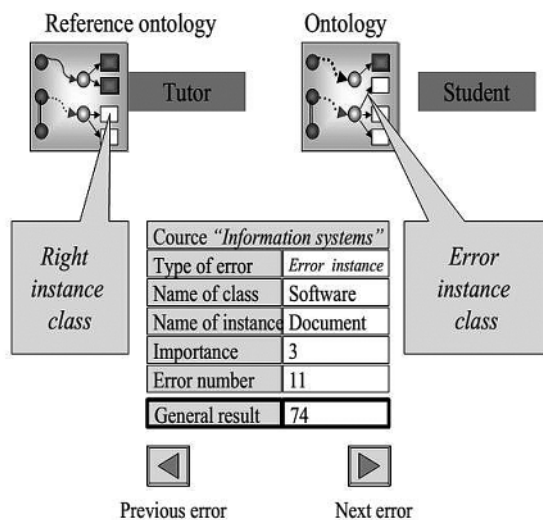


Fig. 3. Assessment of student ontology correctness

with the reference model of the subject. The ontological representation of the domain students' skills can be automatically processed by intelligent software agents. It is appropriate to use e-learning software agents as they work effectively in a dynamic, heterogeneous distributed environment.

### Integration of semantic Wiki resources with Semantic Web ontologies

Modern intelligent information systems is widely used knowledge gained from Web information resources (for example, by using Web Mining and Text Mining) [17]. The presence of semantic markup of information resources being processed, considerably simplifies this complex process and use of ontologies to represent the received knowledge ensures their reuse by other systems.

Therefore, the task of building a semantic markup on the basis on the ontology of a particular subject area, and the inverse of it, the task of building and improving ontologies based on semantic Wiki-resources is the subject of many scientific developments today.

Semantic MediaWiki (SMW) is focused on integration with Semantic Web technologies. The data specified in Wiki resources by semantic properties can be exported to RDF format. SMW data types, in this case, will be converted to the corresponding XML Schema data types, and unique identifiers (URL) are formed by affixing the suffixes to the URL Wiki. Also there is the opportunity to indicate which dictionaries (OWL-ontology) should be used when exporting those or other semantic properties.

SMW semantic properties can be used to create ontologies:

- to establish relations between instances of classes (object properties) – for semantic properties of type "Page", the semantics of which are described on the page of the corresponding property (for example, "works in the organization", "resided in the city"),
- to identify data properties for a specific category of pages (for example, semantic properties "Year

of birth", "Last name", "First name") can be found on Wiki-pages of "Human" category

Wiki-pages contain also other elements that allow to formalize relations between the relevant concepts. They include:

- links to other Wiki pages;
- categories.

In SMW an ontology can be built automatically by the system's built-in tools, but the possibility of managing this process are very limited, and the information that is imported into this ontology in many cases is inadequate for modeling the domain. To do this, use the "Special Pages" menu in the "Semantic MediaWiki" submenu and select "Export Pages to RDF".

Thus, if an OWL ontology is already built, then it can be used in SMW. But the reverse process cannot be completely automated. Moreover, the automatic generation of SMW ontologies will lose the information contained in the OWL ontology and relate to the characteristics of classes and properties that do not have Wiki analogs (especially the equivalence of classes and properties, their intersection, area values and definition). At the same time, some of the SMW content cannot be directly transformed into ontology.

### **Information sources for the construction of benchmark ontologies**

You can use a variety of training materials, textbooks, tutorials, e-courses, and more to gain knowledge of the subject area. However, it should be borne in mind that the processing of natural language (NL) texts in many cases involves ambiguous interpretation and, therefore, not only requires considerable effort, but also may lead to misunderstanding of the subject laws. In traditional education the teacher can easily notice this, but in distance learning, such situation can be a cause of receiving incorrect knowledge and incomprehensible low ratings for students.

Therefore, it is advisable to use such information resources (IR) that, firstly, containing semantic markup, which greatly simplifies their automated processing and in most cases eliminates meaningful ambiguity, and secondly, containing only veri-

fied information that is prepared by experts relevant about, correct framed and has a high level of confidence. One example of the IP for constructing upper-level ontologies is a portal version of the "Great Ukrainian Encyclopedia" (*e-VUE*). This IP is available for at [vue.gov.ua](http://vue.gov.ua).

*E-VUE* was built on the semantic extension of Wiki technology [18]. Each page of an encyclopedia belongs to several categories that link it to the relevant sections and divisions of the various fields of knowledge. The semantic properties of the pages allow a meaningful determination of the connection of each page with other slogans of the encyclopedia.

SMW allows names to be referenced by turning them into so-called "semantic properties" of the page [19]. Moreover, it allows you to mark other snippets of text linking to the page data of different types. The text annotation gives users more possibilities in comparison with the traditional categories.

The information becomes available not only for reading but also for automatic machine processing. Semantic markup text Wiki-pages providing this treatment, and therefore semantic properties and categories that are included to the composition Wiki-article, often called "semantic annotations". Such semantic annotations in SMW are a generalization of the category mechanism in MediaWiki [20].

It should be noted that *e-VUE* can be used in ontology construction only for top-level concepts or for fairly general (not narrowly specialized) training courses. For more specific information, it is advisable to use other industry-specific encyclopedic publications, in which information presented is based on SMW.

According to the described above algorithm for constructing a reference ontology pages, *e-VUE* slogans may use the following way.

1. To identify the main classes and terms of the subject area, you must select the category of *e-VUE* that are relevant to the desired subject area and select those pages slogans that are related to that subject area. To do this, you can use both the search for the names slogans and semantic queries in which conditions will be sets of categories that are

specific to the subject area, and the search results – page slogans and their semantic properties:

- to define a set of names, classes  $T$ , you need starting from the upper level – categories of fields of knowledge – come to the right subcategories names of these categories will meet classes ontology. The content pages of a category are submitted as follows: [[Category: Category name]];

- to define a set of names relation  $R$ , you need to analyze the found pages slogans and identify those semantic relations, which are connected between them, the names of these semantic relations will meet the ratio ontology greatly help in this can analysis templates that are used on pages slogans. In page content, semantic relations are represented as follows [[*property name:: property value | that display on the screen*]];

- that for the class of ontology to define a set of name attributes  $At$ , you need to analyze other semantic properties of pages that link to the data, the names of these semantic relations will meet the attributes of classes ontology;

- attribute types will help determine the type of semantic property value – *INT*, *STRING*, *NUMBER*, etc.

2. To build a taxonomy of domain terms, it is necessary to use the hierarchical relationships between *e*-VUE categories that are indicated on the Wiki pages of the selected categories.

3. To determine synonymy between ontology classes, you must use the links between the page slogans and categories.

4. To describe the instances of the constructed forms, you need to analyze the set of Wiki-pages of selected categories and the value of semantic properties.

It is known that an important component of any socially significant activity is the conceptual and terminological apparatus, which ensures the proper level of branch and general communication of the subjects of this activity (interoperability of concepts). Nowadays, various terms related to the particularly dynamic specific area of human activity related to information security have become widespread.

One example of open-source IP accessible through the Internet might be dictionaries from different subject areas that delve deep into the terminology of a particular subject area, and semantic markup allows for a link between the terms.

For example, the English-Ukrainian Dictionary of Information Technology and Cybersecurity Terms [21] provides in a structured way about 4,000 general and specific terms and concepts that are relevant to the field of cybersecurity, and details the modern foundations of cybersecurity.

The dictionary is a specialist-reviewed edition that can be actively used to create ontologies for both students and distance learning tutors.

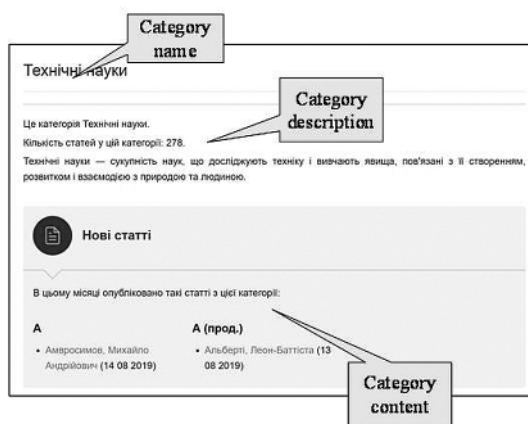


Fig. 4. Page *E*-VUE category of industry knowledge "technical science", which contains information about its subcategories.

## Prospects for use

The main advantages of the proposed approach: the learning outcomes are analyzed automatically, objectively and personally, based on high-level external IRs, students receive structured explanations for their mistakes and tutors can share their knowledge based on reference ontologies. Also, the appearance of changes in such external IPs will cause automatic changes to the content of the materials are being taught.

It is important for those disciplines that rapidly developing and dynamically changing (for example, information technology may reflect updates in software, programming languages, operating systems). This will provide relevant knowledge. However, effective implementation of the proposed ap-

proach requires the availability of a wide range of encyclopedic guides, which are implemented with modern knowledge management methods, con-

taining relevant and reliable information on native language and according to national educational programmes.

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*А.Я. Гладун*, канд. техн. наук, с.н.с., Міжнародний науково-навчальний центр інформаційних технологій та систем НАН та МОН України,  
просп. Глушкова, 40, Київ 03187, Україна  
E-mail: glanat@yahoo.com

*Ю.В. Рогушина*, канд. техн. наук, с.н.с., Інститут програмних систем НАН України,  
просп. Глушкова, 40, корп.5, Київ 03187, Україна  
E-mail: Ladamandraka2010@gmail.com

*К.О. Хала*, н.с., Міжнародний науково-навчальний центр інформаційних технологій та систем НАН та МОН України,  
просп. Глушкова, 40, Київ 03187, Україна  
E-mail: cecerongreat@ukr.net,

## ВИКОРИСТАННЯ ВІДКРИТИХ ЕНЦИКЛОПЕДИЧНИХ РЕСУРСІВ ДЛЯ СЕМАНТИЧНОГО ОЦІНЮВАННЯ РЕЗУЛЬТАТІВ НАВЧАННЯ

**Вступ.** Складні процеси усфері навчання в Україні потребують підвищення ролі формалізованого оцінювання знань студентів та розробки механізму офіційного визнання часткових кваліфікацій, набутих у системі формального, неформального й інформального навчання. Джерелом знань можуть виступати різноманітні енциклопедичні ресурси, словники, доступні в електронній формі та подані в такий спосіб, що забезпечують автоматизовану обробку поданого в них матеріалу. Забезпечення складних навчальних процесів потребує розробки інтелектуальних механізмів об'єктивного оцінювання результатів навчання на основі національних інформаційних ресурсів.

**Мета статті** – представлення підходів для побудови онтологій домену для подання знань викладача та студентів зі застосуванням зовнішнього джерела знань, а також алгоритм для автоматичного порівняння побудованих онтологій, що забезпечує відповідність ієрархічних рівнів у термінах таксономії. Спираючись на оцінки результатів навчання студентів, можна надавати структуровані пояснення щодо помилок, яких припустилися студенти.

**Методи.** Запропонований підхід використовує онтологію домену як інструмент навчання та як смислову модель результатів навчання студентів для оцінювання. Для онтології подання знань як зовнішнє джерело знань було запропоновано використання відкритих енциклопедичних ресурсів знань із семантичною розміткою, яка полегшує оброблення поданого в них матеріалу. Оскільки проблема порівняння довільних онтологій є дуже складною, для оцінювання результатів навчання студентів розглядався окремий випадок із багатьма обмеженнями, а саме легкі (термінологічні) онтології з порожньою множиною аксіом, з фіксованим набором зв'язків з наборами понять, що мають бути підмножинами множини понять еталонної онтології.

**Результати.** Запропоноване оцінювання результатів дистанційного навчання базується на аналізі онтологій дисципліни, створених студентами. Такі онтології будуються з основних концепцій сфери навчання та зв'язків між ними, запропонованих викладачем. Автоматизоване узгодження онтологій студентів із еталонною, розробленою викладачем, дозволяє виявити та класифікувати помилки учнів щодо розуміння дисципліни. Відкриті енциклопедичні ресурси використано як джерело знань для побудови й оновлення еталонної онтології дисципліни. Використання семантичної розмітки (наприклад, *SemanticMediaWiki*) енциклопедичним ресурсом значно спрощує отримання та подальше використання знань.

**Висновок.** Головна перевага запропонованого підходу – це можливість автоматизованого, об'єктивного та персоналізованого аналізу результатів навчання на семантичному рівні. Такий аналіз надає студентам структуровані пояснення їхніх помилок, а викладачам дає змогу поділитися своїми знаннями як еталонними онтологіями.

**Ключові слова:** семантична розмітка, електронна енциклопедія, онтологія, тезаурус, неформальне та інформальне навчання, компетентність.



*А.Я. Гладун*, канд. техн. наук, с.н.с., Международный научно-учебный центр информационных технологий и систем НАН и МОН Украины, просп. Глушкова, 40, Киев 03187, Украина, glanat@yahoo.com

*Ю.В. Рогошина*, канд. техн. наук, с.н.с., Институт программных систем НАН Украины, просп. Глушкова, 40, корп.5, Киев 03187, Украина, Ladamandraka2010@gmail.com

*К.А. Хала*, н.с., Международный научно-учебный центр информационных технологий и систем НАН и МОН Украины, просп. Глушкова, 40, Киев 03187, Украина, ceserongreat@ukr.net

## ИСПОЛЬЗОВАНИЕ ОТКРЫТЫХ ЭНЦИКЛОПЕДИЧЕСКИХ РЕСУРСОВ ДЛЯ СЕМАНТИЧЕСКОГО ОЦЕНИВАНИЯ РЕЗУЛЬТАТОВ ОБУЧЕНИЯ

**Введение.** Сложные процессы в сфере обучения в Украине нуждаются в повышении роли формализованного оценивания знаний студентов и разработке механизма официального признания частичных квалификаций, полученных в системе формального, неформального и информального обучения. Источником знаний могут выступать различные энциклопедические ресурсы, словари, доступные в электронной форме и представленные таким образом, что обеспечивают автоматизированную обработку поданных в них сведений. Обеспечение сложных учебных процессов требует разработки интеллектуальных механизмов объективной оценки результатов обучения на основе национальных информационных ресурсов.

**Цель статьи** – представление подходов к построению онтологий домена для представления знаний преподавателя и студентов с применением внешнего источника знаний, а также алгоритма для автоматического сравнения построенных онтологий, который обеспечивает соответствие иерархических уровней в терминах таксономии. Опираясь на оценки результатов обучения студентов, можно предоставлять структурированные объяснения допущенных студентами ошибок.

**Методы.** Предложенный подход использует онтологию домена как инструмент обучения и как смысловую модель результатов обучения студентов для проведения оценки. Для онтологии представления знаний как внешний источник знаний было предложено использование открытых энциклопедических ресурсов знаний с семантической разметкой, облегчающей обработку приведенных в них сведений. Поскольку проблема сравнения произвольных онтологий является очень сложной, для оценки результатов обучения студентов рассматривался частный случай со многими ограничениями, а именно, легкие (терминологические) онтологии с пустым множеством аксиом, фиксированным набором отношений и с наборами понятий, которые должны быть подмножествами множества понятий эталонной онтологии.

**Результаты.** Предложенная оценка результатов дистанционного обучения базируется на анализе онтологий дисциплины, созданных студентами. Такие онтологии строятся из основных концепций сферы обучения и отношений между ними, предложенных преподавателем. Автоматизированное сравнение онтологий студентов с эталонной, разработанной преподавателем, позволяет выявить и классифицировать ошибки учащихся в понимании дисциплины. Открытые энциклопедические ресурсы использованы как источник знаний для построения и обновления эталонной онтологии дисциплины. Использование семантической разметки (например, *Semantic MediaWiki*) энциклопедическим ресурсом значительно упрощает получение и дальнейшее использование знаний.

**Вывод.** Основным преимуществом предложенного подхода является возможность автоматизированного, объективного и персонифицированного анализа результатов обучения на семантическом уровне. Такой анализ предоставляет студентам структурированные объяснения их ошибок, а преподавателям дает возможность поделиться своими знаниями в качестве эталонных онтологий.

**Ключевые слова:** семантическая разметка, электронная энциклопедия, онтология, тезаурус, неформальное и информальное обучение, компетентность.