Semantic Support of Personal Learning Trajectory Development

Julia Rogushina[1,*], Anatoly Gladun[2], Olena Anishchenko[3] and Serhii Pryima[4]

[1] *Institute of Software Systems, National Academy of Sciences of Ukraine, 44 Glushkov Pr., Kyiv, 03680, Ukraine*
[2] *International Research and Training Centre of Information Technologies and Systems, National Academy of Sciences and Ministry of Education of Ukraine, 44 Glushkov Pr., Kyiv, 03680, Ukraine*
[3] *Ivan Ziaziun Institute of Pedagogical and Adult Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*
[4] *Dmytro Motornyi Tavria State Agrotechnological University, 66 Zhukovskogo str., Zaporizhzhia, 69063, Ukraine*

Abstract

This study is devoted to the problems of informational support for the andragogue professionalization. This problem is complex and interdisciplinary, therefore, in this article we consider only one of its components that concerns the automated development of personalized learning trajectory (PLT) for adult learners. PLT is a complex information object that contains many components and takes into account various parameters and the dynamics of their changes. The analysis of the andragogue's actions performed in the process of PLT generation shows the need in use of external knowledge sources – both relating to the learning course and to the structure of interaction between the student and the andragogue – at different stages of this work. In addition, we have to provide for the possibility of replacing existing sources of information with more relevant and high-quality ones. Therefore, we need to use semantic technologies aimed at the analysis and application of distributed knowledge.

In the paper, we analyze the main stages of andragogue activity aimed to form a set of learning materials for particular student, and found out appropriated semantic technologies that can be used at each of these stages. An ontological approach to representation of knowledge about the learning course and its terminology, about the competencies of students and about learning materials used in this process allows the integration of the proposed technology of information processing with external applications and knowledge sources.

The practical application of the proposed information technology is considered on the example of the learning course "UAV Engineer. Basic course". We select this example by several reasons, namely: the UAV control urgency and the need for effective implementation; 2) lack of a stable and coordinated learning course that meets the needs of today; 3) the need for mass training of a large number of adult students, who differ significantly by their skills and knowledge; 4) the need in regular update of the set of learning materials in accordance with changes in the technical features of drones and the results of their practical use.

Keywords

Semantic technology, ontology, thesaurus, andragogy, learning trajectory

Modern research in the field of digitalization of adult education that takes into account both global trends and Ukrainian realities and perspectives (they significantly actualize the need for adult education) identifies many problems in this multidisciplinary field. Solving these problems requires complex application of models, methods and technologies from various fields. In the broadest sense, learning can be considered as a process of transferring knowledge from one subject to another, and therefore, for the search, formalization, comparison and analysis of learning objects, it is advisable to use information technologies that are designed specifically for the acquisition, representation and transformation of knowledge. That is why we consider the possibilities of applying semantic technologies as a tool that can be used for more effective work of an andragogue. But it should be

14th International Scientific and Practical Conference from Programming UkrPROG'2024, May 14-15, 2024, Kyiv, Ukraine
* Corresponding author.
ladamandraka2010@gmail.com (J.Rogushina); glanat@yahoo.com (A.Gladun); anishchenko.olena@gmail.com (O.Anishchenko); pryima.serhii@tsatu.edu.ua (S.Pryima)
0000-0001-7958-2557 (J. Rogushina); 0000-0002-4133-8169 (A. Gladun); 0000-0002-6145-2321 (O.Anishchenko); 0000-0002-2654-5610 (S.Pryima)

taken into account that correct application of semantic technologies should be based on a detailed analysis of the tasks and goals that the andragogue solves and existing practices. Each andragogue task requires the creation of a technological chain for its solution, selection of relevant technology and integration with other components of learning process.

1. Relevance of the research task

Design of personalized learning trajectories (PLT) in cooperation with students is an important component of the professional activity of andragogues based on the results of a preliminary diagnosis of student's educational needs, cognitive and other individual characteristics. Student becomes a co-author of the PLT, a subject to the choice of differentiated ways of learning offered by educational institutions or other provider of learning services.

The urgency of PLT developing and implementing is determined by the feasibility of improving the learning process in formal and informal adult education institutions.

PLT provides the flexibility in planning the learning process and ensuring correspondence of student competencies with needs of the labor market. In a more global context, PLT can become a conceptual basis for learning that enables the development of communities of equal citizens [1].

During the war, PLT is one of the optimal solutions for students who are temporarily outside the country, are internally displaced persons or cannot sustainable study offline, online or in a mixed format due to missile attacks and other dangerous situation in their region as a whole. Therefore, the demand for the design of PLT of adult students is especially actualized in the conditions of the russian-Ukrainian war.

In the scientific discourse, several terms are used to denote the optimal prognostic models aimed on individualization of the learning activities of students: Personalized Learning [2] and individual learning [3]; Personalized Learning Pathways [4] and Educational Pathways [5]; Educational Trajectories [6, 7]; Developmental trajectories [8]; Personalized Learning Objects [9].

In our study, we use the term Personalized Learning Trajectories (PLTs) to interpret the process and sequence of training of learners in the field of adult education. In our opinion, PLT implies an individual style of educational activity of the student embodied in a sequence of learning steps that correspond to the level of his/her intelligence, opportunities, interests, etc.

IOT can be designed, implemented, and, if necessary, adjusted and coordinated by the andragogue.

It is important that these trajectories are not only individualized, that is, designed for particular student, but also such ones that use personal data about student who consciously provides access to this data and is built in interaction with the student.

Therefore, in our research we use the term Personalized Learning Trajectories (PLT) to define the process and sequence of learning.

PLT design involves three levels:

- *Content level* provides development and implementation of various learning courses used in PLT in formal, non-formal and informal education, learning modules, themes of research projects, etc. that take into account the student needs and wishes;
- *Technological level* deals with identification of personal qualities of students by various tests and questionnaires, defining their specific learning needs and selection of methods and technologies of learning, forms of independent work and forms of control of learning results, etc.
- *Resource level* includes retrieval and selection of information resources relevant to the proposed learning course, their structuring and methodological support for use for PLT implementation.

Andragogue in cooperation with the student usually implement the substantive and technological PLT levels without special obstacles. But resource level requires to take into account the large number of dynamic information objects to prevent reduction of their actuality. This procedure in manual variant requires a lot of time, but it can be automated on base of knowledge about learning domain and specifics of adult students. Therefore, the need for regular support of PLT in an up-to-date state makes it expedient to use innovative solutions based on semantic technologies. Such technologies supports knowledge-based retrieval and analysis of resources to match learning needs of student with semantics of learning course content.

2. Formulation of the problem

The goal of this work is to solve the problem of information overload of the andragogue caused by processing large amounts of dynamically changing information that contain knowledge about learning course. Development of personalized learning trajectories requires matching of all pertinent learning objects with individual characteristics and demands for every student. We have to take into account that professional and psychological characteristics of adult students differ much more than those ones of traditional students. Such differences are caused by various experiences, used learning approaches, prescription of learning, ability to perceive information and additional skills that are not directly related to the learning course, etc. Therefore, the work of an andragogue is significantly complicated by the need to take into account all these differences in the PLT generation.

The use of semantic annotation of subjects and objects of learning allows automating their comparison, and development of method for building thesaurus of learning course is aimed at formalizing the term system where this comparison is performed.

3. Ontological modeling in PLT development

Currently the use of ontology analysis for domain modeling is one of the most common approaches in the field of distributed knowledge processing.

Knowledge engineering considers ontology as a detailed description of some domain that provides formal and declarative definition of its conceptualization of this area [10]. Thus, the ontology can be considered a knowledge base of a special kind, and elements of ontology can be used independently for other tasks. The formalization of the ontology representation provides an unambiguous interpretation of its semantics

The formal model of the domain ontology [11] can be represented in the most general form as a triple $O=<X,R,F>$, where X is a non-empty finite set of domain concepts, R is a finite set of relations between these concepts, F is the set of functions for interpretation concepts from the set X and of relations from the set R.

This model can be refined depending on the domain features and the specifics of information objects.

In this work, we use two ontological models specially developed for this problem that represent different parts of domain knowledge:

- *Ontology of the andragogue professionalization* (Figure 1) models the structure of the learning process at the semantic level, defines the relations between the andragogue and the student, formally defines information objects that are important for this interaction (namely, the competencies, knowledge, skills and abilities that students acquire in the learning process; learning results; information resources used for learning, etc.), and specifies properties and relations between these objects to provide a terminological system for describing metadata parameters for objects and subjects of the learning process;

- *Ontology of the learning course* models the knowledge system of the learning course domain, defines a terminology system for describing the metadata values of instances of objects and subjects of the training process – LOs, students, training results.

Various knowledge sources need in specific means of processing, but their use with a help of various semantic services can enrich and unify the structure of learning course representation.

The ontological model of andragogue professionalization (Figure 1) determine the types of main objects and subjects of andragogy and relations between them on base of andragogues thesaurus and other documents analyzed above. We use Protégé for development and visualization of this ontology that corresponds Semantic Web standards.

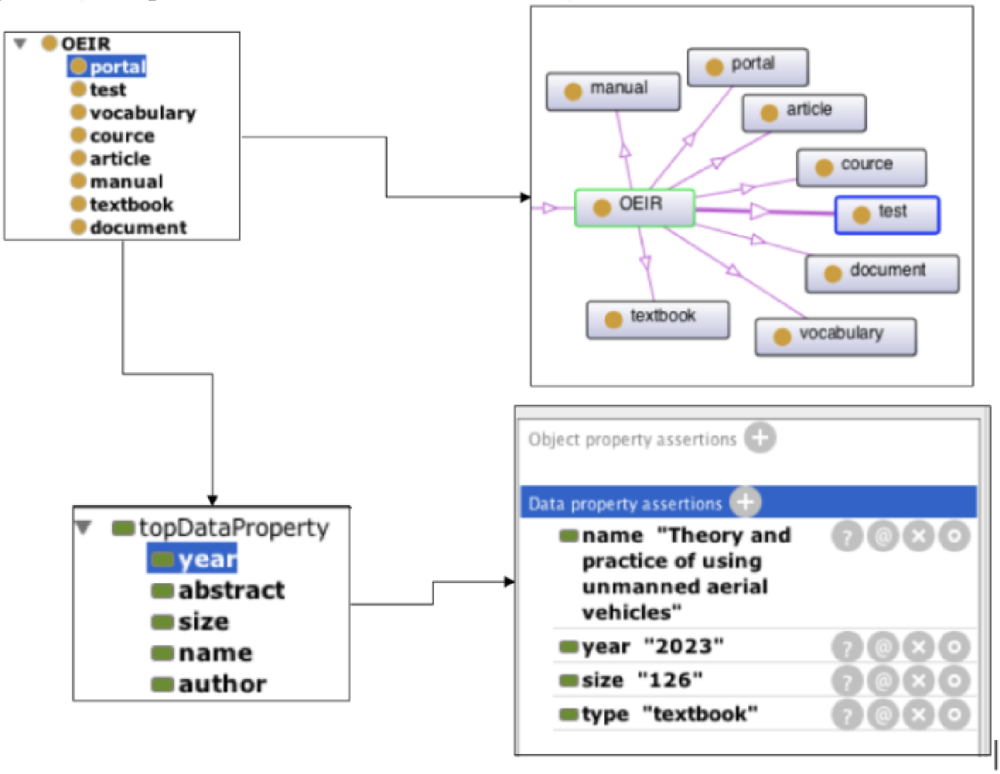

Figure 1: Ontology of andragogue professionalization (fragment).

The first ontology is general for all learning courses (it can be improved and replenished, but its overall structure does not change), and all andragogues can use it, and the ontologies of second type are developed (or can be selected among already existing ones) specifically for particular learning courses, and all andragogue can modify the ontologies of their courses according to their own believes about the domain and specifics of learning.

Other ontologies can be used as additional knowledge sources on all stages of ILT construction. For example, ESCO ontology of the European Multilingual Classifier of Skills, Competencies, Qualifications and Occupations [13] contains information about professions, skills and qualifications. It can be used to represent the specifics of the non-formal and informal learning outcomes (Figure 2).

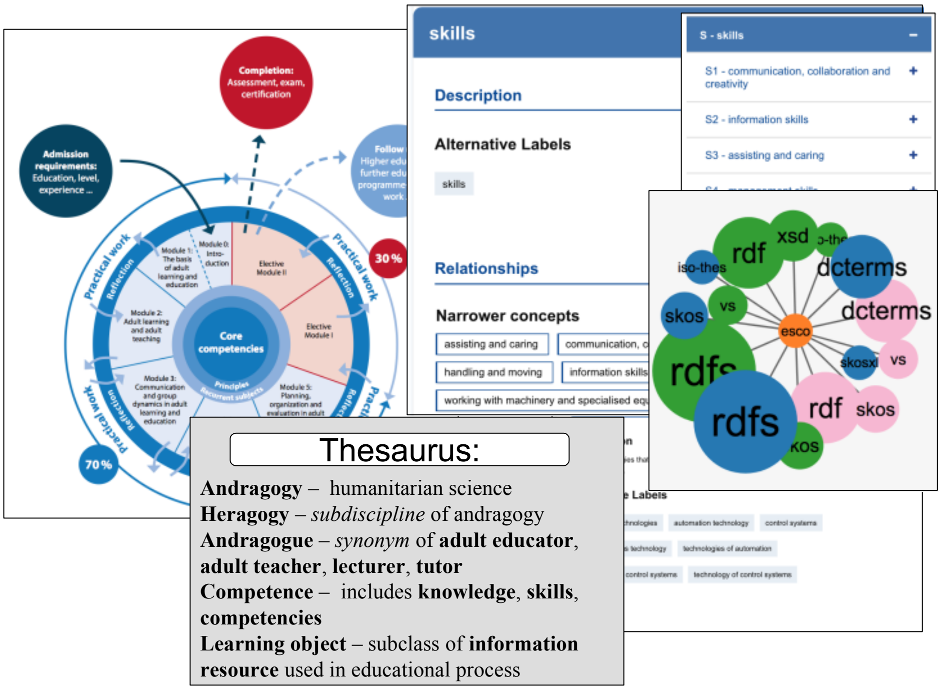

Figure 2: ESCO ontology (fragment).

4. Road map of resource level of PLT semantic support

After analyzing the various definitions and requirements for the construction of PLT, we identified an element that is common to most of them (explicitly or implicitly). This is a LO study plan, the result of which is that the student receives a full set of course competencies, regardless of which set he had at the beginning of his studies. Building this plan in accordance with the student's personal characteristics is the responsibility of the andragogue, and this is one of his main professional functions. Therefore, we determine the expediency of creating informational support for the construction of such a plan.

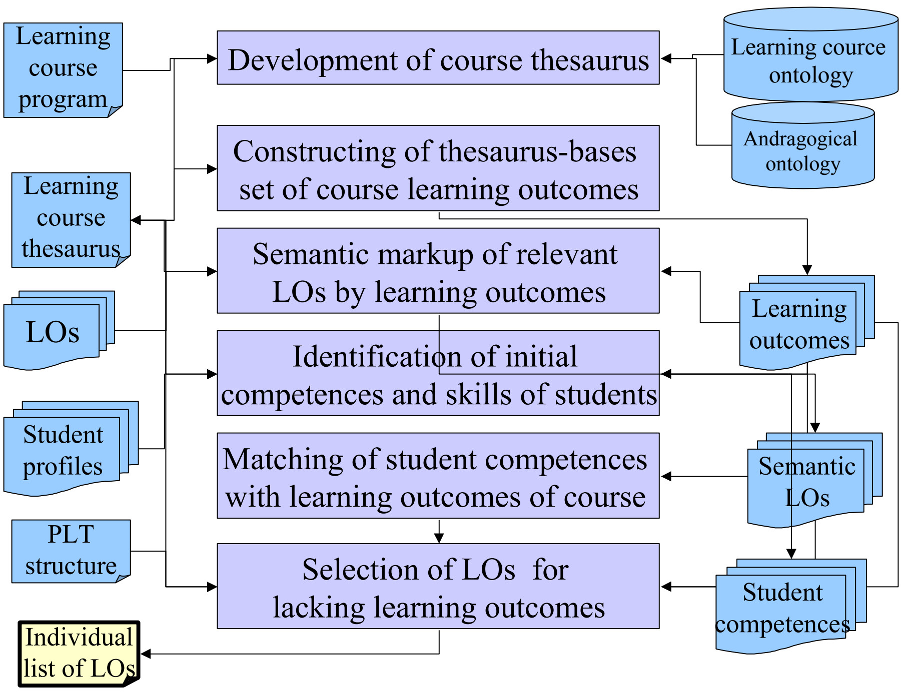

Figure 3: ESCO ontology (fragment).

This task requires to perform the following steps to move from natural language descriptions to some formal information model of learning and means of its semantic processing (Figure 3):

- build a term system of the course represented as thesaurus that includes main concepts and relations based on ontological model of andragogue professionalization and defines the basic subjects and objects of learning process, their properties and relations, and on ontological model of learning domain that represents specifics of course knowledge;
- determine a set of learning outcomes based on the course thesaurus, turning natural language phrases from course content into logical constructions built from the thesaurus concepts and relations;
- select a set of LOs relevant to the course and perform semantic markup of each LO (create LO meta-descriptions), using the thesaurus and learning outcomes as metadata elements;
- determine the existing knowledge and skills of students and formalize them in the same term system of course thesaurus enriched by elements of external knowledge bases (such as ESCO ontology) and services (such as advisory system AdvizOnt [14]);
- determine for each student what learning outcomes he/she needs to achieve, and build a set of LOs that ensures this process.

4.1 Development of the course thesaurus

The main technological phases of thesaurus development [15] in general case are:

Phase 1. Formation of the T dictionary by selection of lexical units and their definitions.

Phase 2. Development of a set of semantic relations R that can define links between elements from T.

Phase 3. Establishing connections between terms as a set of triples $< t_i \in T, r_k \in R, t_j \in T >$ that define relations between elements of T by elements from R .

Phase 1 is usually based on the linguistic analysis of domain-related natural language texts and requires a lot of computation and interaction with domain experts. But the use of encyclopedias allows you to significantly simplify this stage.

Phase 2 has to take into attention the goals of thesaurus development and select domain relations that are significant for these goals. Phase 3 takes the most time, because the thesaurus population needs to process a sufficient number of IRs that can contain information about relations between concepts.

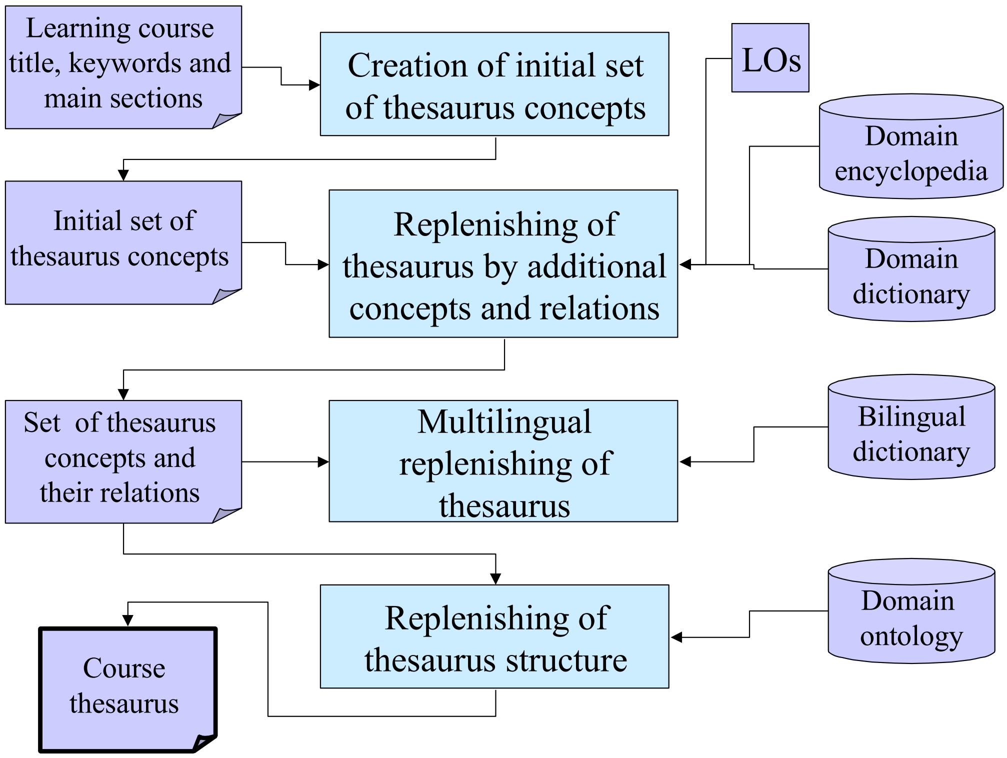

Figure 4: Main stages of course thesaurus development (fragment).

Use of structured IRs can significantly simplify all 3 phases but reduces the thesaurus content by earlier provided domain model (Figure 4):

Stage 1. Construction of the initial set of thesaurus concepts is based on: keywords of the course title; key words from the titles of the lectures.

Stage 2. Replenishing the thesaurus with an expanded set of concepts with use of external sources of knowledge both structures (encyclopedias, dictionaries, glossaries, etc.) and natural language ones (course textbooks, lectures, other course learning objects) that contain additional course concepts and define relations between them.

For keywords, selected on Stage 1, we find relevant definitions in online dictionaries and encyclopedias. This information is more structured and unified. Thus, it is necessary to choose at least one article of the encyclopedia relevant to the course. After that, the title of the article is added from the thesaurus (in addition, a short definition from the abstract of the article can be saved to the thesaurus). The next step is to follow the links in this article (these may be hyperlinks to other articles or categories to which the article belongs). If the information on the links is also relevant to the PR, then the names of the slogans are also added to the thesaurus.

If this information is insufficient, we find definitions and explanations of concepts into course LOs.

Stage 3. Multilingual replenishment of thesaurus [16] by translation of concepts selected on Stage 2 from initially selected natural language into desired ones with the help of on-line bilingual dictionaries. At this stage we can use other course thesauri created earlier for other languages and join them. Thesaurus combination methods are based on establishing mutually-unique correspondences between concepts and relations (for example, synonyms or terms in different languages) and integrating all other content according to these correspondences.

Stage 4. Supplementing course thesaurus with knowledge from domain ontologies. The use of ontologies allows replenishing the thesaurus with significant domain concepts and specifying semantics of relations between them, but it is important to choose the appropriate ontology correctly. In this work, it is advisable to use ESCO and existing domain ontologies.

Thus, the use of ontologies, dictionaries, and encyclopedias greatly simplifies the construction of the course thesaurus. At the same time, the selection of relevant knowledge sources is an important factor in the effectiveness of the proposed approach. For example, universal encyclopedias are usually enough to build the upper level of the domain terminology system, but it is advisable to use branch and specialized encyclopedias to correctly fill in the lower levels.

After these 4 stages, we can create a set of course competencies (learning results) built by the thesaurus concepts. These local competencies can be linked to various classification systems describing competencies and specialties

4.2 Generation of course learning outcomes

The set of course learning outcomes [17] is constructed by andragogue who has to create such constructions from thesaurus Th elements $< t_i \in T, r_k \in R, t_j \in T >$ that represent main semantic units learned by students.

It is important to single out some atomic elements of domain knowledge that are not intersected and cover all competencies and skills that students have to obtain from course LOs.

Andragogue can define such learning outcomes for every structural element of course by analysis of semantics of lectures, practical training, tests, etc.

We can consider learning outcomes as a set $RE = \{re_i\}, i = \overline{1,k}$ that can considered as a function of course content and course thesaurus Th: $RE = f(Th, Course)$ where each $re_i =< t_{i_1}, ..., t_{i_p} >, t_{i_k} \in T \cup R$.

Process of construction of learning outcome set consists in replacement of relevant natural language (NL) phrases from course program and context by thesaurus elements. This process can be automated partially by means of NL analyzers but requires control of domain expert. We have to take into account that this procedure is rather subjective and depends on andragogue beliefs about relative importance of different parts of learning materials.

4.3 LO semantic markup by course thesaurus elements

We propose to use semantic Wiki [18] as a technological platform for creating meta-descriptions of LOs at the semantic level.

Semantic extension Semantic MediaWiki [19] of Wiki technology MediaWiki [20] allows applying an arbitrary set of markup tags based on the course thesaurus. This software provides means for development of the repository of LOs used by the andragogue in the learning. Such repository can contain both LOs from the learning domain and various information resources from the field of andragogy.

We chose MediaWiki and its semantic extension Semantic MediaWiki because this platform provides opportunities for collaborative content creation, easy integration with other web applications, support for Semantic Web standards [21], and possibility of scalable solutions. As a result, the LO repository can be replenished by different andragogues working in similar fields at the same time, and at the same time each of them can use their own set of tags to index the content. Andragogues can use concepts from the thesaurus of the learning course, from thesaurus of corresponding task [15] and from an arbitrary domain ontologies [22], and this markup and the LOs themselves can be available to all members of the community.

Installing the Semantic MediaWiki plug-in enables advanced semantic search of LOs by categories and semantic properties (such as types of documents and tools, their authors, years of creation, languages of representation, etc.), and by various combinations of these parameters. In addition, the use of competencies as a tool for describing the semantics of documents allows to find information support for various tasks. Wiki templates can be used for unifier representation of typical LOs.

The use of Wiki technology simplifies the export of information from other Wiki resources – both semantic and traditional ones. The ontological model of learning process proposed in the previous section is used as a source of tags for the semantic markup of the Wiki pages that correspond to LO individuals. This markup can be added to the already existing Wiki markup - both directly and with the help of LO templates, and parameters of these templates are interpreted as semantic properties of the page.

Such templates can be created by each user of the repository, but in order for the LO search to be effective, it is necessary to use unified names of these properties. For this purpose, it is possible to apply information from the corresponding external ontology or thesaurus that describe the permissible characteristics of LOs and the connections between them.

For example, template for LO “Textbook” has the following structure:

{{Textbook
|Name=
|Type=Textbook
|Competence=
|Author=
|Volume=
|Author=
| Abstract =
|Language=
}}

The semantic property "Competence" has a non-empty set of values chosen from the set of learning outcomes $RE = \{re_i\}, i = \overline{1,k}$ of the C course constructed by the andragogue at the previous stage. If LO indexing is performed for different educational courses $C_1,...,C_m$ by one or different andragogues, then the values of this property can belong to the union of these sets $\bigcup_{j=1}^{m} RE_j$. At the same time, it is desirable to use different names to denote different learning outcomes

.

4.4 Identification of student competencies in course thesaurus terminosystem

An important feature of adult learning is heterogeneity of student knowledge and skills before beginning of learning process. This fact causes an actuality of identification of their competencies relevant to learning course. Such identification can help in development of their PLTs and has to reflect real state of their readiness for learning. We have to take into account results of previous formal, informal and non-formal learning and allow for their actuality. Use of professions and documentary defined qualifications is not a sufficient instrument for this goal. Therefore we need in semantic analysis of user profiles with use of external knowledge models of learning domain.

In general case, identification of competencies can be based on some *competence ontology* that defines semantic properties and relations of learning domain. It provides a base for representation of the various information objects deal with qualification of people. In [23] a competence $c \in C$ is considered as a core element of such ontology that is used as a property for describing of relations between other objects such as organization, specialty, discipline, person, etc., and their subclasses. For example, class “person” has subclasses “student’, “employer”, “andragogue”, “researcher”, “postgraduate student” etc. These classes have various semantic properties with values from class “competence” that define their use of competence obtaining. For example, andragogue A teaches student S for competence C, learning object O is used for learning of competence C, and student C learns this competence C.

In this work we use some subset of these classes that are used for formalization of adult learning.

Competencies can be divided on two main groups $C = C_{atomic} \cup C_{complex}$: atomic competencies C_{atomic} and complex competencies $C_{complex}$: where every complex competence can we defined by the non-empty set of atomic ones, but any atomic competence can not be defined by other competencies. From the point of view of ontological analysis, atomic and complex competencies are disjoint subclasses of class “Competence”.

External knowledge bases that can be used as sources of competence classification need in additional services for access and acquisition of relevant information. For example, advisory system AdvizOnt [14] provides services for analysis of competencies of potential employees and selection of learning courses to enrich them to desires vacancies. These services can be used for more particular case of this task requires for identification of student competencies. AdvizOnt uses the

ESCO ontology of the European Multilingual Classifier of Skills, Competencies, Qualifications and Occupations [13] to represent the specifics of the non-formal and informal learning outcomes. Main elements of ESCO are professions, skills and qualifications.

AdvizOnt processes profiles of user that contains non-formal representation of information (skills, qualification, non-formal and informal learning outcomes, background, cognitive style, etc.) into the formalized set of competencies according to selected ontological structure. But processing of arbitrary ontology is rather complex process that needs a lot of calculations. In this work we use a special case of competence ontology based on learning course thesaurus. We don't take into account other aspects of competence analysis (such as matching of vacancies and resumes). We consider a subset of possible competencies of students defined by list of course learning results defined on previous step.

This approach significantly reduces the dimensionality of decisions and provides a much simpler matching of information from the user profiles and descriptions of those learning outcomes needed to determine the ILT of a specific educational course

We propose the following method of competence identification:

- AdvizOnt services process student profile p_k and create general set of formal competencies of this student $compet_A(p_k)$;
- for every element of the set $R = \{r_k\}, k = \overline{1,q}$ andragogue defines the set of relevant NL words and word combinations for each learning result $W = \{w_{k_m}\}, k_m = \overline{1,q_m}$ where $sem(w_{k_m}) = r_k$;
- then $compet_A(p_k)$ is matched with $W = \{w_{k_m}\}, k_m = \overline{1,q_m}$: $R_k = \bigcup_{k=1}^{p} mm(compet_A(p_k) = w_{k_m})$, where matching function mm is defined by the rule: if $compet_A(p_k) = w_{k_m}$ then student has learning result $sem(w_{k_m}) = r_k$ else student has not learning result $sem(w_{k_m}) = r_k$.

As a result, we generate the set of student competencies $\mathrm{R_k}$ relevant to learning course as a union of such $\mathrm{r_k}$: $c\_compet(p_k) = mm(compet_A(p_k)) \subseteq RE$.

4.5 Generation of personified LO lists for students according to their initial competencies

Process of generation of personified LO list for student k can be represented as a result of matching R_k set that contains course-relevant initial competencies of this student with metadata of LOs that define competencies that they provide.

This matching can be represented as a semantic query that finds information objects from LO class with values of semantic property "Competence" from the set RC (requires competencies) defined as set complement of R_k to RE: $RC_k = RE / R_k$, it means that $r_i \in RC_k$ if $r_i \in RE, r_i \in R_k$.

For example, it can be represented as built-in query of Semantic MediaWiki

```
{{#ask:
[[Category:LO]]
[[Competence::!~{{{Initial_competence}}}]]
[[Competence::{{{Current_course}}}]]
 |?Competence
 |?Annotation
 |format=broadtable
 |limit=10
```

|offset=0
|link=all
|sort=
|order=asc
|headers=show
}}

This query activated from student individual page finds all LOs that contain such learning results of current course with title "Course_name_FFF" that this student doesn't have at the current time.

If we use Semantic MediaWiki as technological base for representation of semantically marked LOs, then the result of such query can be represented as a table where rows correspond to LOs and column content values of semantic properties defined into query. Information into table can be resorted by every property. Such representation is much more convenient for students that can select appropriate LOs for every learning result by representation form, NL, year, volume, etc.

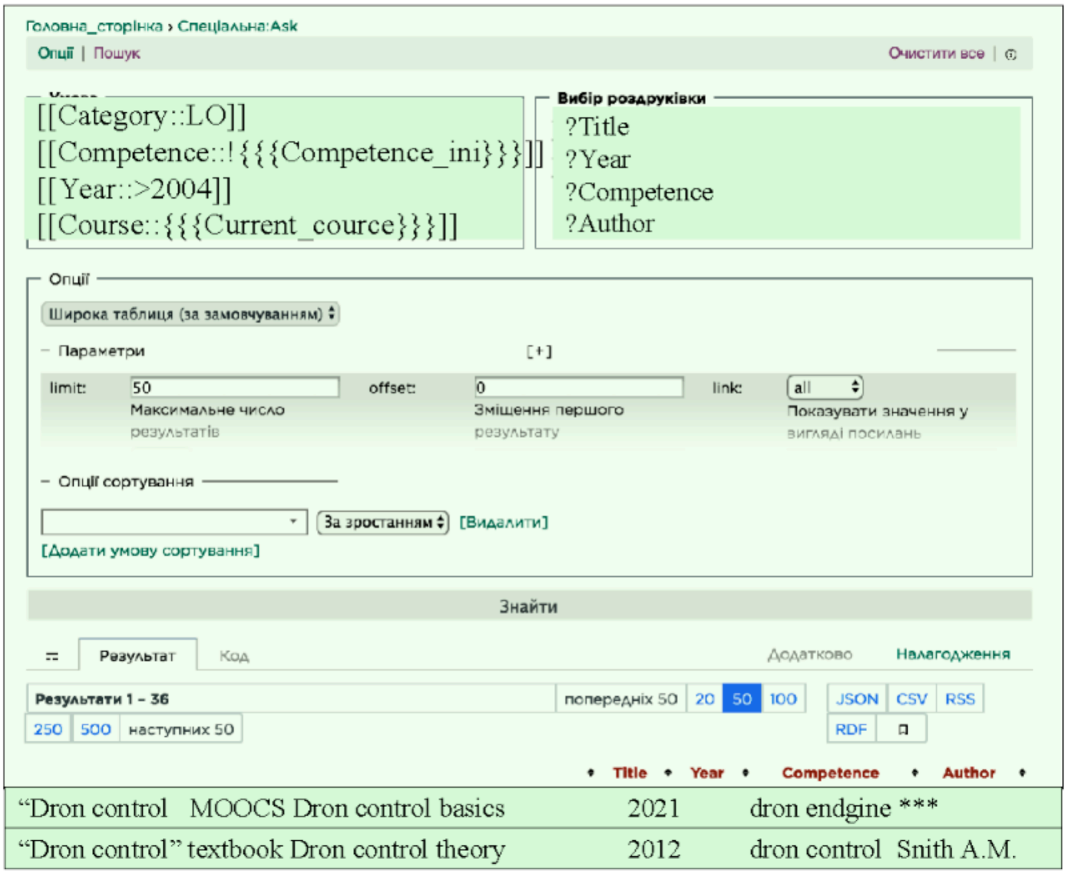

Figure 5: Representation of search for selected set of learning results.

In this demonstration example (Figure 5) we use "magic names" of MediaWiki and elements of ASK query language of Semantic Media Wiki (for representation of current Wiki page characteristics and comparators) that are oriented on use only in built-in semantic queries. Therefore this query can not be executed from the Special page:Ask that is used for automated generation of standard elements of query code.

5. Practical implementation on example of learning course "UAV Engineer. Base Course»

This example shows practical aspects of development of PLT elements on base of proposed approach.

5.1 Development of the thesaurus for course "UAV Engineer. Base Course»

Analysis of course "UAV Engineer. Base Course» description and titles of lectures and practical tasks results formation of:

- Course dictionary *T*=<UAV, drone, copter, aerodynamics, electronic module, software, sensor, navigation device, maintenance, drone assembly, drone breakdown, drone repair, drone engineering, ...> (in this example we propose only a fragment of T set).
- This dictionary is supplemented with terms from andragogue dictionary that contains general learning concepts *Ta*=<knowledge, skill, module, ability>.
- List of course relations *R*=<is a subclass, has class, affects, is of part, detect, control, needs in, affects, executes>.
- This list is supplemented with relations from andragogue list of general learning relations Ta=<know, learn, has competence, understand>.

Then we generate the thesaurus itself in the form of triples $< t_i \in T, r_k \in R, t_j \in T >$ (Table 1). It is important that in general case we can use more complex combinations of concepts with more then three elements.

Table 1
Thesaurus for course "UAV Engineer. Base Course» (fragment)

t	r	t
UAV	is subclass	drone
UAV	needs in	UAV operating
UAV	needs in	UAV modeling
UAV operating	synonym	UAV flight control
copter	is subclass	UAV
dron	has	dron mission
dron	is a member of	dron swarm
UAV swarm	needs in	operating
aerodynamics	affects	UAV modeling
weather conditions	affect	UAV modeling
electronic module	is part of	UAV
software	is part of	UAV
navigation device	is part of	UAV engineering
maintenance	is part of	UAV engineering
drone assembly	is part of	UAV engineering
drone breakdown	is part of	UAV engineering
drone repair	is part of	UAV engineering

5.2 Generation of course "UAV Engineer. Base Course» learning outcomes

Construction of the set $RE = \{re_i\}, i = \overline{1,k}$ for this course is based on thesaurus *Th.* If some important element of learning results can not be represent by Th concepts then we have to return to the previous step and add this element to *Th.*

Examples of earning outcomes of course "UAV Engineer. Base Course» are:

- ability to acquire knowledge about drone mission;
- ability to operate UAV swarm;
- ability to operate UAV;
- ability to execute drone repair;

- ability to detect drone breakdown;
- ability to use aerodynamics for UAV modeling;
- ability to use weather conditions for UAV modeling.

5.3 Semantic markup of LOs relevant for course "UAV Engineer. Base Course»

We propose some examples of semantic markup of LOs that correspond to selected learning course. This markup is based on Semantic MediaWiki syntax and use Wiki templates developed for representation of various types of LOs that contain parameters for semantic properties "Competence" with values from course set RE. We consider LOs of types Textbook, Lecture, Article, etc.

{{Textbook

|Name=Theory and practice of using unmanned aerial vehicles (drones)

|Type=Textbook

|Competence=ability to operate UAV swarm; ability to use aerodynamics for UAV modeling ; ability to use weather conditions for UAV modeling; ability to execute drone repair; ability to detect drone breakdown;

|Author=Petrenko I.V.

| Abstract =This course is designed to train operators of unmanned aerial vehicles of the aircraft and multicopter type.

|Year of publication=2023

|Country=Ukraine

|City=Kyiv

|ISBN=978-966-370-793-8

|Volume=126

|Language=Ukrainian

}}

Other example describes videolectures.

{{Lecture

|Name=Fundamentals of aerodynamics: definitions, basic principles, concepts and hypotheses

|Type=MOOCs Lecture

Competence = ability to use aerodynamics for UAV modeling Publisher - Prometheus site -

|Author = Kharchenko A.P.

| Abstract = The lecture gives the concept of aerodynamics and the study of the interaction of air with moving objects - wings, fuselage, and other elements of an airplane or UAV.

|Year =2023

|Country=Ukraine

|Duration=25 min.

|Language=Ukrainian

}}

Visual representation of information about LOs on Wiki pages is unified on base of used templates (Figure 6).

Name	**Fundamentals of aerodynamics: definitic basic principles, concep and hypotheses**
Type	MOOCs Lecture
Competence	*ability to use aerodyna for UAV modeling*
Author	Kharchenko A.P.
Year	2023
Country	Ukraine
Duration	25 min.
Language	Ukrainian
The lecture gives the concept of aerodynamics and the study of the interac of air with moving objects - wings, fusela and other elements of an airplane or UAV	

Name	**Theory and practice of using unmanned aerial vehicles (drones)**
Type	Textbook
Competence	*ability to oparate UAV swarm; ability to use aerodynamics for UAV modeling ; ability to use weather conditions for UAV modelin; ability to exequte drone repair; ability to detect drone breakdown*
Author	Petrenko I.V.
Year	2023
City	Ukraine, Kyiv
ISBN	978-966-370-793-8
Volume	126
Language	Ukrainian
This course is designed to train operators of unmanned aerial vehicles of the aircraft and multicopter type. The course does not contain academic knowledge, but provides practical recommendations and personal experience in the management of UAVs.	

Figure 6: Representation of information about LOs on their Wiki pages.

5.4 Identification of student competencies for course "UAV Engineer. Base Course»

As we consider above, process of identification of student competencies deals with transformation of student profile into the subset of RE on base of external semantic services. This profile can contain such personal data as full name, date and place of birth, scientific degree, profession, place of study, obtained qualifications, resume, places of work and positions, etc. This information is transformed according to structure of Wiki template Student

{{Student
|First name=
|Second name=
|Scientific degree=
|Competence=
|Profession=
|Year of births=
|Place of birth=
|Gender=
|Alma mater=
|Place of activity=
|Directions of activity=
}}

An example of information about student (this example does not contain real personal data):

{{Student
|First name=Shtonda
|Second name=Viktor
|Scientific degree=PhD
|Competence=ability to use aerodynamics for UAV modeling; ability to use weather conditions for UAV modeling
|Profession=mathematician, engineer

|Year of birth=1958
|Place of birth=Kyiv
|Gender=m
|Alma mater=Kyiv state university
|Place of activity=Institute of ABCD
|Directions of activity=technical modeling, software development
}}

Visual representation of information about LOs on Wiki pages is unified on base of used templates (Figure 7).

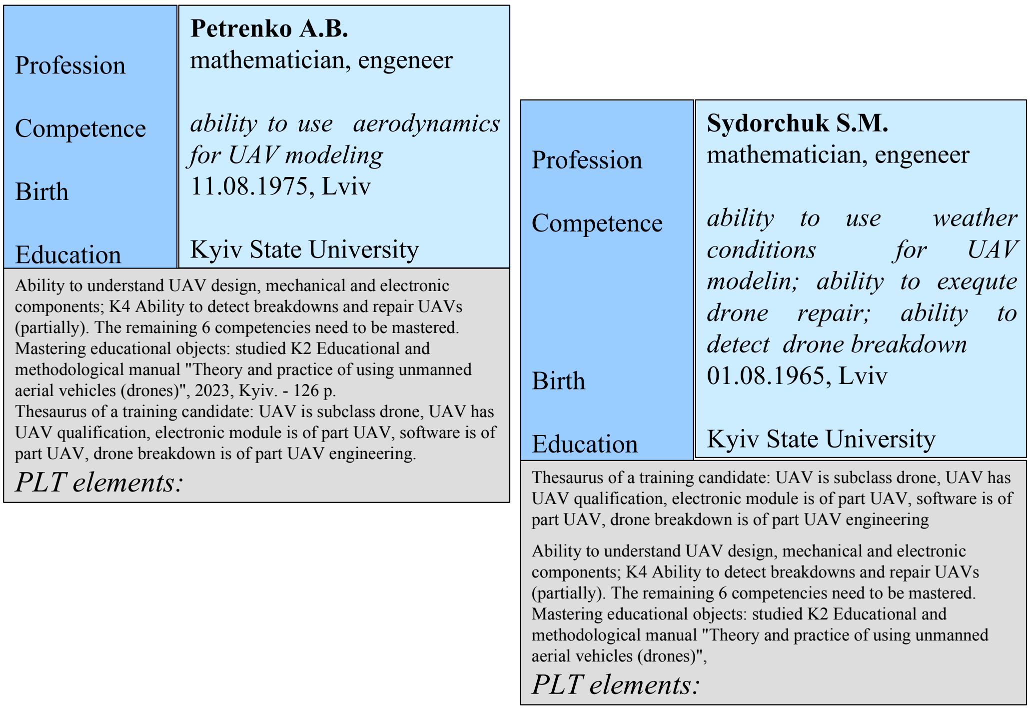

Figure 7: Representation of information about LOs on Wiki pages.

5.5 Identification of student competencies for course "UAV Engineer. Base Course»

On base of previous stage we match the set of initial student competencies with the set RE and build set complement of learning results. This set is used as a parameter for query (as it is described in 4.5) that find previously marked LO with relevant learning results. Query results (Table 2) can be represented individually on student Wiki page or in general for andragogue with information about m students (table rows) and k learning results (table columns) on the course Wiki page.

Table 2
LOs proposed for students for course "UAV Engineer. Base Course» (fragment)

	re_1	re_2	re_k
r_1	know	LO_2, LO_5, LO_p	know
r_2	LO_1, LO_2, LO_p	LO_2, LO_5, LO_p	LO_1, LO_p
r_3	LO_1, LO_2, LO_p	LO_2, LO_5, LO_p	LO_1, LO_p
r_4	LO_1, LO_2, LO_p	know	know
…			
r_m	know	LO_2, LO_5, LO_p	LO_1, LO_p

This information can be used by andragogue and student to select the most appropriate ones for PLT generation. On base of analysis of student features and minimization of general number of LOs for every student Table 2 is transformed into Table 3 that provides the base for PLT execution.

Table 3
LOs selected for students for course "UAV Engineer. Base Course» (fragment)

	re_1	re_2	re_k
r_1	know	LO_2	know
r_2	LO_1	LO_5	LO_1
r_3	LO_1	LO_2	LO_p
r_4	LO_p	know	know
...			
r_m	know	LO_p	LO_p

The rules and criteria by which the andragogue and the student jointly choose the most acceptable LOs from the set of proposed ones are beyond the scope of this article. They can be based both on the relevance and verifiability of the sources [24], additional properties of LOs [25], their reusability [26] and on the individual characteristics of the student regarding the information perception in accordance with his/her psychophysiological type. More complex solutions involve minimizing the number of LOs for one student and their unification for the entire group.

Conclusion

An important feature of adult learning is heterogeneity of student knowledge and skills before beginning of learning process. This fact causes an actuality of identification of their competencies relevant to learning course. Such identification can help in development of their PLTs and has to reflect real state of their readiness for learning. We have to take into account results of previous formal, informal and non-formal learning and allow for their actuality. Use of professions and documentally defined qualifications is not a sufficient instrument for this goal. Therefore we need in semantic analysis of user profiles with use of external knowledge models of learning domain.

The role of personal educational trajectories (PLT) in learning of adults is growing significantly in comparison with the formal education of persons of the same age.

PLT design consists of content, technological and resource levels. Andragogue has to design this trajectory, determine the content of training, define its technological foundations and select required resources. The basic set of competences of an andragogue is sufficient to work at the first and second levels, but at the third level it is advisable to automate the search and comparison of large data sets, rather than to do it manually. This activity aimed to specify the PLT in the form of a study plan for a set of relevant LOs can be automated only partially.

The automation of the PLT creation requires the formalization of information both about the learning course and related LOs, and about students, by application of such models of knowledge representation that are used in semantic technology. Therefore, we propose a roadmap that includes the construction of a course thesaurus to describe the course learning outcomes, semantics of learning materials and initial competencies of students in terms of this thesaurus. This terminological unification greatly simplifies their comparison by reduction of matching of NL descriptions to comparison keyword sets .

In the future, we plan to use these descriptions of learning objects for solution of more complex intelligent tasks. For example, we plan to determine the semantic similarity of different educational courses as a search tool used for higher levels of PLT development and to form groups of students with similar information needs and initial competencies.

In addition, the thesaurus of the course can be used as a semantic basis for retrieval for relevant LOs in the open information space of the web.

References

[1] A. Membrive, N. Silva, M. José, R. I. Merino, Advancing the conceptualization of learning trajectories: A review of learning across contexts. Learning, Culture and Social Interaction, 37(3) (2022):100658. doi:10.1016/j.lcsi.2022.100658.

[2] K. Wozniak, Personalized Learning for Adults: An Emerging Andragogy. In: S. Yu, M. Ally, A. Tsinakos (eds), Emerging Technologies and Pedagogies in theCurriculum. Bridging Human and Machine: Future Education with Intelligence. Springer, Singapore, 2020. doi:10.1007/978-981-15-0618-5_11.

[3] J. Hughey, Individual Personalized Learning. Educational Considerations, Vol. 46, 2 (10) (2020). doi:10.4148/0146-9282.2237.

[4] What Are Personalized Learning Pathways? Leadership in Action: a briefing series for new England's educational leaders. Available at https://www.newenglandssc.org/wp-content/uploads/2015/12/nessc_briefing_no6.pdf.

[5] M. Garcia Gracia, A. Sánchez-Gelabert, and O. Valls, Educational pathways, traceability, and self-perception of academic performance in post-compulsory transitions. Revista de Educación, 396 (2022): 95–123. doi:10.4438/1988-592X-0034-8082-RE.

[6] P. Schnell, R. Fibbi, Getting Ahead: Educational and Occupational Trajectories of the 'New' Second-Generation in Switzerland. Int. Migration & Integration, 17 (4) (2016): 1085–1107. doi:10.1007/s12134-015-0452-y.

[7] K. Burger, Human agency in educational trajectories: Evidence from a stratified system. European Sociological Review, 37(6) (2021): 952–971. doi:10.1093/esr/jcab021.

[8] S. Reder, Developmental trajectories of adult education students: Implications for policy, research, and practice. In D. Perin (Ed.), The Wiley handbook of adult literacy, Wiley Blackwell, 2020, pp. 429–450. doi:10.1002/9781119261407.ch20.

[9] M. Pavlis Korres, E. García-Barriocanal, Development of personalized learning objects for training adult educators of special groups. Journal of Knowledge Management, Vol. 12, 6 (2008):89–101. doi:10.1108/13673270810913649.

[10] N. Guarino, D. Oberle, and S. Staab, What is an ontology?. Handbook on ontologies, (2009):1–17.

[11] T. Gruber, Ontologies. Encyclopedia of Database Systems, (2008). 1959-1959.

[12] R. Sivakumar, P. V. Arivoli, Ontology visualization PROTÉGÉ tools–a review. International Journal of Advanced Information Technology (IJAIT), 1(4) (2011):1–11.

[13] ESCO (the European Multilingual Classifier of Skills, Competencies, Qualifications and Occupations). Available at https://ec.europa.eu/esco/portal/home, last accessed 20.10.2023.

[14] S. Pryima, J. Rogushina, O. Strokan, Use of semantic technologies in the process of recognizing the outcomes of non-formal and informal learning. UkrPROG-2018: Proc. of the 11th International Conference of Programming, CEUR Vol-2139. (2018): 226-235. http://ceur-ws.org/Vol-2139/226-235.pdf.

[15] J. Rogushina, A. Gladun, Task Thesaurus as a Tool for Modeling of User Information Needs. In New Perspectives on Enterprise Decision-Making Applying Artificial Intelligence Techniques, Springer, Cham, 2021, pp. 385-403. doi:10.1007/978-3-030-71115-3_17

[16] M. Hudon, Multilingual thesaurus construction–integrating the views of different cultures in one gateway to knowledge and concepts. Information services & use, 17(2-3): (1997), 111–123.

[17] S. M. Pryima, O. V. Strokan, J. V. Rogushina, A. Y. Gladun, D. V. Lubko, V. M. Malkina, Ontological Analysis of Outcomes of Non-formal and Informal Learning for Agro-Advisory System AdvizOnt. In International Conference on Technologies and Innovation, Springer, Cham, 2020, pp. 3–17. URL: https://link.springer.com/chapter/10.1007/978-3-030-62015-8_1.

[18] S. Schaffert, Bry, F., Baumeister, J., M. Kiesel, Semantic wikis. IEEE software, 25(4) (2008): 8–11.

[19] Y. Koren, Working with MediaWiki, San Bernardino, CA, USA: WikiWorks Press. 2012, pp. 157–159.
[20] M. Krötzsch, D. Vrandečić, M. Völkel, Semantic mediawiki. In: International semantic web conference. Berlin, 2006, pp. 935–942.
[21] A. Gómez-Pérez, O. Corcho, Ontology languages for the semantic web. IEEE Intelligent systems, 17(1) (2002): 54–60.
[22] J. Rogushina, Ontological Approach in the Smart Data Paradigm as a Basis for Open Data Semantic Markup. COLINS-2023: 7th International Conference on Computational Linguistics and Intelligent Systems, CEUR Vol-3403 (2023):12–27. URL: ceur-ws.org/Vol-3403/paper2.pdf
[23] J. Rogushina, S. Priyma, Use of competence ontological model for matching of qualifications. Chemistry: Bulgarian Journal of Science Education, 26, 2 (2017): 216-228. URL: http://elar.tsatu.edu.ua/bitstream/123456789/3181/1/2.pdf.
[24] S. Başaran, Multi-criteria decision analysis approaches for selecting and evaluating digital learning objects. Procedia Computer Science, 102 (2016): 251–258.
[25] N. Palavitsinis, N. Manouselis, and S. Sanchez-Alonso, Metadata quality in learning object repositories: a case study. The Electronic Library, 32(1) (2014): 62–82.
[26] R. J. Windle, D. McCormick, J. Dandrea, and H. Wharrad, The characteristics of reusable learning objects that enhance learning: A case-study in health-science education. British Journal of Educational Technology, 42(5) (2011): 811–823.