Semantic analysis of learning objects: thesaurus approach for digital transformation of educational resources

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Abstract

This study is devoted to the problems of developing digital resources for education based on the use of semantic technologies and knowledge management models aimed at analysing educational content. Digital transformation is a complex problem. Therefore, we analyze only the semantic representation and search of learning objects (LOs) used for constructing personalized learning trajectories (PLT) that consider a complex set of their properties and analyze both LO metadata standards and elements of domain-specific characteristics of LOs.

We consider using a semantic retrieval system that processes formalized knowledge about learning courses and student needs to find pertinent LOs that can be used in student PLT. An ontological approach creates a learning course, thesaurus, which is processed as an input of the retrieval procedure. Search results need additional indexing, using LO metadata standards and individual estimates of andragogy that transform information into the LOs. The Semantic Wiki environment supports such indexing and stores retrieved LOs and their structure.

Keywords

Learning object, thesaurus, digital resources for education, personalized learning trajectory, andragogy, semantic search

1. Introduction

The specifics of digital transformation of adult education significantly relate not only to the acquisition of basic knowledge in a particular speciality (such basic knowledge usually can be proposed by a variety of relevant textbooks or video lectures) and the use of pertinent digital educational resources but also to the improvement and deepening of already existing competencies, as well as the updating of existing knowledge and skills with the most relevant achievements in the chosen domain focused on the practical application of acquired competencies that have to be reflected in the semantic descriptions of these digital resources. Therefore, the professional activity of andragogy requires the use of knowledge processing that can help solve this complex problem. In this research we consider the task of informational support of andragogy by use of semantic technologies that is chosen for several reasons:

- `actuality` – now in Ukraine, the number of adult learners who need to obtain new professions or improve and update already existing ones is significantly increasing, while the number of pedagogues and their level of competence is not increasing sufficiently, and that is why it is necessary to automate (at least partially) their activity on the base of digital transformation of education;

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- `complexity` – the activity of andragogy requires the analysis and matching of various objects and subjects of the educational process, understanding their structure and properties, and this analysis requires mechanisms of integration and coordination of different terminological and knowledge systems used for the creation of digital educational resource based on existing common standards;
- `openness` – now an important component of effective learning is the search and use of new sources of information from the external open environment, and therefore, it is necessary to develop retrieval instruments that support both regular information needs of andragogy aimed at creation and update of educational resources by search in various open repositories and storages and semantic filtering of search results;
- `knowledge orientation` – andragogy needs to apply decentralised knowledge of both the subject domain of learning course, as well as specific knowledge from the andragogy area, to integrate various models of these areas, and this processing of information requires the use of modern methods and technologies of knowledge management and means of acquisition new knowledge from already available information, and therefore it is necessary to develop such tools that can apply the andragogue's beliefs about the subject domain of learning course and select pertinent Web resources that contain semantically similar knowledge, based on existing standards for describing the semantics of these resources – such as an ontology representation language OWL proposed by the Semantic Web [1].

In our previous studies, we determined ways to apply semantic technologies for informational support of professional andragogy activities. These studies define methods and software solutions proposed for identifying the subsets of current competencies of education seekers relevant to the selected learning course and propose means for the formal semantic description of such courses based on the thesaurus. The results demonstrated an example of creating a repository of *learning objects* (LOs) that provides detailed annotations of LO properties and supports the execution of semantic queries. The results of these queries are used as a basis for the construction of *personal learning trajectories* (PLTs) that take into account the individual informational needs of students, their previous experience and their abilities to perceive new knowledge.

However, the search for new LOs corresponding to the single *learning course* (LC) or group of interconnected LCs appears beyond the scope of previous research (we assumed that the andragogy finds and evaluates these LOs independently based on his/her own experience and learning goals). The practical use of the proposed approach shows the need for automated means of LO retrieval based on LC semantics and student specifics. Specific activities of andragogy introduce additional criteria in the selection and evaluation of LOs, namely:

- `actuality` (representation of the most modern achievements) into learning domain aimed at modernisation of adult student knowledge and skills;
- `depth and fundamentality` of domain representation oriented on a specialist with significant practical experience;
- `methodological and terminological integration` with other LOs previously used by adult students at different times.

Searching among LOs already indexed and described by metadata in some storage or repository is insufficient because the criteria for selecting LOs included in the repository remains open. In order to find new LOs in the open information space, the andragogue needs to perform routine queries to various types of information retrieval systems – global and local. At the same time, the specifications of these queries at the semantic level can be permanent or be some modification (clarification or expansion) of previous queries.

2. Problem formulation

The conducted research is a component of informational support for the construction of the PLT that considers the learning course's semantics. We propose to create LO search tools based on the description of the semantics of the learning course. This approach expands the existing means of LO description and search that are based on various schemas and standards meta-descriptions (a comparative analysis of the advantages and disadvantages of such meta-descriptions is given) and allows users to take into account a more significant number of special needs in the search process. Semantic expansion of the Wiki technology used to create a repository of selected LOs provides the basis for defining various LOs properties. Such meta-descriptions can contain both standard metadata elements and user-defined semantic properties. This solution provides a more flexible search and matching of LOs with other information objects in the process of PLT building.

Digital transformation of learning increases its quality and shares results within the community (for example, teachers of semantically closed courses). Preconditions of this study are:

- `large number of open-access LOs` with different levels of modularity, granularity, and forms of representation are developed and accessible into open information space;
- `different metadata schemes` used for LOs descriptions (both general purpose metadata schemas and specialised for learning activities ones) that represent various LO aspects are created, and a certain number of standards fixes these schemes;
- `various LO repositories` contain a large number of LO meta-descriptions, but they describe only a tiny subset of all LOs;
- `the central part of LO descriptions` is focused on use by relatively homogeneous groups of students and practically does not consider the specifics of the work of andragogues who teach adult students with significantly different competencies, experience and learning goals.

Problems in existing approaches used for LO search:

- it is rather difficult for teachers to understand all aspects of available meta-descriptions that define properties and meaning of digital objects;
- most LO repositories offer rigid schemes of LO descriptions that do not involve adding additional parameters for LO by the semantics of a certain knowledge area or specifics of students;
- such repositories are more focused on the work with large communities of teachers and educational institutions rather than on individual andragogue work or collaboration of small groups with similar interests.

Therefore, it is advisable to supplement the existing approaches with tools that support the development of structure and content of digital resources used for educational purposes based on semantic technologies, allowing the creation of a personalised information environment of the andragogue. One of the main preconditions for using these tools is the formalisation of the search domain, which causes the development of the formal model of the learning course. In our previous study, we proposed a method for building a course thesaurus and an algorithm to match meta-descriptions of the LOs [2]. At the same time, elements of the LC thesaurus are used as semantic properties of LOs. Wiki technology and its semantic extension, Semantic MediaWiki, allow users to directly supplement the meta-description of LO with relevant elements that characterise students' existing and desired competencies.

3. Personalised learning and learning objects

Personalised learning is an essential condition for ensuring the quality of adult education. Such learning is based on humanistic values related to recognising persons as individuals and their rights to the free development of abilities. The design and implementation of PLTs are two ways to implement personally oriented learning in adult education. PLT design in adult learning has to consider the specifics of personality-oriented, object-oriented, activity-oriented, andragogic, competence-oriented,

interdisciplinary, and object-oriented approaches that correspond to different aspects of the organisation of the learning process and complement each other. Thus, the activity-based approach is a source for describing the stages of learning, and the combination of personality-object-oriented and competence approaches provides PLT elements based on matching student competencies with learning course requirements before and after training. The andragogic approach describes the interaction between a student and an andragogy in the process of particular LO use. The interdisciplinary approach helps integrate student skills and knowledge from different subject domains and uses them for LO choice. This work considers PLT support based on digital resources and software tools for their representation and processing. PLT is a complex information object that defines the goals, means, and procedures of the learning process for a particular student in interaction with the teacher and using LOs that describe course-pertinent knowledge and skills. PLT contains models of students and learning courses and aims to transform and enlarge student competencies according to curricula requirements. One of the essential PLT elements is a set of LOs selected according to a particular student's personified characteristics and skills. Parameters used for LO analysis can be defined by various metadata standards and by specific properties proposed by Andragogue. Such properties characterise PLT as interoperability and modularity. We understand the interoperability of PLT in such a sense that PLT developed by one specialist is unambiguously interpreted by another. This property is related to the possibility of PLT storage, transfer, and use by other persons without additional explanations. Modularity is a PLT property that allows both to use it separately to teach a certain LC and combine several separate PLTs. LOs play an important role at all layers of PLT implementation, namely:

- for content layer LOs provide the selection and systematisation of information used for learning;
- for procedural layer LOs involves a connection with learning technologies and assessment procedures;
- for context layer LOs enable the performance of specific tasks based on the learning process's actual individual, professional, educational and social context.

In this research, we use the PLT concept to represent a personified process of student learning and a sequence of elements of this process specified for adult education institutions. This learning process is based on the students' styles of learning activities. It contains a sequence of learning steps, tools, techniques, methods, and ways of performing cognitive activities that meet adult learners' needs, interests, and capabilities. PLT choice involves [3]: joint actions of students and teachers aimed at developing students' skills by independent learning activities; selection of adequate general educational goals and relevant local tasks; choosing learning content, methods and forms; self-assessment of personal achievements; initiative and responsibility for decision-making and solving tasks. The ability to use PLT construction helps students learn independently throughout their lives. Personality- and object-oriented approaches lead to individualisation of learning by personified selection of information objects, knowledge sources and data used for educational purposes [4].

According to the [5], the activity-based approach provides active learning and cognitive activities, development and implementation of individual learning strategies. The andragogic approach makes it possible to build the educational process considering students' individual age and psychological and physiological characteristics [6]. The competency-based approach is based on the results of education and training [7] and needs in the use of appropriate diagnostic tools that can be used for student model construction. An interdisciplinary approach [8], makes the coherence of curricula possible based on didactic goals and learning content. An element of these approaches can be used for PLT construction by choosing course-relevant LOs based on their meta-description properties.

4. Models and characteristics of learning objects

Various researchers propose different definitions and descriptions of LOs that complement each others and reflect various aspects of LO processing. IEEE Standard for Learning Object Metadata defines LO as an information object, software object or resource containing elements of animation, multimedia,

graphics, and text that can be used for education. This definition does not provide any possibilities to select LOs from other types of IOs [9] consider LO as a set of educational content modules, lecture materials, practical tasks and knowledge assessment methods, combined based on a specific educational goal. This definition is more advantageous for practical needs by defining LO aim but does not consider all possible types of LOs (such as tests and computer simulations). This work considers LO as an *information object* (IO) supported by metadata relevant to the learning process. Every IO can be transformed into an LO by its meta-description of structures pertinent to some learning course or group of learning courses. Such meta-description provides the base for using LOs in the PLT content set. The main goals of the LO concept deal with some aspects of the learning process:

- unified indexing of various IOs for learning needs that provides their search, storing and selection in special repositories;
- reuse of information modules developed for learning;
- interaction between such objects and possibilities of their comparison.

The analysis provided by [10] distinguishes various types of LO models such as the Verbert and Duval model, Santiago and Raabe generative model, Meyer model, Boyle model, NETg LO model, BNTOPM model, Cisco DNMO/DNIO model, etc. These models take into account different components and their features: content parts, shared content objects, learning objects, content objects, type of LO content, LO compounds, LO reusability, didactic, social and technological aspects of LOs, level of LO in the content hierarchy (from raw data and media items through information objects and software items to sets of tasks and lessons). Models of LOs can describe them in various dimensions such as LO subject (domain), lessons and topics. These models use various classifications of LO content elements, including an overview, definition, block scheme, illustration, guidelines, demonstration, and example. Development of LOR can use ontologies of different types:

- curricula structure ontologies;
- learning course ontologies;
- ontologies of pedagogical and andragogical strategies.

We consider various solutions and pay attention to the fact that using Semantic Web technologies provides possibilities to change ontologies of every type without fundamental changes in LOR software implementations—usually, these changes affect modifications in LO structure and visualisation but don't need to change existing services.

Transforming existing content into reusable LOs is a crucial task aimed at faster and better creation of new LCs by semantic indexing existing learning content. The beginnings of the LO concept are caused by the need to divide the educational material into parts that can be used in different courses. It makes sense if such activities involve many people who can benefit from the intelligent activity of other community members. The advantages of such a solution for improving the quality of education are determined by the shared use of open information resources, increased flexibility and support for personalised selection of learning materials. Companies such as Netg and Cisco introduced an object-oriented approach to developing learning materials many years ago. These approaches provide various means to reduce the time required to develop learning courses.

Cisco uses different terminology to describe LO: they developed a model based on the smallest reusable element, a Reusable Information Object (RIO). Such an RIO consists of content, practice, and assessment items united by a single learning objective. The primary purpose of the LO in this approach is to define content elements and provide information necessary for executing other RIO elements. The design of RIO elements depends on the learning goal to be achieved, the aimed cognitive level, and the types of analysed LOs.

Thus, researchers consider that there is no single "correct way" to create LOs, but some general principles for their construction can be identified. A common metadata system needs to be developed so that each LO can be easily found and identified. The level of detail of such descriptions can vary significantly and depend on the purposes of their application.

It is necessary to compare the cost of LO decomposition and the benefit of their repeated use. The structure of LO and its permissible and necessary elements are also determined by the problems it solves. Some general aspects of LO that can be considered as requirements for their development:

- LOs are modular, that is, they can be stored and be accessed through different technological environments that are oriented on supporting the learning process;
- LOs are non-sequential;
- LOs can satisfy one or more learning goals;
- LOs are a subset of open resources that are available to a broad audience;
- LOs must be coherent with predefined schemes; that is, their semantics have to be represented with the use of a limited, non-empty set of metadata;
- LOs can be used in different combinations to the defined learning objective.

This set of requirements is incomplete and can be expanded according to the specifics of practical problems. The structure of LO distinguishes three main elements of educational materials: learning activity, content, and assessment.

The Educational Modeling Language (EML) is an example of the first implementations of a general set of notions proposed for the representation of the domain model for integrated e-learning. This language is based on XML and is intended to redesign learning courses. Its basic principle is quite simple and requires s the separation of actions and environments: people carry out learning activities in a context that allows and supports them in performing these actions, established by the presence of an appropriate environment and means of support.

There are two types of activities: learning activities performed by a student and support activities performed by a teacher. A learning activity can contain different learning objectives and consists of at least a description and a completed learning outcome statement indicating when the activity is completed.

The problems of LO reuse are related to the fact that often, the course materials are not independent objects but embedded in the learning services, combining the content with the performance of practical tasks. Thus, we can single out several preconditions for the effective transformation of existing learning material into reusable LOs:

- decomposing learning materials into smaller, reusable elements requires expert time and effort and thus becomes useful only if experts expect that they or others plan to reuse existing material;
- anticipating the reuse of LO, it is necessary to clearly define what exactly we expect as a result of the transformation of existing materials into reusable objects – direct use, reshaping (reuse in another context) or customisation (reuse with adaptation to another technological environment);
- if the reuse process extends beyond the boundaries of one institution, this process requires some standardisation means.

The process of LO decomposition consists of a set of checks, analysis and decision-making. Every part of existing courses has to be defined as “content”, “activities” (learning or support), “assessment” or “services”. This process requires several checks, analyses and decisions, as not all existing course materials are immediately ready for decomposition: some course materials are not available electronically, or there can be some problems with copyright or intelligent property rights restrictions. Thus, the decomposition process begins with the study of available materials and includes the following stages:

- determine which course material can be useful for reuse in new courses;
- check the availability of material for reuse: copyright and property rights;
- check the availability of the material in the original format and in a format that is acceptable for reuse.

After selecting the available material, the information is divided into separate LOs, for each of which its function in learning is determined – for example, "content", "activity", "element of assessment" or "service" and their subtypes. Further preparation of LO for reuse is mostly about content, because it is this information that can be integrated into another course with minimal changes. The following steps in the process of decomposition of LO:

- determines the smallest internally significant parts;
- check whether they are independent and self-sufficient (LOS must not contain any links to other LOs);
- determines the beginning and end of each significant part of LO (modularity).

After that, for re-use, a meta-description describing the semantics of this LO and its characteristics should be created for each LO. The openness of LOs is an essential factor for their reuse and digital transformation of other educational elements, and such transformation of *LO repositories* (LORs) into the integrated environment can be based on Semantic Web technologies.

From this point of view, important characteristics of LO are:

- reusability;
- flexibility;
- accessibility;
- interoperability;
- manageability;
- scalability.

In the most general understanding, the Semantic Web is aimed at the transformation of the World Wide Web content with a large number of heterogeneous applications and websites into a global knowledge base where semantically defined relations connect individuals. Similarly, such an approach can be applied to managing LOs as a specific subset of the Web content. This transformation has to cause extended LO search and matching using domain knowledge. The most important influence of the Semantic Web on the LO search deals with the forms of the practical use of LO standards applied for the semantic markup of LOs. An analysis of existing LORs shows they use metadata schemas to describe LO content. Meta-descriptions of LO processed by LOR services have to contain sufficient information for generation recommendations about their use in some learning courses in general and in PLTs of particular students that learn these courses. The generation of recommendations can be partially automated and provides teacher filters in the context of current problems and more structured sets of LOs. The task of LOR services is to create semantically defined links between LOs and other information objects (courses, ontologies, competencies, etc.) and subjects (students, teachers, experts, LO authors, etc.) of the learning process. LORs can be used not only for storing but also for sharing and reuse of LOs. Examples of LORs based on the IEEE-LOM metadata standard are MIT Open Courseware (OCW), CLOE, VCILT, CAREO, NDMA, OLI, Commonwealth of Learning Object Repository, Ed-clicks, Encore, GEM, and LOLA repository for LO and different educational activities design and storage. Most of these LORs require the manual creation of LO metadata.

5. LO metadata standards and repositories

Now, we have various tools, repositories, and environments for processing and analysing LOs that provide their search and indexing. Learning Objects Metadata (LOM) describes LO as a source of knowledge and defines various LO aspects. In this research, we define LO as a combination of IO and LOM that define properties of this IO that can influence its choice for use in learning a course or achieving some competence. Metadata standards define various sets of attributes that can be used to organise, locate, search, and evaluate LOs. The most widely used LO attributes are object type, object author name, object owner name, distribution terms, and object format. We analyse the most widely

used metadata standards for LO descriptions that support their reuse and availability: Dublin Core, IEEE LOM, SCORM, xAPI, and IMS Global Learning Consortium.

IEEE LOM is a standard for LOM representation that provides a conceptual data scheme for LO elements. LOM facilitates LO finding, selecting, evaluating, retrieving, and sharing. This standard defines various LO aspects and dictionaries for their descriptions, defines the data model and provides binding of the LOM data model to XML and RDF. LOM distinguishes the types of information resources that can be included in the LO and its metadata. LO properties in this standard are LC description; content elements such as text, web pages, images, sound, video, etc.; LO version and status; glossary of LO terms and definitions; LO cost, copyrights and restrictions; relations with other courses; grade level, age range, typical learning time, acronyms.

Dublin Core is a general-purpose standard for representing metadata for various types of natural and digital objects. It is intended to unify metadata for describing a wide range of resources (real and digital). The standard contains 15 defined elements to describe the "essential" properties of information: title, creator, subject, description, publisher, contributor, date, type, format, identifier, source, language, relationship, scope, and rights. Dublin Core provides guidelines for encoding Dublin Core metadata in XML and RDF/XML to enable interoperability between different platforms, languages and systems. This general-purpose metadata standard can describe various information, including LOs.

IMS Global Learning Consortium Standard [11] provides an efficient exchange of data and content between different educational platforms, facilitating the integration of educational applications with learning management systems, portals and other educational environments. However, implementing and converting metadata formats to other standards from this standard is complex and needs specialists with high qualifications.

Sharable Content Object Reference Model (SCORM) is the most common standard for e-learning systems that enables developers to create reusable LOs objects [12]. The purpose of SCORM is to increase the interoperability of educational materials in different e-learning systems. The scope of SCORM applications extends from simple content delivery to more complex learning scenarios that include student assessment, progress tracking and personalised learning models. The main advantages of SCORM are its interoperability, reusability, and adaptability. It is easier to implement and widely supported by existing LMS systems. Its disadvantages are the lack of widespread adoption and support among e-learning tools and platforms.

Experience API (xAPI) is a standard that allows recording, monitoring and analysis of learning experiences both online and offline. It is designed to overcome some of SCORM's limitations. It can track a wider range of learning activities (such as reading a book, attending a seminar, or interacting with a simulation). This standard is platform-independent and can work on various technologies. The reviewed standards that can be used for LO metadata – Dublin Core, SCORM, xAPI, IMS Global Learning Consortium, and IEEE LOM – have their unique advantages and disadvantages:

- IEEE LOM standards offer a comprehensive set of recommendations for structuring and organising learning content and data, ensuring a high level of manageability and scalability, but have some difficulties in implementation. The IEEE LOM standard provides a valuable framework for structuring and describing the content and data of an LO repository. Its implementation can increase the LO repository systems' consistency, stability and scalability. IEEE LOM is the most complex of these five standards. The ability to create complex hierarchical relations facilitates interaction with search services.
- Dublin Core is very popular for LOM representation because it allows easy adaptation to metadata processing by software applications. It can work with RDF used for the Semantic Web resources described. However, Dublin Core is not explicitly focused on LOM descriptions. Therefore, it can incorrectly represent some LOM elements.
- SCORM is an established standard that enables the packaging and tracking of learning content in an LMS. However, it has limitations in tracking the learning experience outside the system.
- xAPI efficiently tracks heterogeneous learning experiences across platforms and offers detailed learning analytics, but it is challenging to implement.

- IMS Global Learning Consortium provide a wide range of standards that promote effective integration and interoperability between different learning systems and tools despite requiring technical expertise for implementation. These standards are focused on system integration and interoperability.
- Various tools for data conversion between Dublin Core and IEEE LOM are developed, but the correct conversion requires significant costs and improvement.
- LOM SCORM and xAPI standards are focused on tracking and delivering learning experiences.

All these standards indicate promising directions for the development of technologies to support pedagogical strategies. Choosing the standard for an LO repository largely depends on its specific needs and goals.

Digital repositories of LOs created in foreign and Ukrainian universities use the abovementioned metadata standards. LOs into this LOR are small, semantically and functionally autonomous, reusable, indexed by metadata and open. They are catalogued for educational purposes and supported by management, search, and access mechanisms. The metadata scheme of this LOR is based on the specifications of the IEEE LOM standard. This analysis allows us to draw the following conclusions:

- a majority of LORs are multilingual and provide open access to LOs for their registered users, but vary significantly in learning disciplines, target audience, educational level of students, and detalization of LO descriptions;
- there is no single standard approach to the organisation of the LOR structure, the system of LO search and semantic analysis of LO metadata;
- a significant part of LORs with large volumes of educational content is inaccessible to the general public (with commercial or corporate approaches);
- LORs use their own fixed schemas of metadata that can be converted to other representations but cannot be expanded by users according to their personal needs;
- development of integrated (centralised or decentralised) meta-LOR or unification of a certain subset of LORs with a unified set of search and analytical services is advisable but not realised now.

6. Retrieval of learning objects in the Web

The considered LOM standards provide schemes for describing the most typical and common LO parameters that should be determined for all such objects. But the andragogy quite often works in situations where it is necessary to take into account for the construction of PLT more specific properties of LOs, which are not usually defined into LORs. The andragogy needs to be able to create such additional LO properties, define their names and possible values, and then define those values for a specific subset of LOs into some individual LO storage. Let us consider several examples of such situations. *Situation 1.* One of the students studying the course is a colour-blind person (Daltonian) who does not distinguish colours. Therefore, selecting student PLTs such as LOs that contain only monochrome illustrations and graphics is necessary. Then, the andragogy creates the LO property “Type of graphic elements”, which is not present in the LO standards, and defines its values “monochrome”, “multicolour” and “no graphics”. *Situation 2.*. Part of the student group has hearing problems and cannot freely perceive video lectures. The expressiveness of most standards is sufficient to define this type of LO, but such students can use videos with subtitles in natural languages that they understand. Then, the andragogy creates the “Subtitle language” LO property, which is not present in the standards, and defines its value.

Situation 3. Students have limited access (by speed or volume) to the Internet (for example, caused by blackouts), and then the andragogue tries to select LOs with smaller file sizes. A parameter such as file size is not present in all repositories (parameters such as number of pages or playback time are more often used). Andragogue can create the “File size” LO property and define its values for LOs, which

further allows choosing among LOs with similar content, the most compact ones (for example, with illustrations of a lower resolution).

Situation 4. Students do not have any problems with the health and technical support of the educational process. However, they live in a cultural environment where specific images or videos (for example, images of certain species of animals) are unacceptable for specific ethical or religious reasons. Therefore, it is advisable not to expose these students. Then, the andragogy creates the “Image of animals” LO property and defines its meaning for the LO – for example, “pig” and “dog”, which further allows choosing among the LOs that do not cause problems for students.

Situation 5. Andragogue teaches a course to groups of students with different professional areas where they plan to use the acquired knowledge. Therefore, it is advisable to use examples and methods related to different areas of application. For example, the "Pattern Recognition" course for medics and drone pilots can use different examples—images of the results of human research and object recognition from various cameras and surveillance satellites. Indexing the examples in LO is advisable to speed up the formation of the desired course modification. Thus, all additional properties of LOs can be divided into several categories:

- properties related to the specific perception of learning materials by individual students or groups of students;
- properties characterising the technical features of LOs and access to them;
- properties that characterise specific elements of educational content that can cause ambiguous reactions from different communities of people;
- properties related to the specifics of the use of learning results and the possibility of creating more specialised modifications of LCs.

It is important to understand that using such additional LO properties in a large-volume repository is impractical—it significantly reduces the search speed due to an increase in the number of processed parameters; for the vast majority of LO, the values of such properties are not determined; and it is very difficult to ensure uniformity and consistency of input of additional properties for a large number of users. Therefore, it is advisable to create more local LO repositories focused on individual use or a relatively small community. Specifics of LO retrieval into the Web Queries that are oriented on retrieval of course-relevant LOs can contain information from:

- thesaurus of the learning course [2] ;
- descriptions of learning outcomes and course competencies (more narrow requests related to the selection of educational materials for individual competencies) [13] ;
- elements of descriptions of previously found LOs;
- transformations of the thesaurus elements of the learning course to other terminology systems (for example, translation into other natural languages).
- elements of meta-descriptions of LOs related to their structure and taxonomy.

These elements can be processed by information retrieval systems (IRSs) that support search on the semantic level and provide possibilities to different query elements that represent various aspects of user information needs. Usually, IRSs (such as Google) process keywords without defining their role in the query. Search into LORs considers such roles, but it can analyse only structures IOs with metadata placed into the repository. We can partially solve this problem by using semantic IRS that proposes additional instruments in query construction and result filtering with knowledge about the search domain.

A search of LOs on the Web requires semantic retrieval systems that allow users to apply knowledge about their area of information interests to obtain more relevant results. Now, systems that differ significantly in knowledge representation, thematic orientation, and request complexity have been developed and proposed for use. Most are not directly focused on educational content and learning goals but can be effectively used for these tasks. In our research, we demonstrate the possibilities of semantic

search of LO using an example of an MAIPS retrieval system that explicitly allows users to specify the model of their information needs at different levels of understanding using external knowledge sources.

LO search based on *MAIPS* (maips.isofts.kiev.ua) is an example of semantic search that demonstrates how clearly defined descriptions of the user's informational interests based on the ontological model can be transformed into requests to external information retrieval system (IRS) and how filtering of the obtained results is carried out. It should be noted that this IRS and the means of formalising knowledge about the learning course are only possible variants of semantic search and can be chosen according to the user's goals and beliefs about the subject domain.

MAIPS is a multiagent IRS that uses advanced means of intelligently representing user information needs. It is designed for retrieval of information in relatively narrow subject domains related to users' professional or scientific interests. It can be considered a recommender system focused on forming recommendations for natural language and multimedia information resources (IRs) available through the Web. In this work, we consider only those MAIPS services that can be directly used for LO search.

The basis of MAIPS is the Semantic Web technologies, particularly the OWL ontology representation language. MAIPS is based on a multiagent paradigm describing system behaviour and interaction between system subjects. The concept of intelligent web services is used to describe the functionality of system elements and support their integration with other semantic web applications. Some elements of Web 2.0 technologies (such as tag clouds applied for visualisation of search thesauruses) help to adapt thesaurus models of tasks to the current information needs of users. This system uses domain ontologies and task thesauri to formalise the sphere of user interest. Users have to select ontologies representing spheres of their research interests from the set of domain ontologies the system developers offer on the MAIPS site. The task thesaurus used by MAIPS is a particular case of ontology that can be built by the user according to the appropriate ontology independently [2].

In the LO search task, the user selects the ontology of the learning course domain and then inputs the thesaurus of this learning course built by andragogy. MAIPS system is aimed at users with permanent informational interests who need continual access to relevant information (this type of user includes pedagogues who teach courses in a particular domain). MAIPS enables such users to save and repeat requests, takes into account the user's reaction to previously offered results (personal filtering), monitors the appearance of similar requests from other users (collaborative filtering), stores a formal description of the user's field of interest in the form of an ontology (semantic filtering), etc. In addition, in user profiling, MAIPS uses an evaluation criterion specific to natural language IRs – the difficulty of understanding the text- that can also be used to personalise learning. The specifics of this system are using an original knowledge-oriented algorithm that determines the difficulty of understanding the text for a particular user (task thesaurus is used to select a domain subset that is known to the user).

User interaction with MAIPS requires much more effort at the beginning compared to the use of non-semantic IRSs or semantic IRSs, where knowledge processing is closed from the user because MAIPS demands from users an explicit definition of their informational interests based on a formalised representation of domain knowledge. Such an approach to information retrieval is oriented toward highly specialised professional tasks where utilisation of the search experience of other people is not effective due to the small volume of similar queries. In addition, only the first access to the system takes time. In subsequent iterations, the user's time is significantly saved due to the possibility of reusing saved requests and making changes and clarifications.

Therefore, MAIPS is effective only if the user plans to perform repeatedly a certain set of complex queries in the subject area defined by the domain ontology. Such a situation is typical for andragogy, in which the teacher teaches a certain set of related learning disciplines in which he specialises and seeks to find new LOs to support the already existing structure of the learning course and expand and refine it according to the needs of students and learning conditions. We can define some main stages of user interaction with MAIPS aimed at searching LOs pertinent to learning courses.

Stage 1. Registration in the system and selection of domain ontology. The user receives login and password and then chooses an ontology that characterises his/her area of interest (in this case, area of interest reflects the domain of the learning course). Because processing complex and incorrectly constructed ontologies requires much time, users cannot independently include authoritative ontologies

in the MAIPS knowledge base. Therefore, if the list of ontologies registered in MAIPS does not contain the required one, the user must send pertinent ontology to the MAIPS developers and ask them to add it. After verification, if the ontology corresponds with the system conditions, it becomes available to the user.

*Stage 2.*Creating a task thesaurus for search. The user has to enter the thesaurus of the learning course. At this stage, the andragogue can use the learning course thesaurus developed according to course content and structure. Unlike traditional thesauri, MAIPS allows users to explicitly determine the quantitative assessment (positive or negative) of each element of the thesaurus that defines the importance of this thesaurus concept for the current user task – for example; the user can single out concepts of some lecture or competencies of particular student that needs in additional LOs. A single user can create more than one thesaurus for different aspects of his/her activity, but at least one thesaurus is necessary for every request. In addition, MAIPS provides the following tools for thesauri modifying (figure 1):

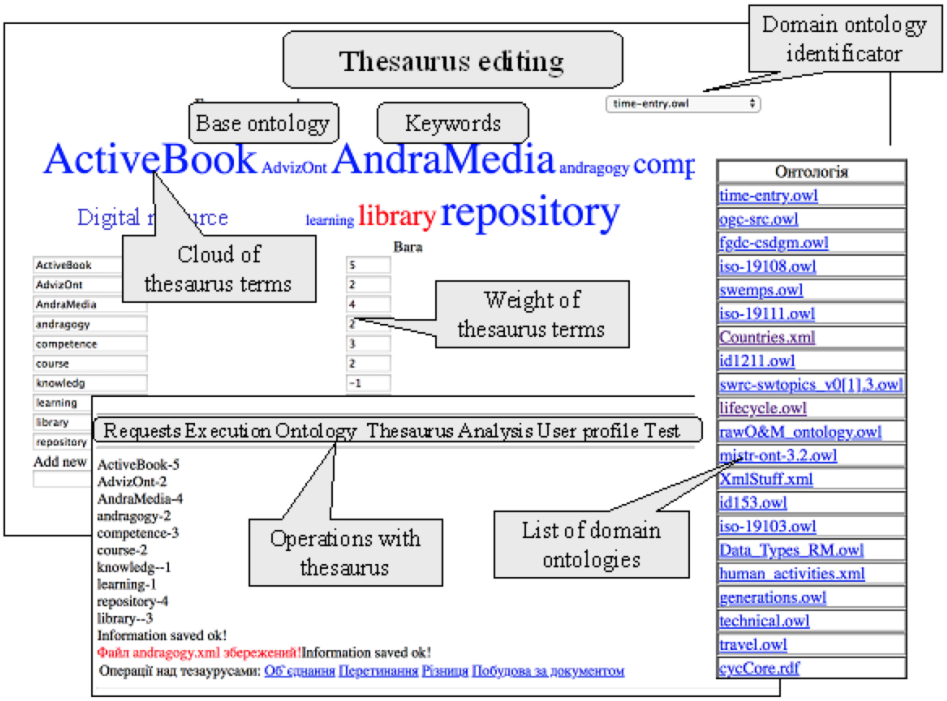

Figure 1: Editing of learning course thesaurus.

- support of the set theory operations of union, intersection, and addition on previously constructed thesauruses;
- manual replenishment thesaurus by corresponding terms from external knowledge sources;
- thesaurus replenishment by selecting the set of several classes from the basic domain ontology and expanding this set by ontology classes with some semantic distance from selected ones (a value that is not greater than the specified by the user constant).

Andragogue can create independent thesauri for the learning course and the LO classification (with typical elements of various LO metadata schemas that can be used for the selection of representation form of information) and then combine them set theory operations according to their own needs.

Stage 3. Creating LO search request Generation of user requests contains such elements (figure 2):

- choose a basic ontology;
- choose one of the previously built user thesauri;
- enter a set of keywords characterising a specific information request;

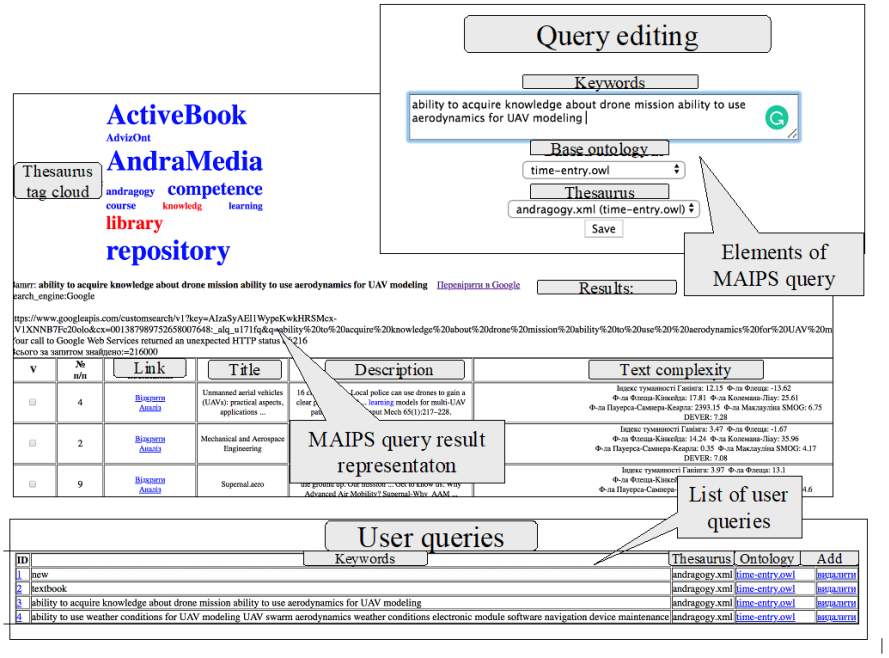

Figure 2: Editing of learning course thesaurus.

- save the request with a unique name.

Stage 4. Query execution The set of keywords from the user request is redirected to an external IRS (for example, Google), and then MAIPS receives the found results and reorders them according to the number of thesaurus terms found in them and their weight. In addition, other properties of the IRs can be taken into account for ordering. For example, the user can indicate the desired level of IR reading complexity, and this parameter also affects the IR rating. Suppose some of the found IRs have previously been offered to other MAIPS users. In that case, ratings of this user can be taken into account either directly or by taking into account the degree of similarity between the domain of interests of these users and their thesauri that are calculated by various information about them from social networks, as well as taking into account the statistics accumulated by MAIPS.

7. Stages of local LO repository construction

The above studies showed the expediency of forming a local LO repository (LLOR) where the pedagogues select the pertinent LOs (from other LORs and the Web) according to personal criteria and supplement their meta-descriptions with their own information needs. In our previous research, we considered the feasibility of using the semantic extension of Wiki technologies to create such a repository: semantic properties and Wiki templates allow users to describe flexibly the IO structure and import such structural descriptions from other repositories, storages and libraries. Semantic Wikis allow users to represent by semantic markup [14] an arbitrary set of properties to describe each Wiki page corresponding to LO as smart data with values that reflect the user's personal opinion about this object. In order to facilitate the work of the andragogy, templates can be used in which sets of properties are already specified that correspond to various standards and schemes for describing metadata for educational objects Stages of LLOR building:

- choose a basic metadata scheme for describing LOs and other objects that can be contained in the repository (based on existing standards and examples of repositories);
- if necessary, create additional properties for the LO description, determine the types of these properties, their semantics and possible values;

- import from external repositories to LLOR those LOs that are relevant to LC that andragogy teaches or required for the work of an analogue;
- converts the metadata of imported LOs to the LLOR scheme (automated or manually, depending on the semantic similarity between them);
- provides the Web search for relevant LOs and places them in the LLOR by creating a complete set of metadata for them by the chosen metadata scheme;
- , if necessary, update the information about LOs, repeatedly performing searches both in the LORs and on the Web.

It should be noted that LO importing from repositories provides the user with more relevant results and requires less effort because a significant part of their metadata is already defined. The web search provides access to a much broader set of information objects. However, additional verification of their relevance to the user's interests and the definition of all necessary metadata values is required. Therefore, practical applications commonly use both methods.

8. Conclusion

Semantic technologies are a necessary condition for the digital transformation of education and the development of applications aimed at learning management. They provide knowledge processing and analysis, support intelligent retrieval of digital educational materials, and define semantic links between LOs selected according to a student's personalised characteristics and skills.

In this paper, we consider the parameters of metadata schemas that can be used for LO search in repositories and analyse practical situations that require required LO properties fixed in initial repositories of digital educational resources.

We also substantiated the expediency of Web searches for digital resources that can be transformed into LOs and the means of semantic support of such searches by using formalised knowledge about learning courses. The semantic retrieval system MAIPS allows processing not only keywords and formal characteristics of retrieved information objects but also a thesaurus of the learning course that describes the search domain.

LOs generated based on retrieved digital resources are placed in a personal repository for reuse in the learning process with metadata schema elements and specific properties that represent personal user beliefs about them. Such properties increase the expressiveness of the knowledge representation model and can be used both for searching and comparing various digital objects and subjects of the learning process.

References

[1] T. Berners-Lee, J. Hendler, O. Lassila, The Semantic Web: A New Form of Web Content that is Meaningful to Computers will Unleash a Revolution of New Possibilities, in: Linking the World's Information: Essays on Tim Berners-Lee's Invention of the World Wide Web, 1 ed., Association for Computing Machinery, New York, NY, USA, 2023, p. 91–103. doi:10.1145/3591366.3591376.

[2] J. Rogushina, A. Gladun, Task Thesaurus as a Tool for Modeling of User Information Needs, in: J. A. Zapata-Cortes, G. Alor-Hernández, C. Sánchez-Ramírez, J. L. García-Alcaraz (Eds.), New Perspectives on Enterprise Decision-Making Applying Artificial Intelligence Techniques, Springer International Publishing, Cham, 2021, pp. 385–403. doi:10.1007/978-3-030-71115-3_17.

[3] F. Kellenberg, J. Schmidt, C. Werner, The Adult Learner: Self-Determined, Self-Regulated, and Reflective, Signum Temporis: Journal of Research in Pedagogy and Psychology 9 (2017) 23–29. doi:10.1515/sigtem-2017-0001.

[4] N. Raj, V. Renumol, A systematic literature review on adaptive content recommenders in personalized learning environments from 2015 to 2020, J. Comput. Educ. 9 (2022) 113–148. doi:10.1007/s40692-021-00199-4.

[5] R. H. Shroff, F. S. T. Ting, W. H. Lam, T. Cecot, J. Yang, L. K. Chan, Conceptualization, development and validation of an instrument to measure learners perceptions of their active learning strategies within an active learning context, International Journal of Educational Methodology 7 (2021) 201–223. doi:10.12973/ijem.7.1.201.

[6] M. Livingston, D. Cummings-Clay, Advancing adult learning using andragogic instructional practices, International Journal of Multidisciplinary Perspectives in Higher Education 8 (2023) 29–53. doi:10.32674/jimphe.v8i1.3680.

[7] C. Bohne, F. Eicker, G. Haseloff, Competence-based vocational education and training (VET): An approach of shaping and networking, European Journal of Training and Development 41 (2017). doi:10.1108/EJTD-07-2016-0052.

[8] S. Morelli, C. Carlachiani, Curriculum, Teaching and Interdisciplinarity, International Journal of Social Sciences and Humanities Invention 5 (2018) 5147–5154. doi:10.18535/ijsshi/v5i12.10.

[9] D. Politis, M. Tsalighopoulos, G. Kyriafinis, Designing Blended Learning Strategies for Rich Content, in: Handbook of Research on Building, Growing, and Sustaining Quality E-Learning Programs, IGI Global, 2017. doi:10.4018/978-1-5225-0877-9.ch017.

[10] V. Dagiene, D. Gudoniene, R. Bartkute, The integrated environment for learning objects design and storing in Semantic Web, International Journal of Computers & Control 13 (2018) 39–49. URL: https://univagora.ro/jour/index.php/ijccc/article/view/3074.

[11] IMS learning design best practice and implementation guide - version 1.0 final specification, IMS Global Learning Consortium, 2003. URL: http://www.imsglobal.org/learningdesign/ldv1p0/imsld_bestv1p0.html.

[12] O. Bohl, J. Schellhase, R. Senler, U. Winand, The Sharable Content Object Reference Model (SCORM) - A Critical Review, in: Proceedings of the International Conference on Computers in Education, ICCE '02, IEEE Computer Society, 2002, pp. 950–951. doi:10.1109/CIE.2002.1186122.

[13] J. Rogushina, S. Priyma, Use of competence ontological model for matching of qualifications, Chemistry: Bulgarian Journal of Science Education 26 (2017) 216–228. URL: http://elar.tsatu.edu.ua/bitstream/123456789/3181/1/2.pdf.

[14] J. V. Rogushina, Ontological Approach in the Smart Data Paradigm as a Basis for Open Data Semantic Markup, in: O. Cherednichenko, L. Chyrun, V. Vysotska (Eds.), Proceedings of the 7th International Conference on Computational Linguistics and Intelligent Systems. Volume III: Intelligent Systems Workshop, Kharkiv, Ukraine, April 20-21, 2023, volume 3403 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2023, pp. 12–27. URL: https://ceur-ws.org/Vol-3403/paper2.pdf.