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USING ONTOLOGICAL MODELING BY INTELLECTUALIZATION OF LEARNING PROCESSES

The purpose of the article is to investigate and consider the general trends, problems, and prospects of using ontological modeling of learning, training, and education processes in the university.

The research methodology consists in methods of semantic analysis of the basic concepts of the considered subject area (learning, training, and education processes in the university and intelligent technologies). The article discusses approaches to intellectualization education in the university with the help of modern systems that are based on ontological modeling and intelligent technologies.

The scientific novelty of the research is the analysis of the ontological modeling use and intelligent technologies for the intellectualization of learning processes.

Conclusions. The article discusses various aspects related to ontological modeling and intelligent technologies.

The use of ontological modeling in the intellectualization of the higher educational institutions' activities makes it possible to move to the individualization of learning processes, to provide students and teachers with access to the ontology of not only a separate course, but also all courses of the educational and professional program in the relevant direction, to involve employers and other stakeholders in improving the educational process.

Keywords: intelligent learning systems; learning process; knowledge testing; subject area; ontology; ontological model; knowledge base; ontograph.

Introduction. It is proposed to use ontological models as a formal basis for modeling earning and management processes at the university.

The ontological approach to a formalized description of the structure and processes (learning and management) occurring in the higher education system contributes to the subsequent automation of these processes.

The purpose of the article is to formalize and intellectualize the processes of the higher education system based on ontological modeling. Achieving this goal presupposes the intellectualization of the processes:

– university management:

– personnel management (teachers (lecturers, professors) and service personnel);
– students' management (selection of applicants, distribution of graduates, monitoring and control of tuition fees, etc.);
– provision of educational material in different specialties, different courses, and topics;
– education (scheduling of classes, consultations, sessions, etc.);
– control and monitoring of students' knowledge in different specialties, different courses, and topics;
– quality management of educational services.

Ontological modeling is based on the choice of models that are adequate to the problem being solved (Sanfilippo, 2018; List, 2018).

The following problems will be considered:
– recruitment of students;
– learning students;
– control of students' knowledge;
– distribution of graduates.

The choice of the appropriate model depends on the ontology of the domain (subject area) under consideration and the tasks solved (Gelfert, 2017).

Any subject area is a collection of meaningful concepts and relationships between these concepts, which are presented in a certain sequence.

Set of specific concepts and relations according to certain characteristics can be divided into a finite number of types of concepts and types of relations.

Research results. The ontological model of information processing is considered a transformation of the corresponding component of the model.

The following components change during this process:
– the state of this model elements;
– configuration of this model;
– its vertices appear or are removed;
– connections between nodes.

When creating ontological models of processes at the university, the types of graphs that are currently being studied in graph theory are not enough for information processing.

Ontograph G is specified by the five $<V, C, K, L, A_l>$, where:

V – set of nodes (primary elements, terms);

C – set of connecting elements of the ontograph, each of which defines a certain fragment of the ontograph;

K is the set of key vertices of the ontograph, each of which defines a certain class of equivalent elements of the ontograph ($K \subset V$);

L is a set of labels of elements of the ontograph, each of which specifies a certain base class of equivalent elements of the ontograph.

Such classes of elements, in particular, include the following classes:
– nodes of the ontograph,
– connecting elements of the ontograph,
– key vertices of the ontograph,
– ontograph labels,
– incidence relations defined on the set of elements of the ontograph.

A_l is a set of incidence relations that are defined on the set of ontograph elements. All incidence relationships are binary-oriented relationships.

Each ontograph *G* will be interpreted as the set of all elements included in its composition:

$G = (V \cup C \cup K \cup L \cup A_l)$. The elements of the ontograph G include all its nodes, connecting elements, labels, and incidence relations.

Set of simple connecting elements can be divided into sets:

– *directed,* the components of which perform different roles within these bundles;

– *undirected,* the components of which perform the same roles within these bundles.

A special case of the directed simple connecting elements is a tuple. The tuple specifies a subset of the ontograph elements, in which the roles of all elements are numbered.

If tuples are included in the ontograph, then among its incidence relations there should be relations "to be component": first, second, third, etc. Bundles can be unary, binary, or multi-component.

The considered ontological models of processes at the university are focused on parallel and asynchronous processing of information.

With the accumulation of large amounts of knowledge, many different concepts appear. This raises the problem of structuring and systematizing this variety of concepts. To solve it, all accumulated knowledge is divided into the interconnected subject area, each of which has its own set of concepts.

Each of the concepts within the framework of the subject area either performs a certain role or is a class of research objects, or is a relation defined on the set of research objects, etc.

The description of each specific subject area in the field of the provision of educational services involves the definition of:

– classes of objects (main, primary, secondary, specific);

– sets of simple connecting elements, the components of which are both primary and secondary objects;

– classes of the above-mentioned ligaments;

– subareas of the subject area.

It is necessary to distinguish between the subject area itself, its fragment, and various ontologies of the specified subject area.

Ontology is a kind of knowledge, each of which is the specification of the corresponding subject area.

Ontology is focused on describing the properties and relationships of concepts that are part of the specified subject area.

Students' education is provided, in particular, by such entities as:

– lecturers and professors;

– information and intelligent learning systems;

– sources of information and knowledge.

Let *E* be a set of subject units. The set of relations between subject units will be designated as $S \subset E \times E$.

The structure of subject knowledge is characterized by attitude $S \subset E \times E$. The ontological model can be visually represented as a special graph model, the so-called ontograph G.

These principles were used in the formation of the ontology and its vocabulary, in particular, in determining: ontology structures, elements (main components) of the ontology; intervals of allowable values of ontology components (Subject Areas and Ranges in Protégé 5.5 (Protégé 5.5., 2016; Musen, 2015; Bechhofer, 2009).

Modeling student knowledge monitoring and testing. Each course contains diagnostic material (tests, special questions, or tasks) for monitoring and testing students' knowledge.

The test item is a clear and precise item from specific subject areas. It requires an unambiguous answer.

The ontological model of teaching and monitoring students' knowledge provides for the use of prompts (information, help) either from the teacher or from the corresponding information-intellectual learning system (Lytvyn et al., 2018; Tkachenko et al.,2020).

Questions that are asked to students can be assigned to one of the following grades:

1. Questions that require explicit assignment of key concepts in answer (relations are explicitly asked in question).

2. Questions that require disclosure in an answer to a typical relationship of one main concept.

3. Questions that require disclosure in an answer of the compound relationship of one main concept.

The student and the teacher must have a holistic picture of the subject area of the course being studied and be aware of the relations of this course with others.

Fig. 1 shows the ontological model of the training (educational, learning) process in the university.

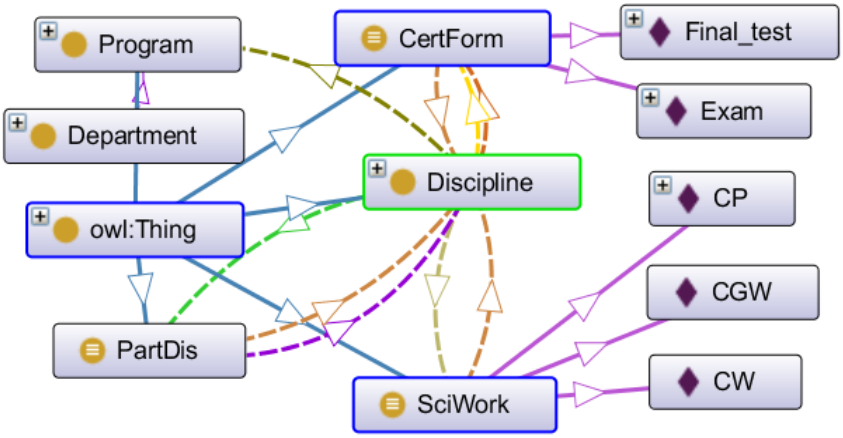

Fig. 1. Part of the ontograph

Each course, which is studied with the help of an intelligent learning system based on the ontology of the corresponding subject area, contains a description of a set of objects (such as for example, concepts of the subject area, tasks, and methods for solving them).

These objects can have a complex layered structure that is mapped using classes and properties. Moreover, these classes and properties can be represented by corresponding hierarchical structures.

Consider an example of checking the level of knowledge of students after studying one of the topics of the course Algorithms and Data Structures. After studying the topic Sorting Algorithms, the student is offered questions, the answers to which are reflected in the corresponding ontology class hierarchy of the course Algorithms and Data Structures (Fig. 2):

– What is the essence of exchange sorting algorithms?
– What is the essence of insertion sorting algorithms?
– How is the complexity of the Betcher sorting algorithm determined?

When studying the course ADS (Algorithms and Data Structures), it is advisable to simultaneously (or a little earlier) study a programming course in a specific programming language. Between these courses within the ontology of the specialty, the corresponding relationship can be indicated.

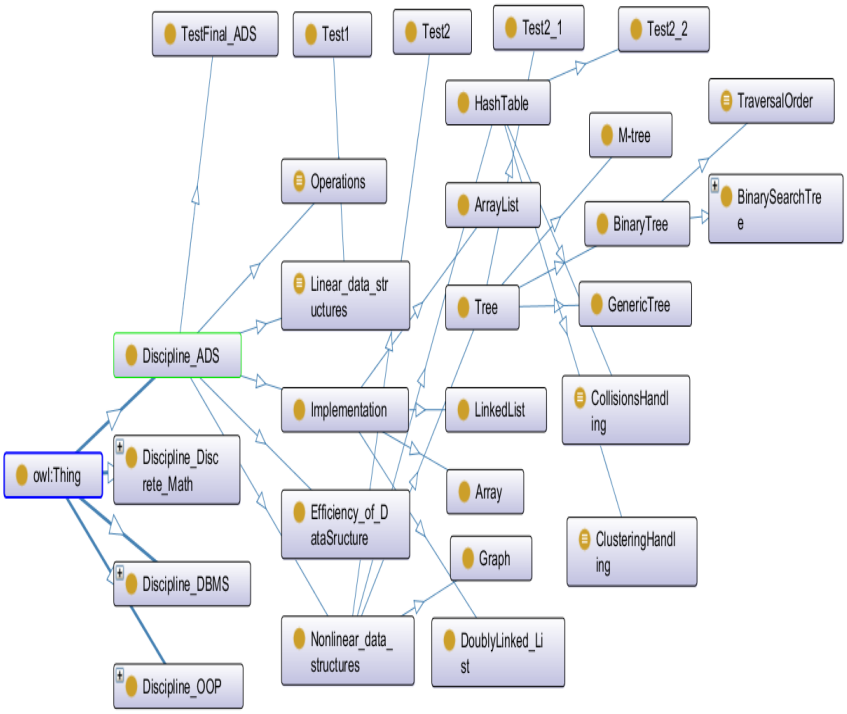

Fig. 2. Part of the ontograph for testing knowledge on the course Algorithms and Data Structures

The presence of this connection contributes not only to the study of the theoretical material of these courses but also to the acquisition of skills and competencies for the practical implementation of sorting algorithms by means of a particular programming language.

The course Algorithms and Data Structure is presented in Fig.3.

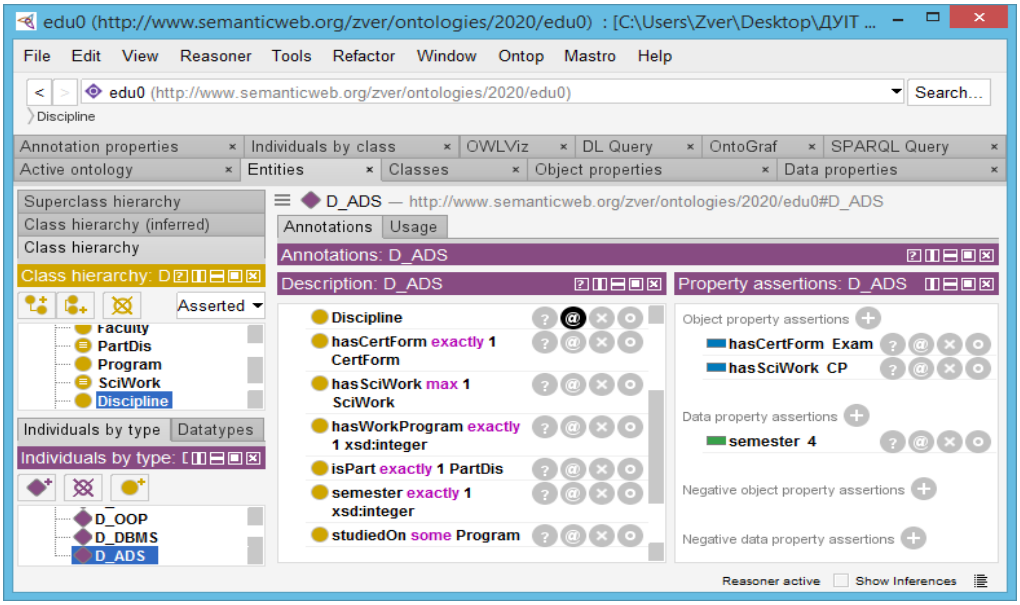

Fig.3. Course Algorithms and Data Structures

For universities, knowledge is one of the most important resources. The university gains competitive advantages if it is able to quickly create and find new knowledge, ensure its practical implementation, forming the scientific and professional competencies of teachers, staff, and students.

Knowledge, intellectual capital, and intellectual property are becoming new sources of development. In this regard, innovative universities strive to effectively manage and manage their knowledge.

The development of formalized knowledge representation models, which would ensure the processing of scientific and educational-methodical information at the semantic level in educational process management systems, is becoming increasingly important.

Ontologies play a decisive role in the knowledge description model. Ontology design is a creative process, and therefore the potential applications of the ontology, the developer's understanding of the subject area, and his point of view on it will influence the management decisions on the organization of learning processes, their monitoring, and provision of relevant educational information to students.

One of the directions of intellectualization of learning processes at the university is the transformation of the information space of the e-university into the space of knowledge and competencies.

Therefore, the problem of developing an ontological knowledge base for an e-university is relevant, since it allows the use of modern technologies (in particular, the Semantic Web) to create a semantic web portal for a learning process management system.

Ontology development is an iterative process. Concepts in the ontology should be close to objects and relations in the subject area under consideration.

These concepts are most often described by nouns (for describing classes) or verbs (for relations) of the corresponding sentences in the description of the subject area.

Thus, knowledge of the purposes of using the ontology and the level of its detailing can influence many decisions regarding the modeling of both the learning processes themselves and their management.

Among the many possible solutions, you need to determine the one that:

– can solve the problem better,

– can demonstrate their advantages more clearly,

– will be capable of modification;

– does not require additional costs for implementation. Ontology is a model of the real world and the concepts in ontology should reflect this reality. After the formation of the initial version of the ontology, it can be evaluated and, if necessary, modified, using it in applications, in solving specific practical problems, and/or discussing it with experts. This iterative design process can continue throughout the life cycle of the ontology.

The development of an ontology (ontological model) involves the definition of:

– subject area;

– goals of ontology development and intelligent learning system based on ontological model;

– class of tasks to be solved;

– functions of the corresponding intelligent tutoring system based on the ontological model;

– categories of users of the corresponding intelligent tutoring system based on the ontological model;

– which user will use the ontology;

– which of the users of the intellectual learning system based on the ontological model has the right to modify the ontology (and, as a consequence, the system itself).

For example, for the subject area Intellectualization of Processes in the E-university, the ontological model will cover the subject area associated, in particular, with educational programs of specialties, educational and methodological complexes of disciplines, working curricula, and working programs of disciplines.

The ontology will be used when accessing information resources and interacting with existing learning environments (spaces) to intellectualize distance learning (e-learning).

To create an ontology, it is important to develop and form a terminological glossary for both individual disciplines and specialties.

Conclusions. Thus, the usage of ontological modeling in the intellectualization of university activities allows:

– significantly increase the degree of completeness and reliability of the assessment of the student and graduates' learning level, due to the consideration of various factors and the degree of their influence on the answers of students/ graduates;

– to form a sufficiently complete and well-structured information base for solving the main tasks of introducing a competence-based approach into the educational process, among which should be highlighted:

• the ability to update curricula and programs in accordance with the identified specific requirements of the labor market;

• the ability to update the content of training (learning) courses in accordance with the requirements of stakeholders;

• the ability to form a set of work schedules for the same curriculum;

– the proceed to the individualization of learning (training, education) processes taking into account the interests and capabilities of each student;

– to provide students and teachers (lecturers and professors) with access to the ontology not only of a single course but also of all courses of the educational and professional program in the corresponding direction;

– to evaluate the student's position and prospects (in the educational process and in the labor market);

– to involve enterprises-employers and other stakeholders in improving the educational process.

REFERENCES

Bechhofer, S., 2009. OWL: Web Ontology Language. In: L. Liu and M.T. Özsu, eds. *Encyclopedia of Database Systems*. Boston: Springer, pp.2008-2009.

Gelfert, A., 2017. The Ontology of Models, In: L. Magnani and T. Bertolotti, eds. *Springer Handbook of Model-Based Science*. Pavia: Springer, pp.5-23.

List, C., 2018. Levels: Descriptive, Explanatory, and Ontological. *LSE Research Online*. [online] Avialable at: <http://eprints.lse.ac.uk/87591/1/List_Levels%20descriptive_2018.pdf> [Accessed 07 April 2022].

Lytvyn, V., Vysotska, V., Dosyn, D., Lozynska, O. and Oborska, O., 2018. Methods of Building Intelligent Decision Support Systems Based on Adaptive Ontology. In: *IEEE Second International Conference on Data Stream Mining & Processing (DSMP)*. Lviv, Ukraine, 21-25 August 2018. Lviv, pp.145-150.

Musen, M.A., 2015. The Protégé Project: A Look Back and a Look Forward. *AI Matters*, 1(4), pp.4-12.

Protégé 5.5., 2016. *Protégé Project*, [online] 19 May. Avialable at: <https://protege.stanford.edu/products.php> [Accessed 07 April 2022].

Sanfilippo, E.M., 2018. Feature-based product modelling: an ontological approach. *International Journal of Computer Integrated Manufacturing*, 31 (11), pp.1097-1110.

Tkachenko, O.I., Tkachenko, O.A. and Tkachenko, K.O., 2020. Designing Complex Intelligent Systems on the Basis of Ontological Models. In: *CMIS-2020: Third International Workshop*

on Computer Modeling and Intelligent Systems. Zaporozhye, Ukraine, [online] 27 April-1 May 2020. Zaporozhye, pp.266-277. Available at: <http://ceur-ws.org/Vol-2608/paper20.pdf> [Accessed 24 April 2022].

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ВИКОРИСТАННЯ ОНТОЛОГІЧНОГО МОДЕЛЮВАННЯ ПІД ЧАС ІНТЕЛЕКТУАЛІЗАЦІЇ ПРОЦЕСІВ НАВЧАННЯ

Мета статті – дослідити та розглянути загальні тенденції, проблеми й перспективи використання онтологічного моделювання процесів навчання та виховання, а також виховання в закладах вищої освіти.

Методами дослідження є методи семантичного аналізу основних понять аналізованої предметної галузі (навчання, виховання та виховні процеси в закладах вищої освіти й інтелектуальні технології). У статті розглянуто підходи до інтелектуалізації освіти в закладах вищої освіти за допомогою сучасних систем, що базуються на онтологічному моделюванні й інтелектуальних технологіях.

Новизною дослідження є аналіз використання онтологічного моделювання та інтелектуальних технологій для інтелектуалізації процесів навчання.

Висновки. У статті розглянуто різні аспекти, пов'язані з онтологічним моделюванням та інтелектуальними технологіями.

Використання онтологічного моделювання в інтелектуалізації діяльності закладів вищої освіти дає змогу перейти до індивідуалізації процесів навчання, забезпечити доступ студентів і викладачів до онтології не тільки окремого курсу, а й усіх курсів освітньо-професійної програми з відповідного спрямування, залучати підприємства-роботодавці й інші зацікавлені сторони до вдосконалення освітнього процесу.

Ключові слова: інтелектуальні навчальні системи; процес навчання; перевірка знань; предметна галузь; онтологія; онтологічна модель; база знань; онтограф.

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