

DEVELOPMENT OF ONTOLOGICAL APPROACH IN E-LEARNING WHEN STUDYING INFORMATION TECHNOLOGIES

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Проаналізовано можливості онтологічного підходу до електронного навчання. Розроблено концепцію створення онтолого-керованих е-курсів, що включає методологію використання онтології, механізми онтолого-управління процесом розробки, архітектуру системи та відповідний інструментарій. Запропонована методологія, яка базується на системно-онтологічному підході до побудови моделей електронного курсу, забезпечує високу ступінь формалізації й структуризації онтології предметної дисципліни та ефективну реалізацію процесів автоматизованої побудови е-курсів для різних рівнів вищої освіти

Ключові слова: е-освіта, онтологічний підхід, електронний курс, автоматизована розробка курсу

Проанализированы возможности онтологического подхода к электронному обучению. Разработана концепция создания онтолого-управляемых э-курсов, включающая методологию использования онтологии, механизмы онтолого-управления процессом разработки, архитектуру системы и соответствующий инструментарий. Предложенная методология, базирующаяся на системно-онтологическом подходе для построения моделей электронного курса, обеспечивает высокую степень формализации и структуризации онтологии предметной дисциплины и эффективную реализацию процессов автоматизированного построения э-курсов для различных уровней высшего образования

Ключевые слова: э-образование, онтологический подход, электронный курс, автоматизированная разработка курса

1. Introduction

Under contemporary conditions of global informatization of society and rapid development of digital systems, e-learning (or EL) occupied its niche on the market of educational technologies. In many cases EL ensures improvement of the quality and accessibility of education, extends its forms and methods and contributes to the integration of countries to the European and world-wide educational programs. In addition, it makes it possible to reduce time for replacement of outdated curricula or for their updating.

However, in spite of the significant costs for developing e-courses (EC) and the abundance of materials, e-learning is not always accompanied by an adequate feedback, in particular, because of low effectiveness of existing knowledge bases (KB).

One of the most perspective approaches in the contemporary education paradigm, increasing the effectiveness of KB, including educational ones, is the ontological approach, which makes studies in this direction relevant, especially in the context of development of innovative methods of teaching on the platform of different informational communication technologies.

2. Literature review and problem statement

The ontological approach in EL is developed in many institutes of higher education throughout the world. The tool of assessment of semantic similarity, using the "Palmer algorithm" and ontology [1] is known. The set of means is still being developed.

The work on “onto-Relational” learning, which deals with incomplete knowledge, is being carried out, one of the applications of which in learning is the direction “Semantic Web” [2]. The set of instruments for this system is being developed.

Many studies, devoted to the improvement of methodology of designing ontologies, are directed toward studying the possibility of automation of the stage of analysis of the course subject area [3–5]. In particular, this makes the basis of the “pattern-approach”, which implies automated analysis of the subject area structures of an e-course [4]. This approach can help in many semantic tasks of designing ontologies, for example, reasoning, agreement of concepts and others. Unfortunately, this set of instruments of this approach has not been developed enough to be broadly applied [5].

In paper [6], to train the system which forms ontologies, it was proposed to use the “concept maps”. This approach is the most illustrative from the point of visualization of the process of forming ontologies, but in a number of cases [4, 6] it leads to poorly structured relations between the elements of the map.

In articles [7, 8], the approach to learning, which is capable of generating semantically connected collections, is proposed. The process of learning includes collecting the documents with semantic connection of concepts. In this case, the semantic depository WordNet is used. To increase the effectiveness of the WordNet, the enriched ontology (WorkiNet as a structure of WordNet) is built up, with the information search in “Wikipedia”. However, the information placed in “Wikipedia” is not always reliable.

In paper [9], the ontology of the domain of courses of MOOCs, offering free access to the materials to unlimited number of listeners, is used. The drawback of MOOCs is a large number of forums, which generate significant flow of comments and questions (transactions) [10, 11]. This causes the problem of ensuring feedback [12].

In Ukraine, there is its own experience of development and introduction of e-learning. Articles [13–16] made a considerable contribution to the development of this new scientific direction.

At various Ukrainian universities, a certain experience, sometimes unique, has been accumulated in the course of implementation of the results of studies in the area of e-learning [14, 15]. For example, during the e-courses development at the Kiev National University named after Taras Shevchenko (the city of Kiev), the “scenario precedent approach”, based on the results of the study, was used [16, 17]. At the Kharkov National University of Radio Electronics (the city of Kharkov) and at the National University “Lvov Polytechnics” (the city of Lvov), the multi-agent ontological approach to the creation of the distributed systems of e-learning, which is based on Semantic Web and the agent technologies, was used [18, 19]. The ontological models in the OWL format are used for the implementation of individual selection of educational materials. However, the task of improvement of the EC quality remains actual since the problems of logical connections between separate concepts was not studied sufficiently. Furthermore, in spite of approbation of e-learning systems at universities, a change in the list of specialties in a number of cases does not allow rapidly adapting the existing e-courses to new specialties [20].

As the analysis of papers [19, 21, 22] showed, to ensure successful EL, a number of program products: Lotus Learning Management System (LLMS), BlackBoard; WebCT as well as agent technologies were developed. In this case, the analyzed products do not consider possible changing of interdisciplinary connections in the process of education and they are not aimed at decreasing the subjectivity of the EC [16, 18, 22].

The known system is AOS BaGER (Base and Generator of Educational Resources). The KB, built on the ontological approach, is included into the system [23]. In [24], the ontological aspect of e-learning is considered. Instrumental means of the automated development of EC are not considered in these papers.

Thus, in spite of a certain progress achieved in e-learning, the real educational practice revealed a number of contradictions, which require solutions:

- under conditions of transition to the information society, the objective need for a new socio-technological paradigm of education, based on integration of the methods of information theory and innovative methods of education has become urgent, and as a part of this paradigm, there is a need for the development of contemporary concept of creating the electronic courses (EC) of learning. It seems appropriate to use, in particular, the methods of ontological engineering in the course of the EC development;

- at present, a large-scale process of education informatization is going on; however, educational effectiveness of EC remains low since the development of technical task (TT) of specification and requirements for the EC does not have a clear regulation;

- within the framework of designing the information space of an institute of higher education, according to the Bolognian model of the system of higher education, the introduction of EC in the educational process does not display system character. Designing EC does not rest on clear axiomatic and semantic basis of general logical theory and interdisciplinary connections and the possibilities of the EC development are not considered either.

Since e-learning and EC are poorly provided for methodologically, normatively and technologically, the courses frequently have subjective nature. Furthermore, in many institutes of higher education, there is no united space of knowledge and the ontological KB, and the instrumental means of EC developing are not fully developed.

Numerous discussions and publications [7, 9, 14, 17, 19, 21, 22, 24], connected with the development of innovative EC, indicate urgent need for development of the concept and methodology of constructing the ontologically controlled EC, implying, in particular, the possibility of automation of this process for the purpose of reduction of human and time resources, involved in the solution of this problem.

3. The aim and the tasks of the study

The purpose of the work is the analysis of possibilities of the ontological approach to e-learning.

To accomplish this aim, the following tasks were set:

- to explore characteristic properties of ontological engineering regarding e-learning;
- to develop the concept, methodology and software of support of development of ontologically controlled EC.

4. Application of ontological engineering in education

Generally, e-learning may be presented as a system that consists of connected components: a set of subject disciplines (SD), education medium and participants of educational process.

The concept of ontological engineering in education and presentation of the objects of EC ontographs and SD interactions in the proposed model is based on the possibility of reflecting the equity of e-learning in the form of composition of the ontologically controlled architecture. The latter is oriented to the subject area and to the automated approach to the development of ontologically controlled EC for a certain speciality independent on a certain platform of programming.

To make the education effective, it is necessary to determine the level of semantic analysis of the sources of knowledge, to arrange the objects of SD and to determine equities, connections between them and specifications. Thus, ontology as a formal semantic system is already closely connected with e-learning, and as a specification of conceptualization provides the integrity of the SD presentation.

Ontology as the presentation of a conceptual system with the help of the logical theory and as a dictionary used by logical theory makes it possible to formalize the models of objects of studying, training processes and training scenarios. Ontology as a meta-level (ontology of the domain of subject disciplines – multitude of disciplines taught by a department [25]), will ensure integrity and directivity of training specialists.

Ontology can be used in many aspects – for describing semantics of e-learning process, for structuring the stages of education and communication means, for determining the context and medium of EO and for constructing the system of evaluation of skills and knowledge, obtained by a student, on the basis of the ontology system [26, 27]. Only with the use of a basic system of categories, it is possible to give the basis for constructing the ontological model of reality at the level, which is reflected by contemporary science, i.e., to develop the EC adequate for the given SD.

Ontology as a conceptual system, Fig. 1, (possibly, implicit) underlies any concrete KB in the context of electronic learning. In Fig. 1, ontology and conceptual system are highlighted by green color; on the one hand, they are initial for the knowledge base (KB), on the other hand, the conceptual system underlies KB. In Fig. 1, the semantic part of KB used for e-learning is highlighted by red color; in this case, the term clarification is given in the context – explanation, illustration and making clear. In the Fig. 1, the KB of SE and its subset, the KB of SD, are highlighted by brown color.

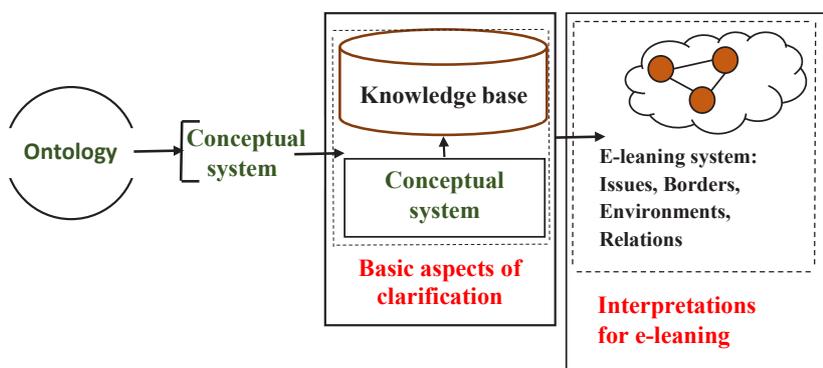


Fig. 1. Ontology as conceptual system

In accordance with the concept of ontological engineering, for the designed automated system of visualization of the indexed SD ontograph and subsequent construction of the corresponding EC, there are used:

- ontologies of SD domains;
- the ontologically controlled EC created with the help of the developed software on the basis of the SD ontologies from the reference information library (RIL);
- the mechanisms of ontological management of educational process and checking acquisition of knowledge.

The architecture of the system includes: the integrated ontological approach; the integrated common concepts and their connection to SD, the software means of the support of the automated construction of SD ontologies, for example, those created on JAVA platform.

In Fig. 2, the diagram of the fragment of architecture reflecting the “ontological” component of EC DSS, as well as the connection with the procedures of information model of processing the knowledge contained in the digitized textbooks, is presented. The following designations are accepted:

- OTL – ontology of top level;
- OEC – ontological electronic course;
- DT – digitized textbook;
- ODS_{D_k} – ontology of the k domain of subject disciplines of the faculty where k=1, K, K=CardD are the capacity of the set of domain ontologies integrated into library;
- LOS_{D_i} – linguistic ontology of the i-th subject discipline, where i=1, I, I=CardSD is the capacity of the set of subject area ontologies integrated to library;
- OSD_i – ontology of the i-th subject discipline).

In Fig. 2, presenting the “ontological” component, designation “O”, the ontological component, is highlighted by brown color. The brown boundaries of the components of the diagram indicate the presence of ontological component.

The methodology of development of ontology of SD domain requires the use of ontological knowledge, the construction of EC models on the basis of the systematic ontological approach [28, 29], considering the categorial level of OUL (ontology of upper level) in the course of the EC development. These requirements are hard to formalize. However, it is possible to use the instrumental means of the automated construction of OUL ontologies on the platform of high-level languages of programming

In Fig. 3, an example of ontograph of initial ontology, assigned by the SD “DB”, is presented. The ontograph is comprised by hand by an instructor. The following designations were used during the composition: the basic disciplines were designated in brown; the fundamental notions and the semantic part of EC were designated in red; the basic concepts and their connection into SD were designated in blue; the methodological components of the support of EC “BD” were designated in dark blue, the green color showed the set of instruments used in the process of ontological engineering.

For the automated construction of EC for arbitrary subject disciplines, it is necessary to use the formalized procedure of designing the SD ontology. At further stages, it is possible to use

this procedure as a basis for the instrumental means of EC developers, or to adapt it for existing SE ontology to SD of EC. The initial information for the automated construction of SD ontology is the existing EC and the textbooks on the given SD.

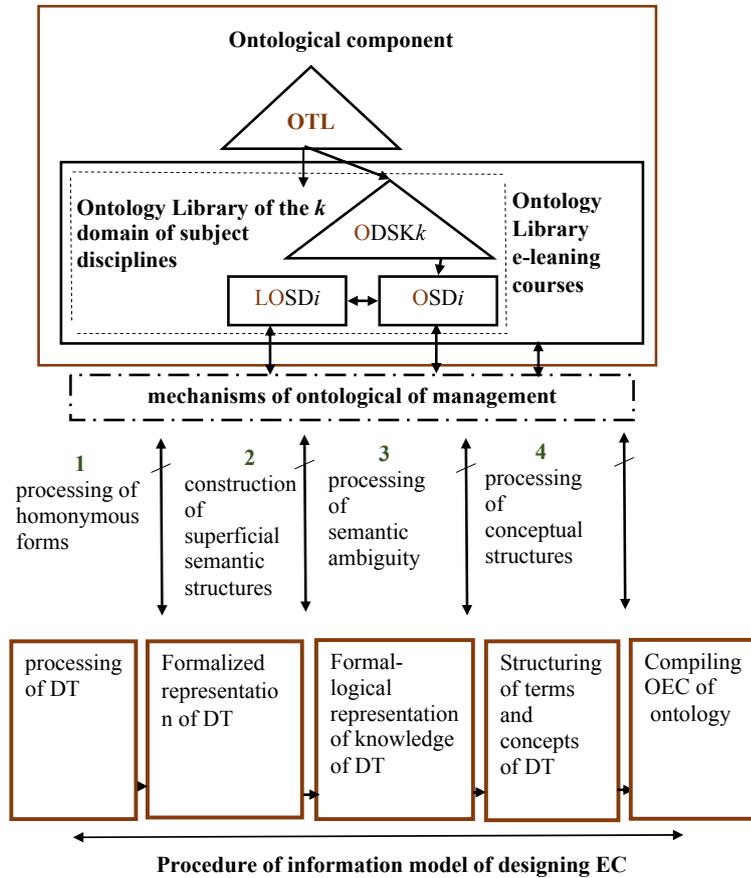


Fig. 2. Fragment of architecture of “ontological” part of CAD of EC

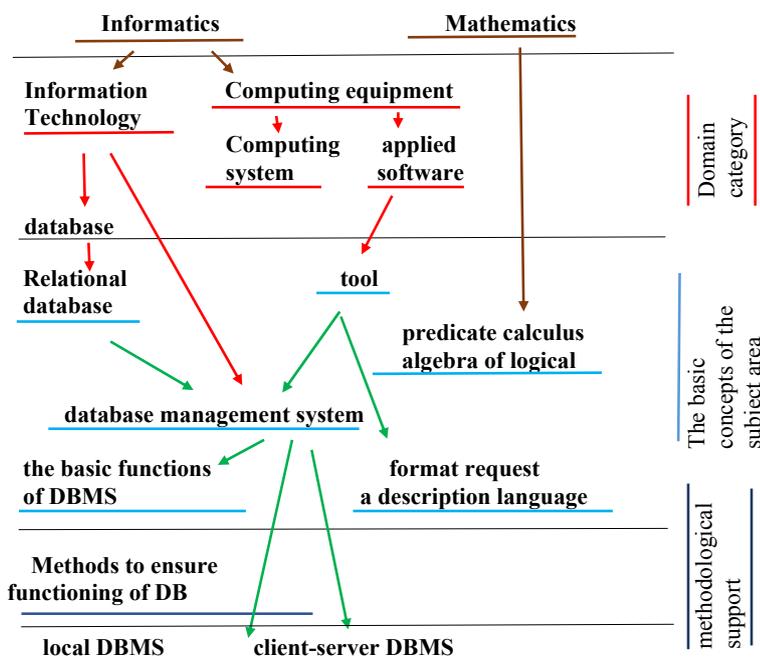


Fig. 3. Ontograph of initial ontology of SD “BD”

For constructing ontology, in sequence the following are determined:

- set $X = \{x_1, x_2, \dots, x_i, \dots, x_k\}$ (the finite set of concepts of the assigned SD);
- set $R = \{r_1, r_2, \dots, r_k, \dots, r_K\}$, $R: x_1 \times x_2 \times \dots \times x_i$, $k = \overline{1, K}$, $K = \text{Card } R$ (Finite set of semantically significant relations between the SD concepts).
- set $F: X \times R = \{f_h\}: \{x_i\} \times \{r_k\}$, $h = \overline{1, H}$, $H = \text{Card } F$ (the finite set of functions of interpretation, assigned by the concepts and/or by the relations).

The conceptual part of the training ontological system is described (1) and presents SD ontology, which consists of the ontology of objects, ontology of processes (which for domain “Education” can be united into one), initial ontology and metaontology of the domain of subject disciplines

$$OO_{HC} = \langle MO^A, O^{O-II}(O^{O-II}, HO) \rangle, \quad (1)$$

where HO is the initial ontology of the assigned SD.

For example, *ontograph* of initial SD ontology of “Data base” includes the following concepts at the levels of the categories of domain “Information theory”: “Information technologies”, “Formal logic”, “Computing system” and others. At the levels “Basic concepts of subject area”, the following concepts relate to HO: “Relational DB”, “Relational model of data”, “System of DB management”, “Predicate calculation”, “Basic functions of DBMS (Data Base Management System)”, “SQL language” and others. At the levels “Methodological support” the following concepts are present in HO: “Methods of transactions serialization”, “Methods of indices organization”, “Methods of journalization” and others.

- O^{O-II} is the ontology of many concepts-objects and concepts-processes of SD, which is considered as a hierarchic structure of classes, sub-classes and elements of classes;

- MO^A is the metaontology of the domain of subject disciplines, considered as a hierarchic structure (basically) of disciplines from the curricula of a department or a faculty;

- ontology O^{O-II} consists of ontology of objects and ontology of processes, as noted above, for the domain “Education” it can be united into one.

The methodology of the automated construction of ontologically controlled EC implies as the first step the development by an instructor in the automated regime of a complete EC ontograph on the basis of existing EC and textbooks on the given SD. It should be noted, that the ontograph is the first component of ontology, and its formalized description in one of the conventional languages of the ontologies description is the second.

Let us show how it is possible to formalize the description of the ontograph based on the example of the fragment of DB ontograph

(Table 1). In the table there are designations for “Information technologies” (IT), “Formal logic” (FL), “Computing system” (CS), “Relational DB” (RDB), “Relational model of data” (RMD), “Data Base Management System” (DBMS), “Internet protocol” (IP), “Basic functions of DBMS” (BF of DBMS), “SQL language” “Methodological support” (MS DBMS) “Methods of transactions serializations” (MTS), “Methods of indices organization” (MIO), “Methods of journalization” (MJ) and others. The sign (→) in the last column of table designates, that there is a connection with the concept, not shown in Table 1. The logical connections represented in this form are used for the computer description of the ontograph. The sign (–) indicates the absence of any connection.

For the ontograph of the typical ontology, it is characteristic to have many branches, a large number of concepts and a strict hierarchy.

In accordance with the proposed methodology, the notation of concepts is used [30], Fig. 4. Designations in the figure are presented in the table of notations, Table 2, which is compiled before construction of the matrix of logical connections.

The procedure of constructing the ontograph is carried out taking into account the levels of SD concepts. In Fig. 4, the levels and their markers are designated by red color.

Matrix of logical connections of ontograph (fragment)

#	Disciplines	Matrix of logical connections										...
		1	2	3	4	5	6	7	8	9	10	
		IT	FL	CS	RDB	RMD	DBMS	IP	BF DBMS	SQL	MS DBMS	
1	IT	–	–	1	1	–	–	–	–	–	–	...
2	FL	–	–	–	–	–	–	1	–	–	–	...
3	CS	–	–	–	–	–	–	–	–	–	–	...
4	RDB	–	–	–	–	1	1	–	1	1	1	→
5	RMD	–	–	–	1	–	–	–	–	–	–	...
6	DBMS	–	–	–	–	–	–	–	1	1	1	...
7	IP	–	–	–	–	–	–	–	–	–	–	...
8	BF DBMS	–	–	–	–	–	–	–	–	–	–	→
9	SQL	–	–	–	–	–	–	–	–	–	1	→
10	MS DBMS	–	–	–	–	–	–	–	–	–	–	...
11	MTS	–	–	–	–	–	–	–	–	–	–	...
12	MIO	–	–	–	–	–	–	–	–	–	–	→
13	MJ	–	–	–	–	–	–	–	–	–	–	→
14	...	...	...	...	...	...	...	...	...	...	...	...

Fragment of SD ontograph «Data base»

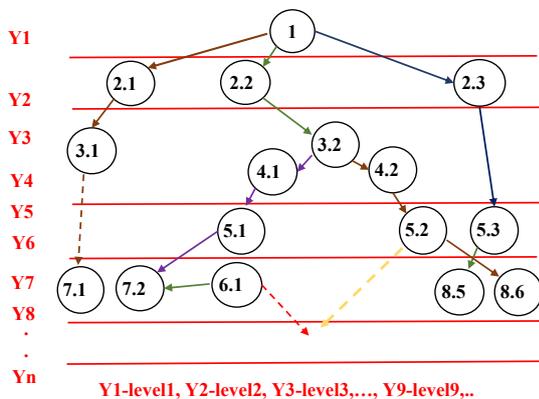


Fig. 4. Fragment of SD ontograph DB

In the process of studying, the possibilities of the automated construction of e-courses for different levels of higher education in the objective – oriented language JAVA were tested, Fig. 5, 6. Given in Fig. 5, the fragment of the form, which visualizes the procedure of indexing the SD ontograph “Data base” makes it possible with the help of floating up prompts, to offer the developer of a course the visual interpretation of the corresponding apexes of the SD ontograph as well as to enhance the expressiveness of the graphic representation of SD ontologies.

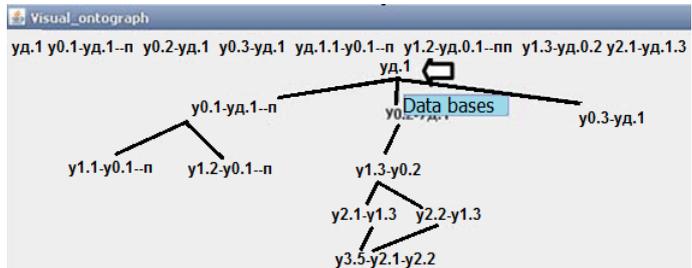


Fig. 5. Forms of program of visualization of indexed SD ontograph “Data bases” [13]

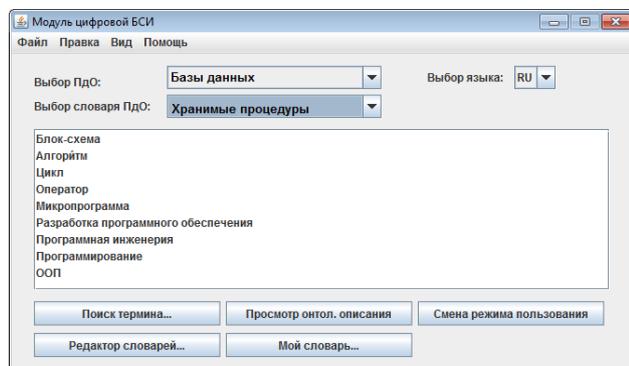
In “User mode” of the program, the main menu, Fig. 6, a, and different dictionaries, Fig. 6, b, become accessible. With the help of the list, it is possible to select the necessary subject area and a required dictionary necessary for ontological SD engineering.

Table 1

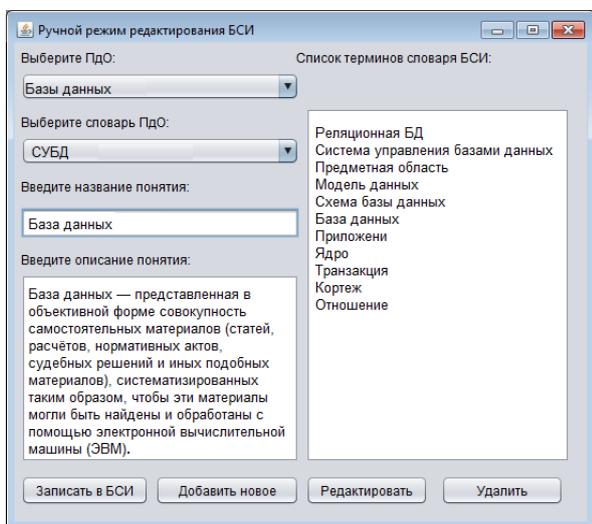
Table 2

Fragment of table of notations of concepts for SE DB

N	Notation of concepts	Concept
1	1.	Information theory
2	2.1	Information technology
3	2.2	Computing technique
4	2.3	Information system
5	3.1	Technology of DB
6	3.2	Means of CT
7	4.1	Hardware
8	4.2	Software
9	5.1	Computing system (CS)
10	5.2	Programme product
11	5.3	Automated IS
12	6.1	Apparatus means
13	6.2	Software
14	6.3	Set of instruments
15	7.1	DB
16	7.2	Management system of CT
17	7.3	Mainframe
18	7.4	Data storage server
19	7.5	Information protection means
20	8.1	Relation data base
21	8.2	HP Oracle Exadata
22	8.3	Sun Ultra Enterprise 450
23	8.4	Interfaces for DB
24	8.5	Internet protocol
25	8.6	Algebra of logic
...
68	16.6	SQL standards



a



b

Fig. 6. Examples of interfaces of program of building ontographs and automated construction of e-courses: a – main menu; b – interface of dictionary for manual editing of reference information libraries of program for automated construction of e-courses

In the context of assessment of knowledge of a trainee, the proposed methodology is based on testing the deviations of the results of education from the real SD ontograph. In the course of evaluating the deviations, the hierarchical quality of ontograph is used.

The evaluation of knowledge is connected with the level number in the ontograph, which includes the studied concept. If a student did not answer the questions connected with the concept “Software” (point 10, Table 2 – the mark of 50 points according to a 100-point scale), the questions with the higher levels in the ontograph are bypassed in the test.

The results of the ontologized test are also used for evaluating the quality of EC. Let us build the graphic representation of the distribution of points by a discipline, by the number of students, who received this mark, and the approximation of its curve (S), enveloping the diagram of Pareto, Fig. 7 [31].

In the figure, the points are marked along axis X, the number of students was marked along axis Y. Small squares designate a total quantity of students, who scored a certain number of points according to the examination records of four groups of students (109 students). Curve Si is plotted according to the distribution of points by the number of

students with the use of the method of least squares for each i-th branch of the ontograph, Fig. 7.

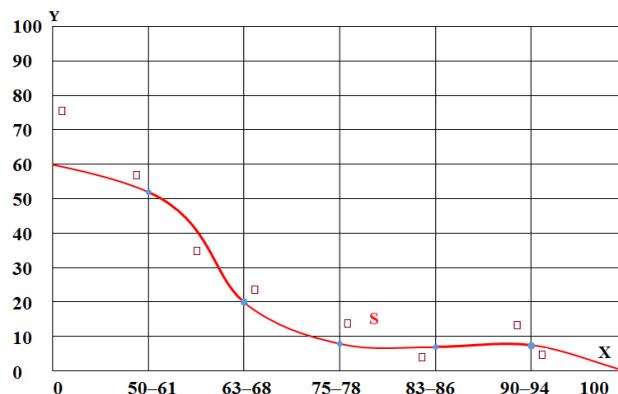


Fig. 7. Curve of approximation of distribution of points (Y) by the number of students (X) who scored these points (S). The curve is marked by red color; square markers designate a total quantity of students who scored a certain number of points

For the family of curves {Si} (i=1÷m, m is the number of branches of SD ontograph) we will plot a curve Smid, averaged by the ontograph branches, and will introduce the measure of distance Si from Smid. The EC fragments, corresponding to the curves of the family {Si}, which are located further from Smid, need modifying.

6. Discussion of results of studying the ontological approach to electronic learning

Nowadays e-learning is developing in parallel with the World Wide Web, improving its procedures and forms of instruction, being oriented toward the latest achievements of the Internet technology. In many countries with the wide spread of the Internet, the new forms of learning are introduced, which are based on computer and telecommunication technologies, including such forms as e-learning.

The decrease in EC subjectivity and the reduction of costs for its development using the described approach can be attributed to the merits of the work. The EC, created by hand nowadays, are subjectivized and require the significant consumption of time of highly skilled developers.

The disadvantages of the work are the following: the procedure of recognition of the EC fragments, which are the most critical for mastering, with the possibility of considering specific features of trainees, has not reached the level of thoroughly tested set of instruments in many institutes of higher education.

The proposed concept and methodology are useful, because on their basis it is possible to pass to the development of instrumental means of the ontologized automated designing of EC which is ready to a wide introduction. After this, it will be possible to use it in any universities and schools.

The given study is the continuation of a number of works, carried out together in the Lugansk National University named after Taras Shevchenko and the Institute of Cybernetics of NAS of Ukraine [13–16]. At present, the results of the studies are undergoing the procedure of implementation to the EC, developed by the Departments of Information

Technologies and Systems of the Lugansk National University named after Taras Shevchenko (the town of Starobelsk) [14, 15, 32], the organization of complex protection of information, information systems and mathematical disciplines at the European University (the city of Kiev and 18 subsidiaries) [20, 33].

7. Conclusions

1. Ontological DBs were shown to be one of the components of the innovative technologies of e-learning. It was demonstrated that the ontological approach to the development of e-courses, on condition of automation of this process, ensures the reduction of costs for their creation and enhances results of learning.

2. The concept of creating the ontologically controlled EC, which includes the application of methodology of the synthesis of ontologically controlled e-courses on the basis of SD ontologies from BSI, was developed. An example of creation of ontologically controlled EC with the help of the programme developed in the JAVA language, based on the system-ontological approach, was demonstrated. The process of construction of EC “Data bases” on the basis of its information and functional models was shown. It was proven, that a high degree of formalization and structurization of SD ontology, as well as the integrated ontological approach to the innovative methods of e-learning, serve as a basis for the creation of effective EC. The results of approbation of the program of automated construction of e-courses for different levels of higher education in the object oriented JAVA language were shown.

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