Ontology-Based Model of Information Technology for E-Learning Systems

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Abstract. The article is devoted to the ontology-based model of information technology for e-learning systems which are based on the creation of the course ontology and the didactics of E-learning. The authors conduct an overview and create a classification of modern information technologies in education. The article also describes what benefits can be obtained using the chunk-based approach to analyze students' knowledge. A new model of interaction between the all members of the educational process is proposed. The authors come to the conclusion that the educational application of the ontology-based model of information technology for e-learning systems should be based on granting lecture lessons with an additional motivational component, creating computer-based support of unsupervised work, automatizing knowledge level control tasks.

Keywords: E-learning, Information Technology, Ontology Engineering, Chunk based, Ontology-based, Model.

1 Introduction

The fast development of information technologies (IT) and everything connected to the IT environment is changing modern people's life in all spheres. Education is not an exception. The use of IT in the educational system allows improving the learning process through the introduction of new methods and approaches not only in learning/teaching itself, but through communication, interaction between students and teachers, and also through the evaluation of the acquired knowledge.

With the development of WEB 3.0, there has been a trend towards the use of a semantic approach to the representation of knowledge in e-learning systems (eLS). In particular, the methods of ontological engineering have been widely used [1, 2]. Unfortunately, these technologies are not very popular in systems of computer education, because there is no ontology of educational disciplines. The approach based on meta-ontology for creation of ontologies of educational disciplines has been suggested in the previous works of the authors [3].

Developing furthers this approach this paper proposes to apply the ontology-based model of IT to eLS which, through the use of the ontological engineering approach, will allow to create an ontologically managed eLS. This one unlike most of the existing eLS, will provide a flexible, individualized approach to learning. Also, in this paper, authors have reviewed modern IT in education [4-8] in order to allocate additional paths for implementation of the methods of ontological engineering.

2 Review of Modern IT in Education

Over the past two decades [9], Learning Management Systems dominated in the field of e-learning, (e.g. Moodle, Sakai, and others). The specified LMS have modular architecture, are universal and provide interaction between students and teachers. They also provide a certain amount of tools aimed at creation and organization of the content. Under these circumstances emerges the idea to reuse content and sharing semantically the educational content between different LMSs.

In LMS, the teacher works on his courses using the Internet, and edits the teaching materials in real time. Thanks to this, students receive a constantly updated content.

The disadvantage of LMS systems is the complexity of their content, which is high-quality content, however, the creation of electronic lectures, practical and laboratory tasks, test tasks requires as much effort as is required to prepare a paper textbook.

Social networks play an important role in the development of e-learning. Teachers use social networks to create groups for informal communication, conduct consultation, counsel and solve other organizational issues. Under these conditions, in the center of the pedagogical process there is a student who not only becomes more autonomous in terms of control, but is also more active in the creation of educational information and interaction with other learners.

Wiki-technology is a technology used for creating a website that allows users to edit any page or create new pages on a wiki site using a web browser. Wiki-technology allows you to accumulate knowledge by presenting them in an easy-to-handle form. At the same time, Wiki may have different volumes and thematic focus: from global Wikipedia and electronic encyclopedias to small reference systems [10, 16].

Momentum from online institutes such as Coursera, Intuit is gaining significant popularity. These contain complete courses that consist of video lectures with subtitles, lectures, presentations, text notes, homework assignments, test and test papers, final examinations. After the successful completion of the course, a student receives a certificate of graduation.

One of the ways to implement e-learning is to create an e-library that will allow for the free textbooks to be posted online in the free-form. The question of filling such a library is solved by creating a repository of educational materials. However, its disadvantage is the need for administration. Also, the responsibility for the quality of the repositories lies with the author. However, if metadata is properly organized, search in

such repositories may become available to well-known search services. The natural indicator of the quality of content in the repository is its usage index.
Based on the review of e-learning technologies, they were divided into three groups (Figure 1): social networks, repositories and LMS.

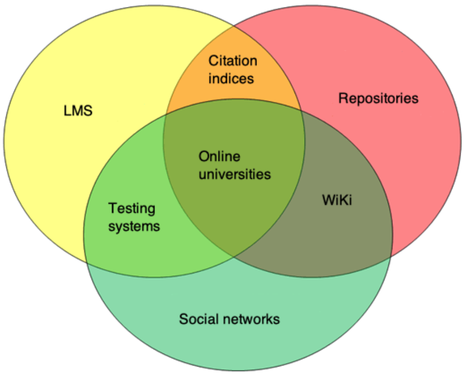

Fig. 1. Diagram of e-learning technologies

However, the aforementioned e-learning technologies don't provide sufficient means to automate the creation of educational content. In particular, they provide tools for conducting lectures, practical, laboratory and monitoring students' knowledge, analyzing the monitoring process, but they do not have the appropriate means to create test questions from existing content or to create an individual learning trajectory.
With the development of Web 3.0 and the spread of social networks emerged new forms of e-learning, which are the result of the networking of students with the teacher and with each other, the so-called collective knowledge. Today's education does not stand still, but the presence of a teacher in the virtual (Internet) environment is a prerequisite not only in terms of content creation, but also when referring to the development of new methodological techniques [9, 15].

3 The Model of Ontological System

Different types of educational content are generally used in e-learning, such as texts, slides in presentations, video files, sound files, quizzes, tests etc. There is a need to link mentioned elements together and to allocate a certain "portion" of knowledge, it will be a set of logically related learning material that can be perceived as a unit that is generalized by the topic of learning [3]. According to the technology offered in [2], the educational material is organized according to the meta-ontology approach. The basic essence of such approach is the meta-ontological system.

$$Z =< O^{Meta}, P, E > \quad (1)$$

where O^{Meta} is the ontology of the upper level (meta-ontology) which contains general concepts and relations that do not depend on the subject domain and are common for all courses; P is a set of ontologies of the subject domain and certain courses; *E constitutes* the rules according to which functions the e-learning engine, which provides the study process. Meta-ontology O^{Meta} consists of two parts, $O^{Content}$ is content ontology and $O^{Didactic}$ is didactic ontology.

Review and analysis [3] of the terms in order to determine a certain set of logically related material and forms of knowledge delivery were carried out. This allowed to determine that for the designation of one unit of knowledge, which on one hand corresponds with the formal concept, gestalt, model, image, notion, quantum [11-14, 18]. But it can be named or imagined and is more rationally referred to by the term of a "chunk of knowledge" in analogy to [15] further referred to as a "chunk". The chunking technique allows us to separate data into small portions of knowledge which human short-term memory can effectively process and work with. And after studding and memorizing these portions ("chunks") it combines them into a single whole knowledge. Chunking technique is often used as a main method for the simplification of big and complex data stream. The base entity of the didactic ontology is a chunk, while content mapping, and relations conform a didactic ontology of a discipline.

$$O^{Didactic} = < C, L, R > \tag{2}$$

where $C = \{c_i\}$ is a set of chunks which compose the didactic ontology; $L_i = \{l_{m_i}\}$ is a set of content mappings; $R = \{r_{ij}\}$ is a set of relations, there are considered two types of relations R_1 *and* R_2. $R_1 \subset C \times C$ are relations among chunks; $R_2 \subset C \times L$ *are* relations among chunks and content.

Content mappings block within the framework of one discipline and varying types of content that allows to display synchronously different types of content in frames of one browser or even on different devices [15, 19]. It can be distinguished that there are relations r_{ij} of different types among the chunks of subject domain. One of those types is the "need to understand", for example, to understand what the decision-making process is, a student must understand what criteria, alternatives, scales and decision-making body are. These relations form a semantic graph of discipline. $< \mathrm{C}_i, R >$, which vertices (C_i) are chunks, and the edges R are the set of relations, "need to understand" (Fig. 2).

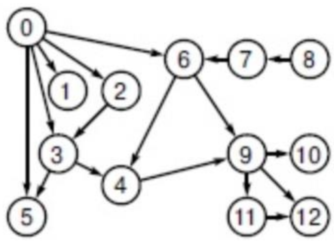

Fig. 2. Semantic graph of mapping between Chunks

The vertices of this graph correspond to the chunks, and the edges show the sequence of learning of the study material. The topological sorting of the vertices of the graph allows to construct the initial pathway of learning (Fig. 3).

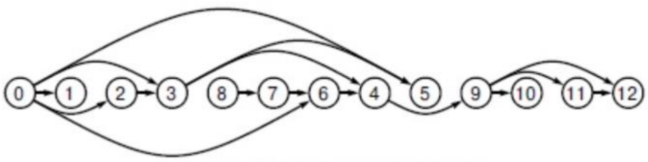

Fig. 2. Semantic graph of mapping between Chunks after topological sorting

Presentation of the didactic ontology of the discipline in the form of a graph allows to: add new chunks to the existing ontology; combine disciplines according to their ontologies; separate ontologies according to their semantic graphs on the subgraphs, for the allocation of a certain subject of discipline for studying; convey topological sorting of the vertices of the graph for the formation of the sequence of learning of the study material; find didactic errors if it is impossible to use the topological sorting for the graph. The didactic ontology gives us an opportunity to organize interactive educational environment and create a personal learning path.

Thus, with the help of the didactic ontology of the discipline, the task of forming the structure and sequence of studying the discipline material is solved.

In accordance to [2] the content part of meta-ontology reflects the other type of the connections between chunks. In comparison to the traditional approaches to building ontologies of educational disciplines, which in fact solely constructed ontology of the subject domain, it is proposed to construct an ontology by extracting from the text the predicates of the following form:

notation – essence – link(relation) – description,

It can be formalized to consider a chunk as a following set of chains:

$$C\colon < N, E, L, D > \tag{3}$$

where N is notation $E = \{E_i\}$ is a set of essences of the subject area, L are *the* links between essences and descriptions, $D = \{D_{ij}\}$ is a set of descriptions.

The set of entities which the content ontology of the discipline $O^{Content}$ consists of, together with the properties of these objects and the relations between them reflects knowledge of a certain discipline.

4 Cross Discipline Connections

One of the main features of the developed model of ontology-based IT is the possibility of cross discipline referencing of chunks in e-learning courses is [2]. With the help of didactic ontology, the ontologies of different disciplines that are build according to a common pattern and rule allow for automatic detection of cross discipline chunks, as well as to make references, and thus to create new cross discipline ontologies.

For example, course tests for “Algorithms and Data Structures” include the use of mathematical chunks such as “Matrix”.

If a student is unable to successfully pass the test for the subject “Representation of mathematical objects using data structures”, with the help of the didactic ontology it will be clear that the given student has not mastered this chunk, and therefore has to be urged to review not only the lectures on “Algorithms and Data Structures”, but also certain lectures on “Algebra and Geometry”. The given example clearly demonstrates the cross subject referencing between “Algebra and Geometry” and “Algorithms and Data Structures” courses with the help of a chunk from the subject areas of “Matrix”. The example that is described above is represented in Figure 4.

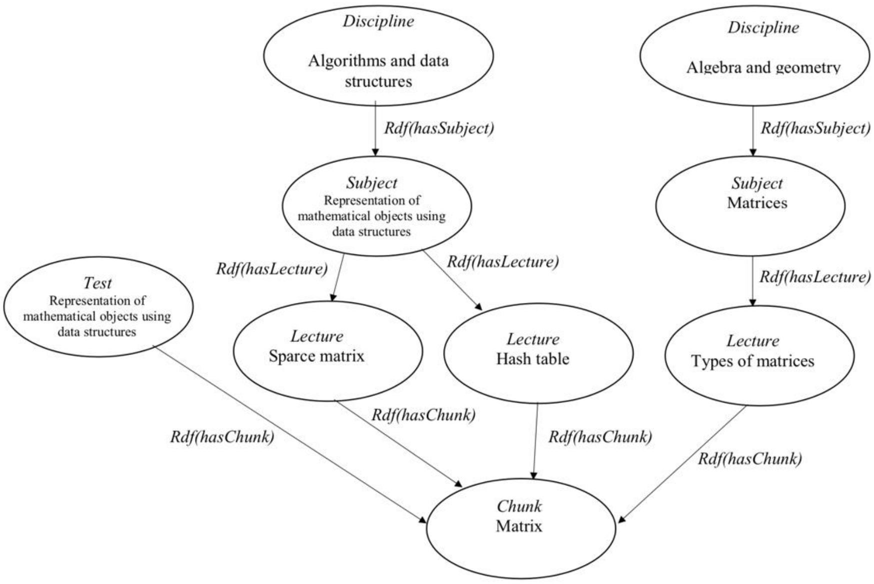

Fig. 3. Cross discipline connection between two disciplines “Algebra and Geometry” and “Algorithms and data structures”

The connection between course objects with the chunks of another course allows to indirectly connecting lectures, tests and methodic materials between each other.
In this case, the didactic ontology implements a chunk-oriented approach to learning and enables the identification of cross discipline connections.

5 Ontology-Based Model of IT for eLS

In the process of teaching of any discipline, a teacher has a curriculum of the discipline and a work program of credit modules.
Based on these normative documents, the teacher develops the entire course. And he also, distinguishes the disciplines that precede the study of this course and follow after it.
For a more explicit consideration of the use of IT for ontology-based eLS is presented in Fig. 5 which shows the conversion graph, and in Table 1. The explanation of the load of arcs of the graph of transitions is provided.

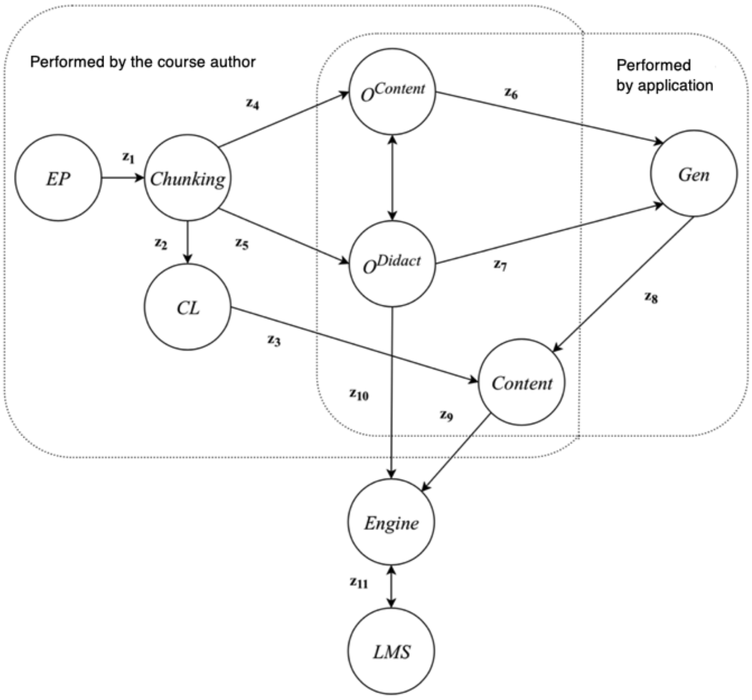

Fig. 5. A graph of transitions in the IT for ontology-based eLS

In Fig. 5 the following notation has been used: EP is educational program; $Chunking$ is chunk selection; CL is content labels; $O^{Content}$ is content ontology; O^{Didact} is didactic ontology; Gen is quiz genretor; $Content$ is educational materials; $Engine$ is the engine of an ontology-based eLS; LMS is learning management system.

Table 1. Transitions in the IT for the ontology-based eLS

Transition	Description
z_1	Selection of the chunks from a work program
z_2	Linking chunks with labels
z_3	Linking labels with educational materials
z_4	Construction of content ontology
z_5	Construction of didactic ontology
z_6	Quiz generation
z_7	Linking quizzes with chunks
z_8	Formatting quizzes and test
z_9	Transferring educational material to the engine, forming references to educational materials
z_{10}	Construction of an individual trajectory of education

Transition	Description
z_{11}	Interaction of the engine of an ontology-based eLS with existing systems

Fig. 6 presents the structural diagram of the interaction in the IT for ontology-based eLS, which consists of two parts of the manual work of the course author (teacher), which cannot be automated and automated work done with the help of a new application [1].

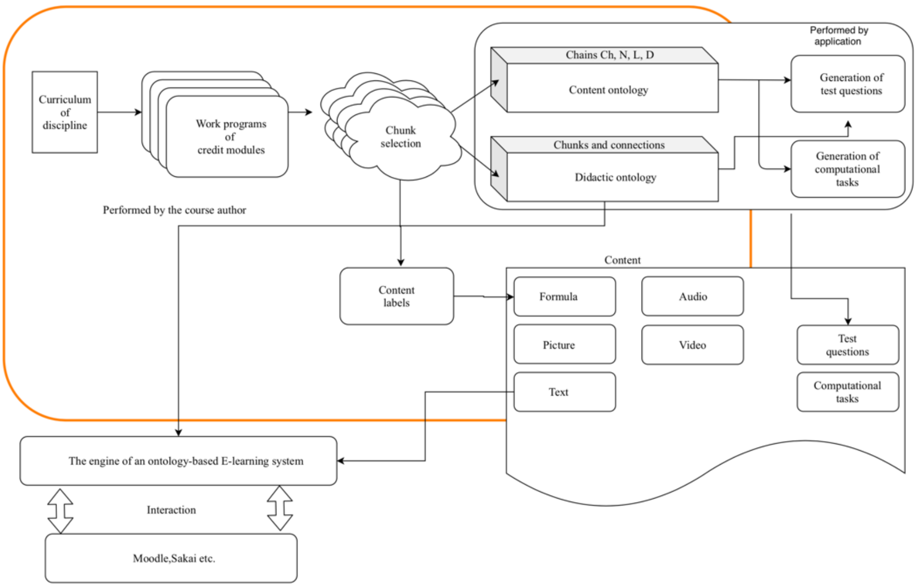

Fig. 6. Structural diagram of the interaction in the IT for Ontology-Based eLS

In the beginning, before using the system, it is necessary to select chunks from the related disciplines which the current discipline relies on. This step is necessary for the entrance control of knowledge on discipline, as well as to be able to identify the gaps and passes in the student's knowledge in the future.

In the first step for each credit module, the author of the course allocates a set of chunks and on its basis builds a didactic ontology:

$$\theta = \{Ch_i\} \tag{4}$$

where θ is a set of chunks for credit module; Ch_i an i-th chunk of credit module $i = 1, \dots, n$.

After that, the selected chunks are formalized and the didactic ontology is built, which will then be responsible for the individual trajectory of education. To represent the ontology, the RDF format can be used or it can be done as a table, guided by the following rules: unidirectional arcs and the possibility of topological sorting.

Also, in order to create educational content, the author of the course must download the required text file and multimedia files (images, videos, mathematical formulas, etc.) from which the educational content will be created. It then will mark up the educational web content and distribute it between the chunks. In addition, the author of the course formulates a system of educational goals, according to Bloom's taxonomy [2] and establishes the relationships of correspondence between the educational goals and the elements of educational web content.

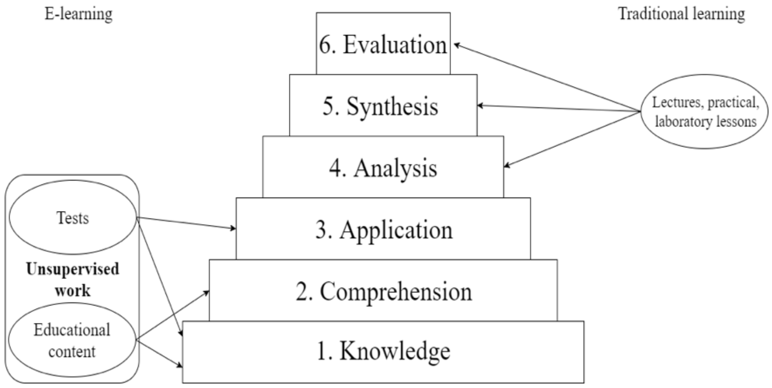

Fig. 7. Suggested algorithm regarding the coverage of Bloom's taxonomy by the educational system

The situation in Bloom's taxonomy coverage proposed by the authors of this article in figure 7, makes it enables to construction of the educational process in such a way, that the teacher would create problematic situations for comprehension and perception by the students, who search for solutions to various problems through constructive interaction during lectures, practical, and laboratory lessons. Students' unsupervised work on the other hand is based on e-learning which consists of two components: the learning content and tracking the progress.

The learning process takes place on the basis of a chunk-oriented approach, with the help of the ontologically driven e-learning engine. For each chunk links are generated to the educational web content and are then provided to the student so that he can study the material using LMS or independently – in the form of hyperlinks to texts, drawings, media in a web browser [15].

The initial trajectory of learning is obtained after the topological sorting of the onto-graph $< Ch_i, R >$.

With the help of the developed tools [1], for each chunk, a bank of test questions and quizzes Q is generated for its content ontology.

$$Q = \cup_{i=1}^{n} Q_i \tag{5}$$

where Q_i is a set of generated test questions and quizzes for Ch_i, $i = 1, \dots, n$.

In this case, each student has a vector of marks – $\bar{v}$, such as:

$$\bar{v} = (g_1, \dots, g_n) \tag{6}$$

where $g_i \in \{-3, -2, -1, \tau, 1, 2, 3\}$
Herewith $g_i \leftrightarrow Ch_i$, that means that i-th mark correspond to i-th chunk.
The initial condition of the vector of marks is uncertain, that is, $\bar{v} = (\tau, \dots, \tau)$.
In the process of learning, the student answers Q_i test questions in accordance with the constructed initial learning pathway.
After each student's answer to the question of the corresponding chunk the grade vector is changing. If the correct or incorrect answer is made, the following options for placing the grade g_i are available, see Table 2.

Table 2. Conversions between grades

Correct answer	
Initial state	End state
0	τ
τ	1
1	2
Incorrect answer	
Initial state	End state
1	τ
τ	0
0	-1

The ontology-based system accumulates the data about the student activity during his interaction with the eLS. That data comprises the history of content attendance and the history of grades' changes. Next, on the basis of received data the system provides recommendations for the possibility of further study or the need for re-studying of certain material related to the specific chunk (it depends on given results). Having completed the study of the credit module, each student has his own vector of marks, which is analyzed by system. There are three following possible outcomes [17]:

- $\forall g_i = 2$, in case when the system will move to the next credit module;
- $\exists g_i = \tau$, in case when the system can't move to the next credit module, since there remains a chunk for which the grade is undefined.
- $\exists g_i = -1$, in case when the system can't go to the next credit module, because there are chunk, grades for which are unsatisfactory, and re-examination of the material is required.

With the help of the evaluation vector, an ontology-based eLS provides recommendations for further education and builds an individual trajectory of learning in accordance with the given didactic part of the meta-ontology of the discipline.
Thus, the work with the content and content of the content ontology of the discipline correspond to the process of knowledge management. Didactic ontology of the discipline implements the sequence of learning, that is, the formalization of the individual learning pathway. Ontology-based model of IT for eLS uses chunk as a base entity. It allows to structure the content of the course and automate the creation of educational

resources with the help of content ontology and allows to formalize the individual trajectory of training with the help of didactic ontology.

6 Conclusion

In this paper an overview and classification of modern IT in education has been conducted. These were divided into three groups: social networks, repositories and LMS.
There was developed an ontology-based model of IT for eLS, in which the basic principles of the educational methodology are implemented. It is proposed to redistribute the load in accordance with educational goals according to Bloom's taxonomy, providing class lectures with the motivational component, and using an eLS for independent work of students, automation of their knowledge control that will increase the time for the individual communication between the teacher and the student and the student's personal development.
The developed ontology-based model of IT for eLS will allow the teacher to free time from routine work in favor of its creative component through the allocation of chunks and then linking them with content and partial automation of the creation of test questions and computational tasks for eLS, as well as motivating students to increase the success; in teaching students through the formation of an individual learning trajectory and the provision of new interactive learning services.

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