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TÍTULO: Ingeniería ontológica de programas educativos.

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RESUMEN: Uno de los objetivos clave de la etapa actual de desarrollo del sistema educativo es mejorar la orientación práctica de la capacitación para el mercado laboral contemporáneo. Es posible resolver el problema especificado solo utilizando métodos innovadores y medios de creación de información y espacio educativo con respecto a la formación y el procesamiento de los objetos educativos y los servicios del programa distribuidos en una red educativa, y permitiendo llevar a cabo procesos flexibles de educación y métodos de prestación de actividad educativa. El objetivo del estudio es determinar las posibilidades de utilizar el enfoque ontológico para la construcción de sistemas innovadores de gestión automatizada de la educación, que incluyen la construcción de trayectorias de aprendizaje individuales.

PALABRAS CLAVES: estándar profesional, programa educativo, ontología, concepto, modelado semántico.

TITLE: Ontological engineering of educational programs.

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ABSTRACT: One of the key objectives of the current development stage of the education system is to improve the practical orientation of training for the contemporary labor market. It is possible to solve the specified problem only using innovative methods and means of creation of information and educational space with respect to formation and processing the educational objects and the program services distributed in an educational network, and allowing carrying out flexibly processes of educational and methodical providing of educational activity. The aim of the study is to determine the possibilities of using the ontological approach to the construction of innovative automated education management systems, which include the construction of individual learning trajectories.

KEY WORDS: professional standard, educational program, ontology, concept, semantic modeling.

INTRODUCTION.

The article deals with the issues of flexible engineering of educational programs of higher education in accordance with the needs of the labor market, reflected in professional standards. To date, research in this area mainly concerns issues, such as technologies and tooling of blended learning, the use of multimedia and simulation programs in practice-oriented training, knowledge testing technologies, technologies and methods to measure the quality of e-learning, as well as portfolio management of students based on competency models. These issues and problems are considered with varying degrees of detail, for example, in (Tarasov, 2015; Telnov, 2014; Zinder, 2015a, 2015b) and other works.

In the modern context, higher education is becoming more flexible, focused on the needs of the labor market and the individual needs of students. The needs of the labor market are currently accumulated in professional standards, while the individual needs of students are most often determined by the real demand for specific vacancies of enterprises and organizations. In this context, there is a need to create tooling for engineering of flexible educational programs, the most focused on the actual needs of the subjects of the educational process, which would be based on the use of intelligent (smart) technologies that allow forming subsets of educational content based on integrated information and educational space of the educational institution.

Building learning trajectories that depend on individual abilities, personal preferences and personal pace of learning material remained an urgent task at all development stages of the automated education management systems. It is obvious that the creation of individual learning trajectories involves a stage of human-machine interaction. Organization of intellectual context-dependent human interaction with software systems that understand the semantics of queries is possible only using ontological model of the subject matter domain of communication. The necessity of using the ontological approach in the problems of intellectual interaction is justified, for example, in the works (Boychenko & Korneev, 2014; Lukinova el al., 2014) devoted to the issues of semantic interoperability (interaction at the semantic level) of information systems.

The creation of education management systems based on the ontological model brings one closer to solving the problems of the automatic generation of individual trajectories in mass education. It should be noted that the first attempts to implement this approach were not successful enough because, first of all, the shallow depth of the hierarchy of the content graph and ignoring the quality and quantity of necessary connections, in particular, between the concepts of different ontologies that made up the model of the educational space. As soon as subject ontologies with five or six levels of concept structure were generated, based on comprehensive queries to the knowledge base, it became possible to construct quite tentatively individual educational trajectories combining retrospective analysis, geoinformation component, as well as intra- and interdisciplinary connections. However, today the question of maintaining links between the concepts of different ontologies, for example, between the ontology of the professional standard model and the ontology of the educational standard still remains open.

The solution of this problem is seen in the need to build a generalized conceptual model for describing the information and educational space (IES), which integrates heterogeneous scientific and educational content, and to which public access is available in the course of solving various problems of educational activity using a variety of software services (Telnov, 2014).

DEVELOPMENT.

Literature review.

Due to the variety of terminology, as well as a large number of components, the construction and detailed description of the ontological model of IES is, according to the authors, a challenging task that requires the involvement of a broad range of specialists both in the subject matter domains (professional communities), and in the field of education management (specialists at the level of educational program managers, university teachers, employees of educational departments of business structures, and other specialized organizations).

Questions of conceptual IES model construction are considered in detail in works (Telnov, 2014; Zinder, 2015a, 2015b; Gasparian et al., 2016; Nartsissova & Kulikova, 2014; Pavlova et al., 2015; Telnov, 2010; Telnov et al., 2015; Gasparian, 2014) and are based on the detailed analysis of key components, such as the following ones: educational standard; professional standard; educational program; preparation profile (the master's program, academic program track, etc.); input and output competencies of the student; obligatory, variable and optional disciplines (modules, practices); results of training on discipline (module) in the form of knowledge, abilities and skills gained as a result of studying of discipline (module); the curriculum as actually integrated structural and logical scheme of implementation of the educational program on the set profile of preparation (the master's program, academic program track, etc.), and the form of training which is characterized by a set of the disciplines (modules) distributed by semesters.

Since each of these components has a rather complex structure, as well as a set of relationships with other components, building an ontological model of IES is of great importance. It serves the basis for parametric adjustment of the educational program, which implements an individual learning trajectory with predetermined output competencies of the student due to the automatic generation of educational content in accordance with the individual needs of the student (Gavrilov, 2016; Larichev et al., 1999; Trembach, 2016).

The implementation of the competence-based approach in education involves the uncovering of concepts such as the competency model and competency standards. Thus, in (Dmitrievskaya, 2010) the competency model is defined as a set of elements in the form of a list of knowledge, skills, relationships, and characteristics that allow a person to successfully perform the functions corresponding to his position. The competency standard in the same work is defined as the competence norm for each element of the competency model, which is the target level of learning outcomes and serves the basis for the application of the assessment procedure. Competencies, in fact, define a set of activities that should be carried out by a professional in a particular field at a certain level, while competence is the implementation of competency in a particular subject of activity, which depends on personal characteristics, and is defined as demonstrated professional behavior in the workplace.

The application of the competence-based approach in the formation of professional educational programs in terms of practical activity causes the need for maximum orientation to the actual professional standards that determine the competence and qualification requirements for the work performed. In this regard, the professional standards developed by the Russian Association of Computer and Information Technology Enterprises (ACITE), such as Information systems specialist, Information resources specialist, System Analyst, and System Architect (Professional standards in the field of information technology. Moscow, Film and Television Producers Association (APKIT), 2008) are of great importance. They are based on the National Qualification Framework of the Russian Federation (NQF), which clearly defines job responsibilities as well as professional competencies and requirements for education in the field of information and communication technologies by qualification levels.

Approaches to the development of the engineering system of innovative processes to generate individual educational content.

The problem of modeling and algorithmization of the educational programs in the form of a chain of interrelated training modules and objects, taking into account the implementation of a competence-based model of learning in a distributed educational network of the university, seems to be very intriguing.

Educational programs formation methodology under development is based on the research results of these authors and is progressing towards the construction of computer ontology, which classifies and sequences objects of professional and educational standards and formed educational programs that, according to the authors, is consistent with global development trends of science in the given field of knowledge.

One of the directions of improving the system of vocational education is the development of the methodology of generating educational content, which is based on a comprehensive account of both personal characteristics of the student, and various factors, such as the subject matter domain of training, the level of educational background of the student, the form and methodology of training, requirements for learning outcomes (knowledge, skills, abilities to perform certain labor functions), and many others. Therefore, the issues of design and development of the educational models engineering system in order to more effectively organize repetitive typical information and educational processes and procedures, are on the agenda. Without solving the problems of building an individual learning environment based on the intellectualization of the processes of generating educational content, this gap is almost impossible to eliminate.

In this regard, it seems to be extremely useful using special tooling for the accumulation and storage of knowledge in the form of an intelligent repository, which should contain both ready-made standard information and educational solutions (let's call them cases), and individual educational objects which can be used in the generation of one or another educational program of any complexity. According to the authors, such tooling should have the capacity for continuous development and accumulation of new knowledge obtained from experts on the subject. To develop such tooling, it is necessary first of all to describe in detail each of the stored objects using meta-description tooling, as well as to correctly establish relationships between the objects of the model, using, for example, the apparatus of relational algebra.

Before giving a description of the objects of the integrated IES model, detailed and correct from the viewpoint of establishing links, it is necessary to determine how the terms used in educational and professional standards relate, and to outline the points of their interface. Table 1 presents the results of the analysis of the possibility of correlating the terminology of educational and professional standards.

Table 1. Compliance with terminology in professional and educational standards

Professional standard.	**Educational standard.**
Name and code of the type of professional activity	No analogs
Name and code of the class group	No analogs
Name and code of economic activity	No analogs
Code and name of the generalized labor function	Types of professional activity (partially)
Skill level	The level of education (partially)
Possible job titles	No analogs
Education and training requirements	The level of education (partially)
Code and name of the labor function	Competency (partially)
Labor actions	Competencies (partially)
Necessary skills	Competencies (partially)
Required knowledge	Competencies (partially)

In a consequence of the analysis of terminology in professional and educational standards, it can be concluded that it is difficult to formalize the relationship of these standards. It can only be set at the level of individual components of educational programs (curriculum, working programs of disciplines, educational and evaluative content), tailored to the requirements of both standards and with the participation of both employers (creation of the requirements model to the employee), and educational institutions. Moreover, it is obvious that no one educational program can currently fully meet the requirements of any professional standard. But, this, apparently, does not need to be required, because the contemporary specialist should have some basic knowledge and reasonable versatility, allowing him to independently hone his professional skills under the requirements of a particular employer. Nevertheless, the issues of combining professional and educational standards should be reflected in the educational activities of educational institutions for different levels and forms of education.

Thus, there is an obvious need for the development of a flexible integrated system of educational content engineering for individual learning environments based on the IES description model, as well as the use of intellectual tooling for its implementation.

In this regard, it is necessary to systematize all possible IES objects and develop a set of meta-descriptions for each of them. Another important task is forming unified directories of possible meanings for different descriptions of IES objects in order to ensure the compatibility of information.

According to the authors, the main research stages in the decomposition of the main purpose of the study and the solution to these problems should include the following steps:

1. Developing a conceptual model of an intelligent integrated educational environment based on the collection, analysis, classification, and generalization of information from various sources, including the information contained in professional and educational standards.

2. Systematizing and organizing of elements (concepts) of the intellectual integrated educational environment model based on the conjugation of different ontologies with respect to the scope of the model.

3. Forming of intelligent ontology repository (the digital repository) and developing on its basis of algorithms and services for the generation of educational-methodical and organizational-managerial content for specific parameters of the educational environment and requirements for learning outcomes.

Results.

Let's dwell in more detail on the issues of creating an ontological model to describe IES objects. According to the authors, the task of describing the IES, at least its basic part, can be reduced to the distinguishing and conjugation of the following ontologies.

a. Ontology of professional competencies.

This ontology should be based on information from professional and educational standards, as well as from other normative-reference and organizational-managerial documents related to the development of knowledge, skills, and labor actions necessary for the mastering professions.

One possible approach to the organization of such ontology can be an approach using the matrix of competencies, which sets target indicators in conjunction with the passports of competencies, as well as the sequence of their achievement within the areas and levels of education, enlarged groups of specialties and areas of training associated with certain types of professional activity.

The analysis of the practice of applying the competence-based approach to the development of educational programs shows ambiguity in the understanding of what the professional competency is. As a result, today there are different interpretations and ways to describe this term. Thus, there are concepts of universal competency, general professional competency, and professional competency, which are sufficiently developed and widely formulated in the Russian Federal State Educational Standards (FSES).

Competencies are formed during the implementation of the educational program in the form of a sequence of academic disciplines, modules, and practices, and are evaluated using indicators of their achievement (for example, knowledge, abilities, and skills), set in the form of learning outcomes. However, professional standards operate with terms differentiated by skill levels, such as generalized labor function, labor function, knowledge, skill, labor action, which, in fact, corresponds to the concepts of competency and indicators of its achievement. Thus, when constructing the ontology of competencies, it is advisable, according to the authors, to identify elements (concepts) such as competencies, knowledge, abilities, skills (formulations taken from the FSES), as well as elements from the terminology of professional standards, such as generalized labor function, labor function, labor action, knowledge, and skill. Each of the selected elements can be described by a set of parameters (attributes), while the links established between the elements of the ontology will allow conducting semantic analysis and coupling of the terminology of educational and professional standards.

b. Ontology of the subject matter domain.

This ontology should be based on the semantics of professional activity, which includes terminology and classification by subject matter domains and types of activities, groups of occupations, positions, and related skill levels.

Thus, professional standards, currently approved by the Ministry of Labor and Social Protection of the Russian Federation, described in sufficient detail the qualification characteristics of professions using a broad range of different parameters, such as belonging of standard to a certain area and type of professional activity, and the relationship with the lists of groups of occupations (based on All-Russian Classifier of Occupations (The All-Russian Classifier of Occupations OK 010-2014 (ISCO-08). Adopted and enforced by the Order of Rosstandart of 12.12.2014 No. 2020-st)), types of economic activities (based on Russian National Classifier of Types of Economic Activity the All-Russian National Classifier of Types of Economic Activity OK 029-2014 (NACE Ed. 2). Adopted and enforced by the Order of Rosstandart of 31.01.2014 No 14-St) (Ed. 08.09.2017)), professions, specialties, and training areas (based on All-Russian Classifier of Professions by Education (The All-Russian Classifier of Professions by Education OK 009-2016. Adopted and enforced by the Order of

Rosstandart of 08.12.2016 No 2007-st)), with positions (based on Unified Qualification Directory of Positions of Managers, Specialists and other Employees (The Unified Qualification Directory of Positions of Managers, Specialists, and other Employees, 2017), as well as with a set of associated levels of required qualifications, knowledge, and skills, labor actions, and other characteristics of the profession, established by a group of developers of one or another standard by expert means, which, as should be noted, does not exclude inaccuracies, mistakes, and other problematic situations and, as a consequence, requires constant clarification and improvement.

Also, according to the authors, the ontology of the subject matter domain should include information about enterprises and organizations (The Russian National Nomenclator of Businesses and Organisations OK 007-93. (ed. 28.02.2018)). The analysis of economic agents based on a set of parameters using open information sources will promote a more detailed analysis of a subject matter domain and, consequently, understanding which specialists mostly correspond currently to requirements of the employer.

c. Ontology of educational tooling.

To systematize information in a particular area, it is necessary to conduct a detailed meta-description of all possible training and test objects that make up the global learning environment. This ontology should include information not only of educational and evaluative nature but also of organizational and managerial nature, containing also information about the specialists involved in the educational process, including training, teaching methods, and organizational support of education, as well as acting as experts and employers. Such ontology deals with a variety of attributes, such as brief biographical personal data of specialists, their qualification profile (academic degree, academic title, codes of specialties according to All-Russian Classifier of Professions by Education, related to basic education, and codes of specialties for awarding academic degrees), codes of held positions in chronological order, indicating places of work with the codes of organizations, major publications, including scientific and educational works indexed in Russian Science Citation Index, Scopus, Web of Science, etc.. These attributes include also Hirsch index, results of intellectual activity, professional competencies possessed by a specialist, formulated in accordance with the approved current professional and educational standards, professional achievements and awards, and other characteristics that comprehensively assess a particular specialist, and help to assess his contribution to the development of education and science in a particular industry sector as an educator and academic worker, specialist, expert, etc. (Gasparian et al., 2018).

Discussion.

The simplest form of ontology storage is an Object Windows Library file (OWL-file). When such a file is read, a model (a set of claims) is created in memory and further operation is performed with a created model. The obvious drawback of this approach is the increase in memory costs, as well as a significant increase in the loading time of OWL-files as the volume of metadata contained in the ontology increases. The need to use special language tools to extract metadata stored in ontologies necessitates the construction of ontology repositories based on the database management system (DBMS).

From the standpoint of structural features, graph databases are best suited for ontology storage. In this case, graph vertices can be used to store ontology concepts, while graph edges can be used to store relationships between concepts. Vertices and edges can contain arbitrary sets of attributes. An edge always has a starting node, end node, type, and direction. Graph database management systems support methods for creating, reading, updating, and deleting data (CRUD for short) based on the graph data model. The SPARQL-like languages are used as a linguistic means of manipulating data. Syntax of these languages is close to SQL-language, which is the query language of the relational database (for example, the Cypher query language in Neo4j graph DBMS). Graph DBMS began to be actively used with the development of social networks, and are now widely used, for example, to solve problems related to the search for fraudulent and suspicious transactions in payment systems. In such tasks, it is important to quickly find the vertices associated with the source information (for example, search for friends in social networks or accounts to which funds have been transferred from a certain account).

Graph DBMS got an extra boost for use by optimizing search queries (fast graph traversal algorithms) and creating indexes. Indexes help to optimize the process of finding specific nodes. Despite the fact that most queries to graph DBMS are associated with the selection of the necessary information when traversing relationships between vertices, there are certain situations where it is necessary to select specific nodes directly, rather than by detecting them using traversal. For example, when identifying nodes that serve starting points for crawling, it is necessary to find one or more specific nodes based on a specified combination of attribute values (for example, select all members of a social network under 20 years of age). To increase the efficiency of node search in graph DBMS, there are tools for creating indexes for combinations of labels and properties.

Further, the possibilities of relational DBMS as a mechanism for creating and storing ontologies are considered. Traditionally, the disadvantage of relational DBMS, when working with graph data models, was the lack of tools for implementing hierarchical queries. For example, searching for vertices connected to a given vertex through any other vertices required numerous join operations, which significantly slowed down query execution. To solve this problem, standard SQL-1999, as compared to SQL-92, makes it possible to create a temporary view to store hierarchies, which is described by the WITH operator. After that, data are retrieved from it through a simple SELECT command. A number of DBMS have their own means to implement these requests. For example, in ORACLE DBMS, starting from version 8, hierarchical queries are very effectively implemented using the CONNECT BY command, while to implement these queries through MS SQL-2008, one can apply a set of standardized stored functions to work with hierarchy levels (Hierarchyid).

Summarizing the above, it can be noted that relational DBMS in comparison with graph DBMS have higher efficiency of data search by values superimposed on attributes (the task of selecting graph nodes directly, without taking into account relationships). Graph DBMS implement queries more effectively taking into account the relationship between the vertices.

The approach for the organization of semantic search of data which takes into account advantages of both graphs and relational DBMS is described in (Boychenko et al, 2015). In this case, a set of interrelated concepts reflecting the semantics of the subject matter domain is stored as a graph. Data are stored in relational tables that contain a significant number of records. Initially, the query selects the vertices of the graph according to the specified conditions imposed on the relationship between the concepts. The selected vertices contain attribute values by which records in relational tables are searched. Search by graph model is organized by means of Neo4j DBMS, while search of records in relational tables is carried out by means of MySQL DBMS.

Analyzing the possibilities of using the graph and relational DBMS to work with ontologies, it should be noted that they lack specialized mechanisms that support axioms and rules for inferring statements based on the interrelations of concepts. To implement these mechanisms, it is necessary to develop software packages in procedural languages, whose use with regard to large volumes of stored data is inefficient.

In this case, Oracle DBMS, which today can be attributed to the object-relational class, requires special consideration. The ORACLE 11g implements mechanisms, which are united by the term Semantic Technologies. Version 11g provides the ability to export and import OWL- structures and support for the OWL Prime ontology description language, which is a subset of the above specified OWL DL language, and includes capabilities for:

- Creating ontology structure (class, subclass, property, subproperty, domain, range, and type).
- Specifying characteristics of properties (transitive, symmetric, functional, and inverse).
- Comparing classes (equivalence and disjointness).
- Comparing the properties (equivalence).
- Comparing entities (same, or different).
- Specifying restrictions on properties (hasValue, some values From, allValuesFrom).

More than 50 rules that are used in the inference process are developed to support OWLPrime. A rule consists of a condition if, a filter (condition), and a conclusion then. The ORACLE 11g provides the ability to configure user-defined rules using OWLIF language (IF-THEN constructs). Users can set specific restrictions on the rules. For example, one can specify that the system should allow a user to create only logical inference within the subClassOf hierarchy. At that, the number of inference steps can be limited.

Queries to retrieve information from ontologies in ORACLE 11g are performed using SPARQL language. To connect rules of inference created by the user, SPARQL-queries use SEM_RULEBASES construct.

CONCLUSIONS.

The article presents the results of the analysis of IES objects, defines the requirements for meta-description of educational objects and services, as well as describes the concepts of basic ontologies included in the object-based method (OBM) of IES description.

The authors show the possibilities of using the graph and relational DBMS to create ontology repositories of the IES description model. Based on the above, it can be concluded that at present it is most appropriate to use ORACLE DBMS version 11g to create ontology repositories used to build the OBM of IES description. However, it should be noted that to work with ontologies of noted type, pre-configured inference rules (mentioned above) will be used less efficiently. This is due to the fact that they are focused more on working with ontologies whose vertices are linked as a class and a subclass.

In ontologies that can be used to construct the OBM of IES description, there are vertices connected by more complex types of connections. More complex connections between ontology concepts are indicated in (Boychenko et al., 2018). In this case, the processing of such vertices requires developing custom output rules, which were mentioned earlier. This will allow establishing not always explicit interrelations between IES components based on expert estimates that in turn will give the chance to generate educational content under specific requirements of the employer, setting in various combinations query parameters such as, for example, the code of the professional standard, a type (types) of professional activity, a position, a skill level, labor functions, labor actions, knowledge, abilities, skills, and other necessary characteristics to be met by the trainee.

It should be noted as a positive trend that at present, mechanisms to work with ontological structures appear both in relational and graph DBMS. As it was indicated, to date, such mechanisms have been most developed in the ORACLE DBMS 11g database, which was given the name Semantic Technologies. It can be predicted that noted mechanisms will continue developing further, and at some point, it may appear that creating ontology repositories by means of other DBMS (for example, graph Neo4j) or applying the technology of joint use of graph and relational DBMS would be more convenient (Boychenko et al, 2015).

A promising direction for further research is the development of algorithms and services to generate educational-methodical and organizational-managerial content for specific parameters of the distributed educational environment and requirements for learning outcomes based on the use of intelligent storage of ontologies containing the rules of logical inference.

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