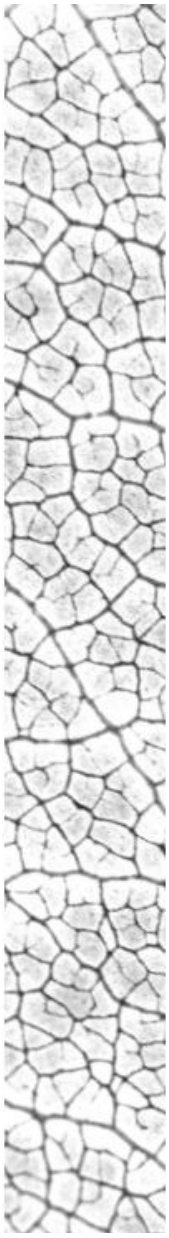

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The innovative educational programs engineering using intelligent technologies

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Abstract

The purpose of the present research is to develop innovative educational programs at the stage of the digital transformation of higher education and the transition to practice-oriented project training of university graduates in IT majors.

This goal can be achieved only by integrating all components of the educational process into single information and educational space. The solution to this problem is seen in the development of methods and tools for generating academic methodological and organizational-administrative content based on the digital repository of the electronic learning system through knowledge management technologies that ensure the adaptability of the educational process using an ontological approach.

As a result of the conducted analysis of factors for improving the quality of the educational process, the ways to improve the training of bachelors are outlined in terms of the development of an educational program in the major of *Applied Informatics* in the context of combining ontologies of professional and educational standards. The article also presents approaches to the engineering of such educational programs based on the interaction and composition of integrated information and educational space elements, as well as the semantic modeling, and automatic generation of educational and organizational-managerial content based on engineering.

Thus, the proposed method will contribute to improving the efficiency of the educational process and meeting the global trends in the development of science in the concerned field of knowledge, which will bring the training of highly qualified specialists in the IT industry to a qualitatively new level.

Keywords: information and educational space, ontology, professional standard, educational standard, educational content, competency, learning result, job function, semantic modeling

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INTRODUCTION

The implementation of contemporary information and communication technologies in the educational process has positive impact on all aspects of professional activity, such as the results of scientific and pedagogical activities in their dynamics, professional development, as well as in solving scientific problems in the relevant field of knowledge, in the development of teaching methods, and mastering new technologies. The current stage of digitalization of education is associated with the transition to professional standards being the basis for training competent professionals who are able to actively perform in the information society and possess a high degree of professional qualification and competitiveness.

Obviously, the ever-expanding range of contemporary professions and, as a result, an avalanche growth in volumes of generated educational content for their attainment, even despite the use of the latest digital learning technologies, often lead to a situation of information chaos in which for a potential employer it is quite difficult to deal with a large variety of educational programs, differentiated by areas, levels, forms, and specialization. At the same time, it is increasingly difficult for graduates of an educational institution to objectively assess their professional capabilities and correctly determine their role in the labor market.

According to the authors, this contradiction can be overcome by developing integrated information and the educational environment of a new type that would combine various groups of ontologies related both to the education content and, in general, to the infrastructure for its development and improvement. The main idea of building such a learning environment is to describe in detail, as well as systematize as many different elements of the entire information and educational

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space as possible, and build a global ontology of learning based on such an environment.

On the verge of significant changes in the development of practice-oriented educational programs aimed at building-up professional competencies that would take into account the requirements of the contemporary labor market, the task of optimizing educational planning, improving the competence model of training, the network form of implementing educational programs, as well as using a developed learning management system in the educational process comes to the fore. Works (Bogoslovsky, Izvozchikov, Potemkin, 2000. Dmitrievskaya, 2010. Dmitrievskaya, 2010. Bayandin, et al. 2017. Kulikova 2016) are devoted to these issues with varying degrees of detail. However, with the development of the project approach in training, as well as taking into account the need to combine educational and professional standards when implementing educational programs, the situation is radically changing (Digo, et al. 2016. Konyashina, 2016. Gavrilov, 2015). Therefore, the relevance of the present research is to develop an original methodology aimed at providing educational and methodological support for educational programs, based on the construction of a certain global ontological model of the information and educational space, taking into account the vast amount of knowledge both in terms of subject areas (professional standards) and from the standpoint of education (updated educational standards).

Analysis of the information and educational space components

To identify factors affecting the educational process quality in general, and the quality of training of IT specialists, in particular, it is necessary to consider in more detail the information and educational space components, such as educational planning, competency model, learning management system, as well as determine the extent to which they impact achieving the main result, namely, improving the quality of graduate training.

Educational planning. According to the authors, the main problem of this component is excessive congestion of the curriculum with numerous rather small-scale disciplines, which leads to the blurring of the subject matter in several disciplines, duplication of the material, and loss of students' interest in the subject. Moreover, an attempt to include as many subjects as possible in the curriculum often leads to a violation of existing requirements for the maximum labor intensity of the student's academic load. The experience of most of the world's leading universities shows that a relatively small number of succinct disciplines whose successful study guarantees training of high-class professionals are enough to train a qualified bachelor.

Foreign experience shows the feasibility of optimizing the curriculum due to the rearrangement and consolidation of disciplines by combining them into logically complete modules. Such optimization, according to the authors, will simplify the construction of a structural and logical scheme for studying disciplines, eliminate duplication of content, allow simplifying the procedures for monitoring the quality of educational program mastering by reducing the range and integrating assessment tools into enlarged complex tasks, which will give importance to each discipline studied, and make the technology of mastering the educational program and the formation of the required universal, general professional and professional competencies more transparent.

When optimizing educational planning, it seems appropriate to redistribute the labor intensity of the educational program in favor of disciplines that create the professional image of the graduate. For example, for the major of *Applied Informatics*, the labor intensity of the block of general professional and professional disciplines and practices should be at least 75% of the total labor intensity of the educational program. Certainly, reducing the number of disciplines in the curriculum will inevitably lead to the need to optimize the staff structure of both the research-academic and supporting departments of the university. However, according to the authors, with a competent approach to the staff deployment, such optimization will likely have a positive effect by increasing competition among research and teaching staff, which will serve as an incentive to improve their qualification. At that, employees of supporting departments will be able to reallocate their workload in favor of analytical work, which will help to improve the quality of supporting the educational process.

Competencies model. Applying the competence-based approach when implementing the educational process, requires organic integration of the curriculum and academic schedule with developed competences in a way to comply with the correct structurally-logic scheme of mastering the disciplines, modules, and practices. The competency model is implemented based on the construction of a competency matrix whose columns define a set of disciplines, modules, and curriculum practices, while rows define a list of competencies appropriate to educational program orientation (profile). The intersection of rows and columns indicates whether the competency being formed is present or not. The problem here is that as a rule, one discipline (module or practical training) forms several competencies, respectively, the same competency can be formed by several disciplines, which significantly complicates the structural and logical design of the educational program. One possible implementation of a competency matrix can be an indication of not just the availability of created competency, but the level of its formedness using, for example, the taxonomy of the American psychologist B. Bloom as a certification method. This taxonomy includes

the levels of competency formedness, such as knowledge (level 1, the lowest), comprehension (level 2), application (level 3), analysis (level 4), synthesis (level 5), and evaluation (level 6, the highest). It seems logical to build a sequence of studying disciplines in such a way that they are ordered by increasing the level of competency formedness. Note, however, that the compilation of a competency matrix can be a rather complex optimization problem to be solved based on the iterative process of mutual coordination and harmonization of the views and expert assessments of the research-academic staff involved in the development of the educational program.

METHODOLOGY

As it seems to the authors, to build an optimal model of professional competencies, besides the competency matrix, it is necessary to form a set of complex tasks representing cases, of which each should integrate assessment tools of disciplines involved in the formation of a particular competency or group of competencies. Such a set of complex tasks should ensure full coverage of all professional competencies and serve as a basis for improving the final state certification procedure, making such a procedure even more transparent in terms of the ability to objectively assess the knowledge, skills, and abilities of the graduate.

Learning management system. The development of in-house intra-university automated learning management system can be aimed at solving two main tasks:

- online learning;
- organizing the discipline information center (module), i.e. a special working area for joint work on improving the discipline within the educational program.

In the first case, the advantages of this form of training are providing students with access to a variety of educational materials, including multimedia, 24 hours a day and seven days a week, organizing various forums, including consulting, operational ads, conducting testing and surveys, providing detailed feedback on the course materials, issuing and collecting promptly control tasks and cases, informing about literature and Internet sources, as well as concerning results of tasks and tests.

In the second case, the benefits of organization workspace for collaboration of research and academic staff to improve discipline include sharing views and experience of application of those or other teaching tools, posting information for the participants on various information resources related to the concerned discipline, placing training materials to their collective improvement, conducting a forum-based joint discussion of emerging challenges, and searching for solutions to the problem, as well as collecting and processing materials for writing the monograph or textbook.

RESULTS AND DISCUSSION

Analysis of ways to integrate educational and professional standards

Let's focus in more detail on the key points in determining the structure and content of the Bachelor's degree program in the major of *Applied Informatics*, influencing the achievement of compliance of the educational program with one or more associated professional standards.

One of the important competitive advantages of the training in the major of *Applied Informatics* is the possibility, on the one hand, for students to study in-depth subjects related to a specific subject area, while on the other hand, to simultaneously study software and information technology aspects of automation.

The main professional activity areas in which graduates of this field of training can carry out professional activities are areas, such as “06: Communications, information, and communication technologies (in the field of design, development, implementation, and operation of information systems, management of their life cycle)", as well as "40: Cross-cutting types of professional activities in the industry (in the field of organizing and conducting research and development work in computer science and engineering)" (Federal'nyj gosudarstvennyj obrazovatel'nyj standart vysshego obrazovaniya – bakalavriat po napravleniyu podgotovki 09.03.03 Prikladnaya informatika (Federal state educational standard of higher education – the bachelor training in major 09.03.03 Applied computer science). Approved by the order of the Ministry of Education and Science of 19.09.2017).

The updated educational standard of the bachelor's degree in the major of *Applied Informatics* provides for the possibility of training in four types of professional tasks, namely, research, engineering and manufacturing, organizational and managerial, and project. At that, the educational organization has the right to independently determine the direction of the educational program, focusing on one or more types of tasks. At the same time, the educational program specifies the provisions of the educational standard and provides for the possibility of its orientation to the professional activity objects, such as applied and information processes, information technologies, and information systems.

When developing educational programs in the major of *Applied Informatics*, it is necessary to take into account the relationship with professional standards, such as “Information systems specialist", "Software specialist", "System analyst"," Project manager in the information technology", "Software development manager", as well as "Research and development specialist" (Professional'nyj standart specialista po informacionnym sistemam. Professional'nyj standart

sistemnogo analitika. Professional'nyj standart programmista. Professional'nyj standart rukovoditelya proektov v oblasti informacionnyh tekhnologij. Professional'nyj standart rukovoditelya razrabotki programmnogo obespecheniya. Professional'nyj standart rukovoditelya razrabotki programmnogo obespecheniya).

A comparative analysis of the job functions of an information systems specialist and the competence model of a bachelor's degree in the major of *Applied Informatics* has revealed the need to improve educational programs. This concerns the following.

1. The set of curriculum disciplines should maximally correspond to the types of professional activities and groups of classes specified in the professional standards.

2. Incorporating in the work programs of academic disciplines of information about the knowledge, skills, and abilities of the student according to the functional maps of professional activities from professional standards.

3. Increasing the volume of educational material in disciplines related both to system and application programming, organizational and technological support for coding, modular, and integration testing of information systems.

4. Incorporating in the educational program of a larger volume of educational material (including a possible increase in the number of disciplines) related to the issues of team building, planning, and implementing the interaction with customers when performing work, technical documentation management, development of tools and methods for analyzing requirements for the information system.

5. Expanding the interaction of the university chair with employers in terms of wider involvement of practicing specialists in the teaching of professional disciplines in the course of implementing the educational program.

In more detail, the issues of designing the main professional educational programs in the major of *Applied Informatics* according to the needs of the labor market, reflected in professional standards, are discussed in (Telnov, Lebedev, Gasparian, 2017). When implementing an effective educational program taking into account professional standards, it is necessary to develop a unified methodology for its creation, which includes the following generalized implementation stages:

1. Selecting a subset of generalized job functions that are most relevant to the professional standard associated with the given training area, and for each generalized job function, choosing from the educational standard job functions that correspond to professional tasks;

2. Formulating professional competencies of a graduate of an educational program based on the selected job functions; at that, generally, one professional competence may cover several job functions.

3. Determining the results of training (knowledge, skills, and abilities) corresponding to the wording of labor actions, knowledge, and skills from job functions according to formed professional competences based on the selected job functions.

4. Creating a structural and logical sequence of disciplines and developing educational and methodological materials for them with the inclusion of selected didactic units (knowledge, skills, and abilities) in the results of training based on these materials.

Features of an educational program engineering based on an ontological approach

Conducting high-quality engineering of any educational program should be based on present-day achievements in semantic modeling of both the entire educational process in general and its components based on an ontological approach and knowledge management technologies. In this regard, it is extremely useful to use the research results described in (Zinder, 2015. Shibut, 2010. Blagov, et al. 2018. Balashova, 2015. Gruber 1993. Tarasov, 2015. Gavrilova, Kudryavtsev, Gorovoy, 2006. Chung, Kim, 2016).

These results allow identifying the main stages of an effective educational program engineering, such as developing a conceptual model of the intellectual integrated educational environment by formalizing integrated information and educational space elements, combining ontologies of professional and educational standards, systematizing and organizing the digital repository elements, developing algorithms for generating academic methodological and organizational-administrative content of the intellectual integrated educational environment, as well as approbating the proposed methodology in terms of a real practical example of the formation of academic methodological support for an educational program (Trembach,. 2016. Telnov, 2014. Larichev, et al. 1999).

The diversity of components of the intellectual integrated educational environment requires as a priority conducting their systematization for further integration in the form of a distributed repository of heterogeneous information sources and developing information-retrieval and logical-semantic algorithms to generate a variety of educational and methodological information that will help to select the most complete educational material and build the educational process based on the pre-set parameters of training a specialist in a specific subject area.

Let's consider the principles of building-up ontologies of components of the intellectual integrated educational environment at the conceptual level.

Ontology of regulatory reference information, reflecting classifiers, industrial, professional and

educational standards and other normative reference documents related to education, sets the general outline and education development vector in terms of forming a common terminology, systematizing information about economic sectors, areas of professional activity, knowledge, skills, and labor actions necessary for developing professions, setting target indicators to achieve professional competencies within the areas and levels of education, enlarged groups of specialties, and training areas.

In this regard, combining ontologies of professional and educational standards becomes a particularly relevant problem. Competencies, as a result of education, should be formed taking into account current professional standards that adequately reflect the needs of the economy (Kulikova, 2016). At that, it is necessary to correlate the tasks of professional activity from the educational standard with the set of job functions from the professional standards of the corresponding skill level associated with each of the generalized labor functions.

The ontology of specialists involved in the educational process, including training, academic methodological and organizational support of training, as well as acting as experts and employers. This ontology deals with a variety of concepts, such as brief biographical personal data of a specialist, his qualification characteristics (academic degree, academic title, specialty codes related to basic education, and specialty codes for awarding academic degrees), codes of positions held, listed in chronological order, indicating places of work with the codes of organizations, key publications, including scientific and academic methodological works indexed in the Russian Science Citation Index (RSCI), Scopus, Web of Science, etc., the Hirsch index, results of intellectual activity, professional competencies of a specialist formulated according to the approved current professional and educational standards, professional achievements and awards, and other characteristics that comprehensively assess a particular specialist and help assessing his contribution to the development of education and science in a particular industry as a research-pedagogical associate, specialist, expert, etc.

The ontology of institutions, organizations, and enterprises should, in the authors' opinion, be based taking into account the key factors and evaluation parameters that affect the level of scientific and technical maturity of a particular entity of economy, science, culture, business, etc. Using rather well-studied methods of image classification and recognition, it is necessary to conduct a detailed analysis of such subjects with respect to many parameters based on open sources of information, setting and allocating the various relationships between them, which eventually can exert a synergistic effect from the use of a set of employed digital technologies in the specific subject area, focusing on the most promising breakthrough directions of the contemporary economic development. The construction of such ontology needs more detailed specific study. Nevertheless, it should be noted that the ontology of institutions, organizations, and enterprises should play a significant role in the development of integrated information and educational learning environment, strengthening its practical orientation.

The ontology of IT tools, which can include almost all developments in the field of information systems and technologies, such as software and hardware complexes, information systems and services, integrated design solutions, and other inventions in the field of IT. The contemporary digital world has accrued quite a lot of problematic issues associated with the accumulation of a huge amount of heterogeneous information, which is almost impossible to comprehend even for specialists. Information chaos often leads to duplication of new ideas, inventions, and other scientific achievements, and begins to slow down the development of the IT industry. The broad variety of various standards in IT technologies negates the very idea of standardization in this area. In this sense, an attempt to conduct a global inventory of IT tools in the field of economy and business, carrying out at least partial, conceptual classification, and the construction of an ontology of IT tools on its basis, will be a useful step towards systematizing research in this area.

The ontology of educational resources. The need to build such ontology is dictated by an increasing amount of educational content in the form of various educational and academic methodological materials. To systematize information in this area and organize a digital repository for the automatic generation of educational content, it is proposed to conduct a detailed meta-description of all possible educational and test objects that make up the global learning environment.

The ontology of educational programs. This ontology is still poorly studied and characterized by a variety of involving elements and processes of a different nature. It is characterized by complex structural-logical and cause-effect interrelations between elements.

The list of mentioned ontologies is conceptual and requires further clarification and improvement.

When building-up the ontologies described above, it is necessary to carry out the following:

1. creating a glossary of terms;
2. describing the rules and restrictions that can be used to generate reliable statements;
3. building a statement-based model that would allow generating the necessary additional assertions.

Since each of the mentioned ontologies can be constructed by different groups of experts and have a subjective character, the task of coordinating these ontologies arises when building a global ontological model to ensure the correct integration of heterogeneous information resources into a single

information educational space. A harmonized global ontology should be open and expandable due to constant changes in its components and the appearance of new elements (for example, the appearance of new standards or changes in current educational or professional standards, the manifestation of new educational technologies and means of their implementation, changes in the dictionary of occupational titles, etc.).

This problem is solved by using methods for evaluating the semantic proximity of ontology concepts. Many well-known methods for determining the measure of closeness between ontology concepts are based on Tversky's set-theoretic approach, based on comparing the properties of concepts (Kuznetsov, Sukhoverov, Shipilina, 2010). Works (Boychenko, Korneev, Kazakov, 2018. Korneev, Boichenko, Kazakov, 2019. Korneev, Boychenko, Kazakov, 2019. Li, Bandar, McLean, 2003) deal with the analysis of the mutual arrangement of vertices within the ontology by calculating the lengths of paths between pairs of concepts and defining the shortest path length as the number of concepts in the ontology, which are located between two vertexes connected to each other. It is assumed that the shorter is the path between vertexes, the semantically closer is the pair of concepts of the ontology under consideration. In (Nguyen 2006), the basis for calculating the measure of semantic proximity of two concepts of different ontologies is the frequency of occurrence of the concept and its subclasses in one and the other ontologies. The methods described above for calculating proximity measures between ontology vertices are symmetric. The article (Maedche, Staab 2002) describes a calculation method, whose essence is that the proximity of two concepts depends on the proximity of concepts having hierarchical relationships, and is calculated recursively.

The so-called hybrid measures are the most promising for use in algorithms employed to calculate measures of semantic proximity of ontology concepts. The hybrid measure proposed in (Maedche, Zacharias 2002) consists of three parts: taxonomic, relational, and attributive. The difficulties in comparing different ontologies of subject areas are caused by the differences in the names of concepts and relationships, as well as approaches to defining concepts. When displaying two ontologies, for each concept of a given ontology, a search is performed for a similar concept of the other ontology taking into account the synonymy of the concepts. In (Rodríguez, 2000, Karpenko, Sukhar, 2009), a method for calculating the measure is proposed, taking into account the lexical proximity of concepts, properties, domains and ranges of relations (value domains of relations arguments), and parent/derived concepts.

It should be noted that the main disadvantage of most methods for determining semantic proximity is the need to involve an expert to confirm the correctness of detecting similarities and differences in semantic concepts. Given the significant number of concepts contained in these ontologies, as well as their dynamic changes, further research should be focused on developing an automatic intelligent algorithm to harmonize the above-mentioned ontologies.

CONCLUSION

Thus, in the context of higher education development, it is necessary, according to the authors, to conduct a thorough and comprehensive analysis of the accumulated experience of higher education institutions in professional training of specialists at various qualification levels, and to unify and standardize, as far as possible, the educational programs developing methodology.

The analysis of the information and educational space components has allowed determining the degree of their influence on the achievement of the main result which is improving the university graduates' training quality.

The analysis of ways to combine educational and professional standards has shown the need to improve them. At that, the given unified method of building-up an educational program, according to the authors' idea, will significantly increase its effectiveness.

Engineering of an effective educational program is impossible without developing a conceptual model of an intelligent integrated educational environment that would allow formalizing numerous elements of integrated information and educational space and combining ontologies of professional and educational standards. At that, the systematization and organization of the digital repository elements will allow developing effective algorithms for generating academic methodological and organizational-administrative content of the educational program.

The idea of building an intelligent integrated educational environment is seen in a detailed description of its constituent ontologies and building a global ontology of integrated educational space based on cognitive harmonization methods.

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