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# Ontological simulation for educational process organisation in a higher educational institution

**O G Berestneva[1], O V Marukhina[1,3], S V Bahvalov[2], O N Fisochenko[1] and E V Berestneva[1]**

[1] National research Tomsk Polytechnic University, Tomsk, Lenina Ave., 30, Russia
[2] National research Irkutsk technical University, Irkutsk, Lermontova Str., 83, Russia
[3] National research Tomsk State University, Tomsk, Lenina Ave., 36, Russia

E-mail: Marukhina@tpu.ru

**Abstract.** Following the new-generation standards is needed to form a task list connected with planning and organizing of an academic process, structure and content formation of degree programmes. Even when planning the structure and content of an academic process, one meets some problems concerning the necessity to assess the correlation between degree programmes and demands of educational and professional standards and to consider today's job-market and students demands. The paper presents examples of ontological simulations for solutions of organizing educational process problems in a higher educational institution and gives descriptions of model development. The article presents two examples: ontological simulation when planning an educational process in a higher educational institution and ontological simulation for describing competences of an IT-specialist. The paper sets a conclusion about ontology application perceptiveness for formalization of educational process organization in a higher educational institution.

## 1. Introduction

Changes, which take place in Russia, have determined the necessity to develop and implement new-generation educational standards of higher education. Implementation of new-generation educational standards requires a great work to be done over basic degree programs including calendar educational schedule, syllabus, work programmes, practice programmes, methodical materials needed for a certain technology realization and other materials that ensure the education and qualification quality.

The third-generation federal educational standard differs greatly in structure and demands from the educational standards of previous generations. The principal differences are defined by the demand to integrate the Russian system of higher education into the world system of higher professional education aimed at world job-market formation [1].

## 2. Peculiarities of new-generation educational standards

Demand peculiarities of new-generation educational standards can be divided into two groups: formal, connected with matching to Bologna process formal demands, and informal, connected with ensuring changes in an educational process structure.

Formal demands can be as follows:

- adoption of a two-level system of higher education (bachelor-magister) by the majority of specialties;

- increase of higher educational institution rights in subject and syllabus formation (a higher educational institution has a right to form educational disciplines including formation of educational programme specializations and degree programmes);
- introduction of point score for discipline workload (introducing credit workload).

Informal standard demands define the essence of educational process organization:

- adopting a competence approach to specialist training;
- use of active and interactive forms of class work (with a percentage);
- accordance of the right to a student to form an educational trajectory by him/herself (by means of optional disciplines);
- essential annual correction of a list and content of educational disciplines with respect to development of science, engineering, culture, economics, technologies and social sphere of life;
- attraction of specialists from production activity field (i.e. employer representatives) in order to form demands for graduate students, to take part in students' education and attestation.

Consequently, following the new-generation standards is needed to form a task list connected with planning and organizing of an academic process, structure and content formation of degree programmes. At the beginning of a degree programme formation process, it is necessary to solve some problems with educational schedules, educational plans, list of subjects and their content (selection of not only knowledge and skills, but also competences and ways for their formation).

When supporting an academic process, one forms some tasks connected with formation of new competences, subject content (according to employers' and students' demands), educating methods and ways.

Even when planning the structure and content of an academic process, one meets some problems concerning the necessity to assess the correlation between degree programmes and demands of educational and professional standards and to consider today's job-market and students demands to qualify a graduate with an ability to work successfully in his-her professional area on the basis of acquired common cultural and professional competences. A competence approach is needed because of the following reasons [2]:

- development of a common language between academics of higher educational institutions, employers and graduates for discussing academic results, explicating academic and professional specializations, i.e. to solve a problem of including higher educational institutions into the market, ensuring transparency of an "exchange system" between the "academic market" and "labour market", ensuring their compatibility, internationalization of the labour and academic markets;
- clarification of the "language" basis in common (universal) notions and professional (subject oriented) competences;
- obtainment of a possibility to include intervals into an academic process on the basis of the two-level (two or three-level) system of higher education and education during the life;
- actualization of adaptation by higher educational institutions of new result types, which are outside of the framework of professional knowledge and skills, applicable in wide contexts of employability and civic consciousness;
- a module form of an academic process that ensures formation of corresponding competences and development of European Credit Transfer System (ECTS).

Some researchers consider these peculiarities as drawbacks connected with economical globalization and formation of market fundamentalism principles and a global system of capital free movement. Under these circumstances, "neonomads" are formed, the people who have the same movement freedom as capital does. Nevertheless, these principles form the basis of Bologna process aimed at education standardization.

A positive result is that a competence as a category has to ensure systematic integration of education, to provoke an increase of the system-social (system-professional) quality of a university graduate [3].

Competence is a complicated, integrated notion that characterizes a person's ability to realize his/her potential (knowledge, skills, and personal qualities) for solving professional and social problems in a certain field. An obligatory use of the competence approach when planning an academic process leads to great difficulties connected with defining competence content, their formation ways, and formal appraisal of competence return against by the student. In general, the main point of the degree programme formation process is in solving these problems.

Consequently, there exists a necessity to choose some instruments for formalization of degree programme components. Ontologies could be used as these instruments.

## 3. Ontological simulation

Ontological simulation is a process of producing, developing, processing and using ontologies in a subject field. Ontology is a formal specification of a divided conceptual model [4] or formal presentation of a notion set in a subject area and connections between these notions.

$$O = \{C, R, A\}, \quad (1)$$

where $O$ – ontology, $C$ – a concept set of a subject area, $R$ – a set of relations between them, $A$ – an axiom set (laws and rules, which describe concept existence principles).

According to study degree [4], the ontologies are divided into:

- Heavy-weighted ontologies with axioms $\{C, R, A\}$.
- Light-weighted ontologies without axioms $\{C, R\}$.

Ontological simulation can give people or software agents such opportunities as multiple use of general understanding of information structure, knowledge reusability in the subject area, separation of knowledge from hot knowledge in the subject field, assumption admission as evident in the subject area, knowledge analysis in the subject field. One of the most common aims for ontology development is multiple use of general understanding of information structure by people and software agents [6]. One more certain ontology advantage is a possibility of relations and concept visualization, which improves understanding of subject area specific. At that, there still exists a possibility to describe ontology formally with the help of special languages (OWL, XML, etc.). It gives an opportunity to keep and replicate solutions.

When developing ontologies for any subject area, one should take into account peculiarities of this information simulation kind:

- there are some ways for subject field simulation – there always exist vital alternatives. The best decision depends on a supposed application and expected enhancing;
- ontology development is necessarily an iterative process;
- in ontology, notions should be close to objects (physical or logical ones) and relations in the subject area.

Ontology development starts with defining its application field and scale. Ontology scale defines its complexity. To decrease complexity of the subject field, they use different methods for its structuring. It is considered to be an interesting approach to knowledge structuring that uses a fractal stratifiable model (FS-model), which is used for deriving layers of homogeneous informational objects in a certain subject area with respective object visualizations from one layer to another. This approach allows becoming closer to ontology system formation, i.e. ontological space of the subject area [5].

## 4. Ontological simulation application when planning an academic process in a higher educational institution

Some authors applied ontological simulation for academic process organization in the higher educational institution to assess the need for specialists, interconnection between academic subjects, and to form a syllabus [4-7].

The authors propose to apply ontological simulation for structure and content formalization of basic degree programmes developed according to the Federal State Educational Standards (FSES-3) + Higher Vocational Education (HVE). At the first stage, the authors have developed the following subject ontologies: ontology of basic degree programmes, syllabus ontology (Fig.1), academic subject

ontology (Fig.2). These ontologies could be considered as typical ones; they will be specificated and used for description of degree programmes, syllabuses, disciplines from different degree programmes.

When developing basic degree programmes for majors 09.03.01 "Informatics and Computer Engineering" and 09.03.02 "Information System and Technologies" according to the Federal State Educational Standards-3+ Higher Vocational Education, the authors have developed applied ontologies for the majors on the basis of subject ontology data. The developed applied ontologies allowed analysing correspondence of degree programmes and major syllabuses to FSES-3+.

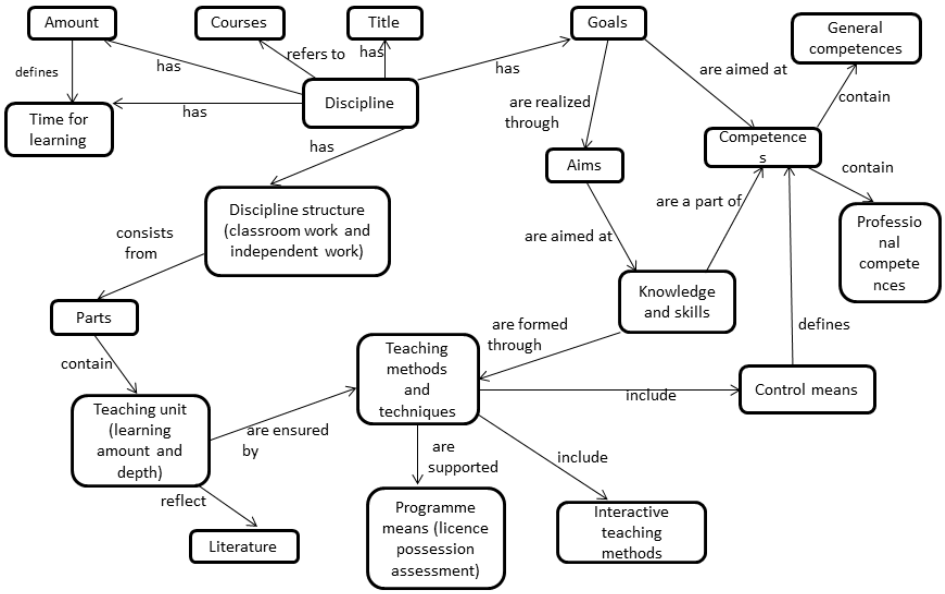


**Figure 1.**Syllabus ontology.

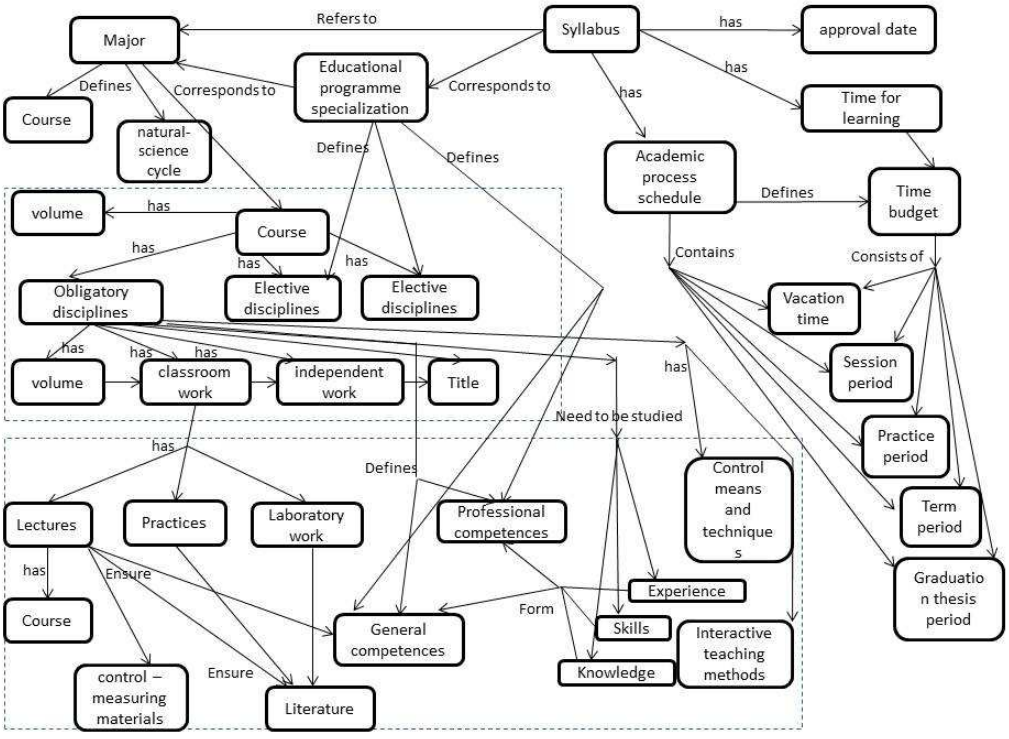


**Figure 2.**Academic subject ontology.

## 5. Ontological simulation application for description of IT-specialist competences

Modern enterprises use information technologies everywhere. Enterprises need IT-specialists able to develop new products, accomplish concrete tasks, and apply knowledge and skills in certain technology areas. But when graduating from the higher educational institution graduates have mostly general professional knowledge and skills not oriented to solving concrete applied problems. It reveals unbalance between employers' demands to graduates and their real knowledge and skills after graduating from the higher educational institution. This problem determines a necessity for advance specialist qualifications to meet demands of modern society. We need mechanisms for collaboration between higher educational institutions and employers to quickly form demands to specialists and realize them.

Nowadays, there is a set of vocational qualification demands in the information technology area [8], which says what a specialist in a certain field should know and be able to do. But these demands are quite general; they give just overview of professional competences. It reveals a necessity to formalize and concretize demands to students with a specialization in information technologies. To solve this problem, one can use a competence approach methodology.

The peculiarity of the competence approach is formation of not only particular knowledge and skills, but also competences that are focused on application of the knowledge and skills in real life situations. The competence approach is based on two basic notions: competence and competency. Competence includes a combination of interconnected man's features oriented to a particular range of subjects and processes. Competency is relevant to man's possession of a particular competence including his/her personal behaviour to it and a subject.

Academic competence is a combination of a student's conceptual orientations, knowledge, skills, and work experience oriented to a particular object range in the reality that are necessary for important human and social activity. Academic competences are classified according to three levels: key (realized by means of the content common for all subjects); educational (realized with the help of the content integrated for a combination of subjects, an academic field); discipline or professional (formed within particular disciplines).

Educational-professional competences can be formed as the result of coordination of business interests and non-state organizations, an academic community and an educational regulatory body. There could be three opinion lines concerning competences: teachers' opinion, students' opinion, and opinion of organization heads. The peculiarity of the competence approach is that during the process of competence formation all interests should be considered. Content formation of professional competences is a complicated task, which needs experts' opinion.

To form professional competences, it is necessary to formalize graduates' qualification demands. To formalize these demands, one can use ontological simulation. Ontology is an attempt of universal and detailed formalization of a particular knowledge area with the help of a conceptual scheme. Ontological simulation can be used both for syllabus formation and assessment, and for IT-specialist competence significance assessment [9].

The list of professional competences can be formed on the basis of labour market assessment and specialized professional standards [10], or on the basis of professional standard demands of the Ministry of Labour and Social Protection of the Russian Federation [11].

On the basis of analysis of higher vocational education standards in the sphere of information technologies and professional standard of the Ministry of Labour and Social Protection of the Russian Federation [11] the authors have developed ontological models meeting demands for specialists in the field of information technologies.

The ontologies are described formally by means of XML language. The authors have developed special software for processing XML-files and presenting this knowledge to users in an easy and clear way. With the help of this software users can form a range of demands to graduates, assess importance of this or that part of knowledge in the sphere of information technologies. These tools can be used both for assessing existing demands to specialists, and for new demand set formation connected with changes in technologies and systems. The development prospect of this approach is realization of the competence assessment system in the field of information systems and technologies.

## 6. Obtained results

As the result of analysis, made with the help of the applied ontologies, the authors have revealed the following unbalance:

- formal mismatch between lists of competences in different academic standards. Even in IT academic standards which are close to each other one observes a different list of general cultural and professional competences. It should be noted that the analysis of a competence list in FSES-3+ showed that this drawback had been eliminated;
- demand mismatch in competence lists. In an academic standard of the degree programme 09.03.01 "Informatics and Computer Engineering" there is a mismatch between a general competence list and a list of competences that have to be obtained at the end of learning all the disciplines in the syllabus;
- the authors have done an analysis of formal matching between degree programmes 09.03.01 "Informatics and Computer Engineering" and 09.03.02 "Information Systems and Technologies" andFSES-3+ according to discipline workload, the competence list identified in degree programmes, the list of obligatory academic disciplines. The analysis has revealed some mismatches, which are now eliminated due to syllabus correction;
- the authors have developed ontology specification of the information technology knowledge area, software and programming language hierarchy;
- on the basis of professional competence ontology for major 09.03.02 "Information Systems and Technologies", the authors have realized an expert system for assessment of matching the graduate's qualification level to employer's personal demands [8].

## 7. Conclusion

Ontology application for formalization of such a subject area as academic process organization in a higher educational institution is quite challenging. Further researches in this field are oriented to both developing subject and applied ontologies in the subject area, and development of tools that allow not only fixing developed ontologies, but also analysing qualitatively and quantitatively the subject field with the use of these ontologies.

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## References

[1] Baidenko V I 2004 *Bologna process: on the way to Berlin conference. (Moscow)* 408
[2] Zamyatina O M, Mozgaleva P I 2014 4th IEEE *Proceedings of the Global Engineering Education Conference: Engineering Education towards Openness and Sustainability, IEEE EDUCON* 114-118
[3] Tarasenko F P 2010 *Applied system analysis* (Moscow: KRONUS) p 110.
[4] Bakhvalova Z A, Massel L V, Makagonova N N and Triputina V V 2008 *Proceedings of XIII Baikal Russian conference* **2** 267 – 278.
[5] Rotshtein A P, Shtovba S D 2001 *News of Russian Academy of Science. Theory and control systems* **3** 150–154.
[6] Docking R 1994 *Prospect* **9(2)** 11 – 15
[7] Romanchukov S, Berestneva E V 2016 *The European Proceedings of Social & Behavioural Sciences (EpSBS)* **7** 88-94
[8] Berestneva O G, Marukhina O V, Benson G F and Zharkova O S 2014 *Proceedings of The Int. Conference on Research Paradigms Transformation in Social Sciences* **166** 296-302
[9] Studer R, Benjamins R and Fensel D 1998 *Data & Knowledge Engineering – Special jubilee issue* **25** 161–197
[10] Larukhin V B, Piyavskiy S A 2012 *Design ontology* **2(4)** 44-57
[11] Bakhvalov S V, Arshinskiy L V 2014 *News of IrSTU* **9** 12-17