Methods of virtual modeling of dynamic educational programs in terms different manufacturing sectors requirements

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Abstract. The article considers problems connected with the professional standards implementation at an enterprise. The principles of dynamic construction of educational programs are revealed. The approach to the formation of dynamic educational programs taking into account the requirements of the professional community and foreign experience is proposed. To cut the transition costs we suggest that a specialist selection process as well as dynamic design and methodological support formation should be automated for the implementation of the new generation curricula according to the professional standards requirements. This approach can be applied, among other things, to the training of physicists for various production sectors.

1. Introduction

Professional standards implementation in many countries has been successful in terms of labour efficiency growth. The report [1] provides an analysis of different methods of developing and using professional standards in Germany in comparison with other countries. The interaction between the education system and the requirements of the German labour market is achieved through the application of the integrated principle of the development of vocational training provisions as an educational standard that includes a professional standard. In Germany, as elsewhere in the world, there is a close link between professional standards and vocational and theoretical programmes in the development of curricula and didactic principles. It should be noted that training is not carried out on the specific requirements of the employer, so the employees has to get additional education. There is also no possibility to adapt the curricula in the process of their implementation to the requirements of the professional community. In Russia, the Unified Rating and Skills Guides for jobs and occupations of manual workers and the Reference Book of managers, specialists and workforce qualification are getting outdated: they either contain no new occupations or their descriptions don’t line up with reality. The Ministry of Labour and Social Protection of the Russian Federation has signed up and published a lot of professional standards to create the All-Russian qualifications framework for all economic sectors. About 60 standards have been adopted in mechanical engineering by now and more than 40 of them are coming up for discussion. According to the Federal Act of May 2, 2015, No. 122-FZ the employers have been required to use them since June 1, 2016. The project realization will
allow us to solve the problem of demand for skilled personnel in mechanical engineering by 2018. Based on the obtained result, we can say that the examination of welders’ professional competence has made it possible to reduce accident incidence rate by 20-25 per cent at “Gazprom” and “Rosneft” facilities. Besides, the new legislative acts are designed to coordinate educational and professional standards and eventually eliminate the disconnect between the learning process and the professional association as well as standardize the requirements for the skills level and job functions with the learning outcomes.

2. Methods
The notion of “professional standards” in the given regulatory documents is defined as a qualification characteristic required for an employee to perform a certain kind of professional activity (part 2, art191.1 of the Labour Code of the Russian Federation). In the professional standards the description of requirements for a specialist includes more contemporary schemes such as combination of knowledge, skills, occupational skills and work experience. From the beginning of the academic year, the training and retraining of specialists will start in all educational establishments according to these and subsequent standards. But the professional standard is more connected with reality as it is based on the hands-on experience of the specialist’s occupational activity rather than educational programs.

In the near future, the development of new Federal State Educational Standards (FSES) 3++ will begin. They will contain the characteristics of the graduate's professional activity, universal competencies (uniform to the level of education in all areas), general professional competencies, that set general requirements for the area of study and are independent of the focus of training. So the problem that has arisen in recent years consists in the fact that a graduate of an educational institution has certain professional skills, while the employer needs quite different ones. The given problem is especially important for the field of mechanical engineering as it is a high technology and quickly developing branch, after all it accounts for more than one third of overall commodity output of Russian industry.

Organizations of various sectors of the economy try to employ graduates of higher educational institutions with well-formed professional qualities that allow them to provide higher labour productivity, with the appropriate competencies that will make it possible not to increase the company’s non-production expenses on additional training and retraining of personnel. If the employee does not comply with the professional standard, then, according to the Article 196 of the Labour Code, the employer has to organize training, which will require additional funds. It is obvious, that in such situation the employer will prefer to employ an employee who does not need additional training or it should be minimal.

To this end, at the moment when forming the Federal State Educational Standards for vocational education, it is necessary to take into account the provisions of the relevant professional standards, but within a year they will have to be updated and brought into compliance.

The enormous work carried out to develop and introduce new educational standards is designed to reduce the distance between employers and educational institutions and create a more effective system for their interaction. The main areas of cooperation between the university and employers are not only work on the modernization and implementation of educational standards and programs; they also include the establishment of basic departments for large employers, cooperation with them in the professional standards formation, taking steps towards advancing through professional and public accreditation of educational programs.

In Russia, machine building industry in the Council for Vocational Qualifications in Machine Building is represented by All-Russian industrial association of employers “Russian Engineering Union”. There are changes in the requirements for the workforce: uniformity and interchangeability of workers give way to the “uniformalised” type of employee; blurred boundaries between professions are formed, under which identification of the traditional types of labour is lost; the isolation of professional castes is destroyed, and professions are “globalized”.
The same set of functions and qualifications of a specialist can be a competitive advantage in the labour market at a specific time, and at another time it is of no importance for a specialist to be in demand.

When developing and implementing higher education programs, educational institutions should first and foremost focus on the needs of employers, which will create a mechanism for continuously monitoring changes in the labour market conditions and the requirements of key consumers for the quality of education. Therefore, practice of employers' participation in the educational activities of institutions (Figure 1) and in the evaluation of quality of education is becoming commonplace in Russia, because employers need specialists of the required qualifications who are able to start working without additional training.

For employers, the task consists in forming professional standards in the light of which the Federal State Educational Standards are designed. The duration of standards formation is supposed to take up to three years. Nevertheless, even if the new FSEs are released within a year (which is unlikely), it will be necessary in accordance with them to develop curricula for the graduation of new specialists. Thus, it will take 8-10 years before the first cadre of students will graduate from university educated according to the FSEs taking into account the requirements of employers. In fact, nowadays specialists have the competencies that were required about 10 years ago and even earlier.

A natural question arises as to how to accelerate this process as much as possible. You can try to predict the competencies that will be required after 10-15 years and provide advanced training, but it does not mean that the forecast will be confirmed. There is also a problem of rapidly changing requirements for the graduates of higher professional education for the developing branches of the national economy.

Therefore, a task of operational training of a certain number of students having the required competences is becoming now more urgent.

This task can be solved with the help of the formation of dynamically changing educational programs that reflect the relationship between the theory and its definite practical application, corresponding to the vocational aptitudes of the future bachelor, specialist or master [2].

Such dynamic educational plans can also be useful in upgrading the skills of employees working in various sectors of the economy, so that they could get the right qualifications.
Within the framework of the standard approach, it is rather difficult to describe the elements of the educational activity and the connections between them. The federal state educational standard of higher professional education considers competencies to be an ability to apply knowledge, skills and personal qualities for successful activities in a certain field.

In general, the formation of agreed requirements for the competencies of a specialist includes the following stages:

- building a business model of production processes;
- determination of specialist’s core competences;
- harmonization of requirements with the FSES;
- analysis and formation of the hierarchical structure of requirements;
- approval of a set of requirements by the parties involved;
- formation of the training sequence in the form of a training program;
- object-oriented analysis of the training programs feasibility.

Figure 2 shows the harmonizing of the requirements for the professional standard with the FSES within the competency-based approach.

![Diagram](image)

**Figure 2.** Federal State Educational Standard (FSES) and professional standard interaction.

As noted earlier, the experience of Germany as well other foreign countries is analyzed by W. Petersen and M. Jepsen in report [1], in which the approach to the development of structure and professional profile for new “professional standards” and “educational professions” is proposed. This
approach is based on the change of professional profiles, focused on the theory and scientific and technical knowledge, to professional profiles, focused on production and business processes. Thus, the new “professional standards” and “training professions” are changing in a direction based on “competence or qualification” and “orientation towards learning outcomes”. The main innovation of these changes is that three descriptors of “knowledge, skills and competencies” should be used for all qualification levels of education and training.

In accordance with the above-described approach [1], the development of educational standards adopted in Russia is close to foreign.

3. Results
The prerequisites for establishing a learning management system of new generation, which should satisfy the need in a changing business environment and education, are described in [3-5]. From this and in accordance with the analysis of other sources it follows that the method of formation of dynamic educational programs with the requirements of employers is new.

One of the problems arising in the selection of specialists by the employer is the discrepancy between the qualification requirements given in the professional standards and the competencies that are presented in the training standards. Therefore, the first task in reaching harmonization is preparing a thesaurus for the subject area, constructing and using a mechanism of determining the necessary competencies. Such thesaurus can be formed as an ontological database and later general requirements can be developed based on the built-on ontology [6].

For example, let’s consider the ontological model of the master degree educational process developed in compliance with the requirements of employers that was implemented in the Protege 4.2 software product (Figure 3) [7, 8]. This ontology allows the developers of educational programs and employers to obtain information that meets the criteria of concern [9]. So, the employer can get information about the competencies formed by graduate students in the process of preparation and will be able to formulate the requirements for the prospective employee on the basis of the received information analysis.

In addition, this ontology makes it possible to determine elective disciplines for master students in accordance with the employers’ requirements. For example, an employer wants a potential employee to perform a work function of “Managing the identification and implementation of IT innovations”. This work function is included under the professional competence of “Ability to conduct searches and analyse innovations in the economy and management” from the educational standard of the “Business Informatics” training area (38.04.05).

Figure 3. A fragment of ontology of the educational process of master degree students training.
This competence can be formed with the help of elective discipline “Information technologies in the development of managerial decisions” (Figure 4). Thus, the ontology allows determining the elective disciplines for the master degree training in accordance with the requirements of employers and, thereby is used to form an educational program that meets the requirements of employers.

As a result of ontological modelling, the appropriate knowledge base was created for specialists in the field of information technologies that includes both the requirements of the FSES and formalized requirements of professional standards. The labour functions needed for a certain position were put in line with professional tasks. The side effect of the detailed description of the user's competencies is that it dramatically simplifies the employer's task of selecting the necessary personnel.

Several hundred competencies of different levels from different areas of knowledge that can describe the model of a modern graduate's preparedness provide an effective formalized search for candidates of the right profile and necessary qualifications.

For the realization of this task the informational system was created where the employer’s requirements formation proceeds in several stages. At first, the employer chooses a profession from the professional standards, if there is none, the employer inputs the profession himself. Description of occupations can be found in the Directory of Occupations in the reference guide section. Further, the employer determines the required competencies based on the professional standard. These competencies can be further determined by the university. At the final stage, additional competencies related to the requirements of a particular employer are added. As a result of the query concerning the given competencies, it is determined the federal educational standard that is closest to the developed model in terms of the structure and content of the basic competencies.
Based on the specified requirements the most proper standard is selected. The employer gets a list with the most appropriate training areas and the level of the required competencies satisfaction that can’t be found in the existing FSES (Figure 5). These competencies are formed within the variable part of the curriculum or in the course of additional training if the variable part cannot cover the competence difference. A specialist’s training area that meets a set of the required competencies and differs little from the competencies formed on the basis of the training standard, is determined based on the interplay of a variety of the specialist’s competencies and a host of the FSES competencies.

| Training direction | Percentage of realization | Unfulfilled competence |
|--------------------|---------------------------|------------------------|
| 239100             | 27.2727272727            | The ability to carry out selection of the source data for the design of |
|                    | 27.2727272727            | The ability to conduct modeling of processes and systems |
|                    |                           | The ability to carry out the calculation of health and safety conditions |
|                    |                           | Willingness to participate in the work on the final design and development of information technologies in the course of implementation and operation of information systems |
|                    |                           | The ability to use technology development facilities of professional activity in different areas |
|                    |                           | The ability to participate in the formulation and conduct of experimental studies |
|                    |                           | The ability to execute operating results obtained in the form of presentations |
|                    |                           | Scientific and technical reports |
|                    |                           | Articles and papers on the scientific and technical conferences |
|                    |                           | The willingness to ensure the security and integrity of information systems and data technology |
| 239400             | 23.528411764706          | Develop components of software systems and databases, using modern tools and programming techniques |
|                    |                           | Participate in setting up and commissioning of hardware-software complexes |
|                    |                           | Install hardware and software for information and automated systems |

**Figure 5. Unsatisfied competences.**

To design or change the curriculum of the training area closest to the competencies that are being formed, qualification requirements are decomposed to the level of competencies and subsequently to the level of disciplines. On the basis of the performed decomposition, a compliance matrix of the competencies and constituent parts of the educational program (disciplines, training units) is designed, on the base of which a curriculum in this area is subsequently developed. Based on the description of the competencies presented to a specialist that are not formed in the chosen area of study, the designing of changeable or replaceable disciplines is carried out. After that it is necessary to develop training and methodological support for teaching the disciplines to be added or changed.

Training toolkits are developed by the teacher on the base of the knowledge and experience he or she possesses, as well as materials from libraries or the Internet. On the basis of the educational standard the teacher compiles a list of issues that are obligatory for studying in this discipline, and forms a list of modes of education based on the curriculum and the complexity of the discipline. After that, the issues are divided into lectures in accordance with their amount. Search for materials on the theme of the lecture as well as synopses and lectures preparation are carried out using the materials provided by the teacher and/or information available from the library and/or the Internet.

After putting together the lectures, materials are prepared for conducting other types of academic activities: laboratory operations manuals, methodological guidelines for practical training, course papers, or computational and graphic work. This allows automatic formation of the necessary methodological support for the discipline from the invariant parts in accordance with the requirements of the educational standards.
4. Conclusion
With the application of the competency-based approach to the design and development of the new generation educational programs and using the object-oriented approach to the structuring of knowledge, it becomes possible to dynamically update educational programs in accordance with the requirements of the new professional standards. A data model used for knowledge representation has a decisive effect on the functionalities of computer-aided data processing application in any subject area. The advantage of ontologies as a way of representing knowledge is their formal structure that simplifies their computer-aided processing.

Dynamic design and provision of the teaching and methodological support for the educational programs implementation may be used to address the issue of increasing the training effectiveness of the in-demand specialists due to a deep analysis of the requirements made by all the entities interested in their competitiveness (university-government-employer), and through the study process and curriculum building automation.

This paper is also part of the project VEGA No.1/0235/17 “System identification of complex assumptions to support industrial innovation and employment in the less developed regions of Slovakia”, built on the results of successfully finished project KEGA No. 037STU-4/2012 “Implementation of the subject of “Sustainable corporate social responsibility” into the study program of Industrial Management in the second degree of study at STU MTF Trnava” and APVV No. LPP-0384-09 “Concept of HCS model 3E vs. concept Corporate Social Responsibility”.

References
[1] Petersen W and Jepsen M 2015 Report “German approach and experience of development of occupational standards” (Flensburg) p 47 http://www.ilo.org/wcmsp5/groups/public/---europe/---ro-geneva/---sro-moscow/documents/publication/wcms_397644.pdf
[2] Martynov V V, Filosova E I and Filosova V K 2016 Automating the formation of dynamic training plans for FSES 3+ based on the requirements of the employer Proc. Int. Conf. ITRT-2016 (Togliatti) (Russia) 54-61
[3] Stone D E and Zheng G 2014 Learning Management Systems in a Changing Environment Handbook of Research on Education and Technology in a Changing Society 2 pp 756-767
[4] Ryneveld L V 2016 Introducing Educational Technology into the Higher Education Environment: A Professional Development Framework In Innovative Professional Development Methods and Strategies for STEM Education 8 126-136
[5] Kelly M, Costello M, Nicholson G and O'Conner J 2016 A Collaborative Academia-Industry Approach to Developing a Higher Education Programme in Building Information Modelling International Journal of 3-D Information Modeling (IJ3DIM) 5(2) 39-54
[6] Hitzler P, Gangemi A, Janowicz K, Krishnadi A and Presutti V 2016 Ontology Engineering with Ontology Design Patterns: Foundations and Applications (IOS Press) p 388
[7] OWL 2 Web Ontology Language Quick Reference Guide (Second Edition) Available from https://www.w3.org/TR/2012/REC-owl2-quick-reference-20121211/
[8] Guarino N 1996 Understanding, Building, and Using Ontologies Available from http://ksi.cpsc.ucalgary.ca/KAW/KAW96/guarino/guarino.html
[9] Ternai K and Szabo I 2016 Semantic Application for the Internationalization Audit of Higher Education Institutions Proc. Int. Conf. EGOVIS 2016 (Portugal) 194-205