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An industry-specific personnel training system: development and implementation

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Abstract: The article reviews the main aspects in the development of a system than manages training and re-training of personnel. Problems in the subject area and in search for engineering and functional solutions are presented. The industry-specific system for training personnel is intended for creating an informational environment for support of business processes that implement the full life cycle of multi-step training and re-training of world-class personnel for innovation economy industries. Conceptually, the different qualification levels of specialists incorporated in occupational standards are to be reflected in educational standards and curricula for different educational levels (colleges, BS and MS courses, etc.)
To develop informational and functional models of the information system under design, subject areas were analyzed: brief characteristics of business processes were presented and qualification characteristics and state-of-the-art standards (educational and occupational) were specified. The items were identified where the standards interact with each other thus forming a joint functional field described using the competence language. The models proposed enable one to more efficiently implement information and computer technologies in education for innovative economy industries and will be used as a basis for subsequent implementation. They will also facilitate employment of innovative approaches for training highly-skilled and competitive specialists. This study enables specialists to consume educational services in a more efficient way using the Internet, to get prepared to using Russian experience by means of information and computer technologies, and to acquire knowledge of information society in the environment of the modern economy based on competences. The development of the system enables one to implement this process in practice in a smoother way; generalize experience in efficient cooperation between business and educational institutions; and to create an environment for efficient secondary and tertiary education. It will also enable assessing the quality of training assessed in compliance with the requirements of employers and labor market and to have curricula upgraded in accordance with the changing requirements of occupational standards. A set of criteria for assessing efficiency is proposed and an assessment methodology is described.

Keywords: Education Management System, Competence-Based Approach, Education, Professional Competences

1. Introduction

Currently, the rate of incorporation of innovative achievements in science and technology get into curricula of the secondary and tertiary vocational institutions is not sufficiently fast.

This circumstance significantly deteriorates the overall quality and efficiency of training specialists in engineering. It also prevents them from shaping specialized competences the application of which is not infrequently on a trial stage but which feature a high innovative potential. Such a situation negatively affects smooth integration of specialists-to-be into the professional area where such knowledge is a prerequisite.

This said, it would be very useful to employ world experience and implement foreign practices, specific of Anglo-Saxon educational system, which involve high degree of integration of industrial enterprises, research institutions, and academic laboratories and educational institutions. Such interaction being implemented in practice enables one to incorporate into curricula the cutting-edge achievements of science and technology and to equip educational institutions with state-of-the-art facilities and laboratory devices. All this will undoubtedly facilitate ensuring high quality of training specialists on all educational levels.

To use the nation's scientific potential in the most effi-

cient way, integration of educational and research activities is to be launched and promoted. University research is to be conducted with consideration for the specific economic features of the marketplace, be implementable in practice, enjoy demand, and be used by potential consumers/employers. However, currently these requirements are not fulfilled in full; it is not infrequent that research results are not required in practice, are not focused on specific consumers or an economy cluster; do not comply with the modern requirements of national economy; and are not in line with the current and future needs of society (1).

The specialists trained within the continuous engineering education system must possess required amount of theoretical and practical knowledge in innovative technologies and in different areas related to such technologies, including materials, accessories, and instruments.

The time factor is also of great importance. Students must be timely or even proactively acquainted with newest achievements in science and technology that occur in Russia and abroad. The reason is that, at modern production plants, young specialists will have to get acquainted without delay with everything new that was lately developed in technology, management systems, or services.

These are the problems experienced by professors and lecturers in upgrading lecture courses and materials for seminars and laboratory works. Providing training and methodical assistance to students is an important and significant issue. Its solution is to be based on implementing into training and pedagogical practice the advanced achievements in science and technology, and primarily in high-tech, such as basics of modern technology progress (2).

A solution to this issue will not only enable the quality of training students to be improved but also open for them wider prospects in selecting future carriers. Using gained knowledge and skills in high-tech they will be able to become leaders in the competitive environment of labor market. This means that students and professors are the parties that are most interested in high quality and practicability of the content of education.

To provide an efficient solution to the tasks described above, the authors developed a system for managing training and re-training of world-class specialists. A functional scheme of the system is displayed in Figure 1.

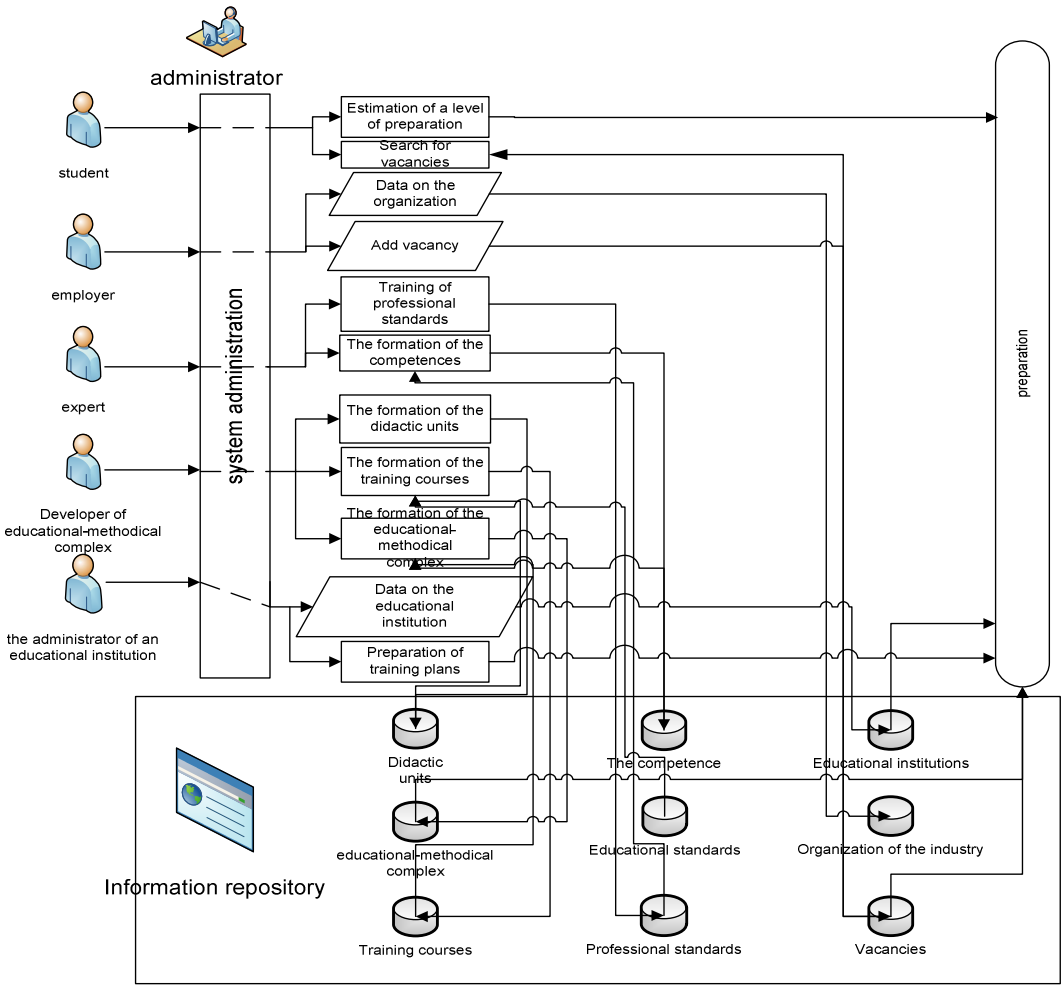

Figure 1. *A system for managing training and re-training of world-class specialists.*

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The main goal for the development of an information system similar to that shown above is to provide the educational community with a multifunctional, open, flexibly customizable, and scalable instrument for organizing a multistep training of specialists.

The scientific novelty consists in the functional and structural organization of the system and a formalized description of functioning and operation scenarios that are implemented using UML (Unified Modeling Language) charts.

The chart above displays key system roles and the business processes they can access for fulfilling the main goal. All business processes are implemented on the basis of the methods and technologies for processing structured information. A factor of significant importance for the success of this normalization and methodical activity is that it uses the world trends in development of education and current approaches to harmonizing education area with employers' representatives which are currently in the focus of attention of all major corporations (1).

The practical value of the development is related to the important issues of relationship between business processes of enterprises and educational institutions and the standardization agencies needed for fulfilling the common goal and boosting the quality of the decisions made. The concepts of the employed functional and structural organization on the basis of a formal description of processes and objects are driven by the unified logical and algebraic description applied on all levels of simulation and design.

As an additional goal, one may specify integration of heterogeneous information and computer resources implemented on the basis of generally accepted and prospective standards for the development and usage of educational and training curricula, training and methodical courses, achievements in science and technology, innovative approaches, and state-of-the-art information and communication technologies. All of this enables one to create an overall data warehouse enabling the information to be handled as part of an individual business process. As shown on the chart above, the warehouse contains:

- didactic units;
- training and methodical facilities (hereafter TMF) and curricula;
- information about vacant jobs and list of competences;
- occupational and educational standards;
- information about enterprises and educational institutions related to the industry.

The data contained in such warehouses are primarily organized into a hierarchical structure. Relational databases do

not fit this structure since relational tables are single-selection text boxes. However, hierarchically organized data contain 'parent-descendant' relationships that are not implemented in a relational structure. To solve the problem, methods and techniques for designing tools for processing structured information and algorithmic support and software were used and the tools provided by Doctrine object-relational mapping were applied. This enabled us to create a set of required classes and generate the database structure by running several procedures. Owing to this, expenses on implementing the management system were reduced and the rate of data processing was boosted.

2. Solution of Occurring Problems

Below is a brief description of the main functions and solutions for the functional and structural organization and practical implementation of the system proposed by the authors.

Development of industry-specific occupational standards

This function assumes that occupational standards are to be developed, comments and remarks be made, and job functions, competences, and job positions be handled. It is expedient to structure competences using expert work teams that include representatives of industry and specialists in vocational education. Currently the decision-making theory offers approaches to estimating the number and professional level of participating experts and assessing the reliability of the provided expert assessment and the probability of obtaining expert information (3). The procedure of approving an occupational standard is represented as a formalized business process where development is effectively managed using a system of the statuses of the standard and restricting the rights of developers, experts, and the approving organization.

The development of occupational standards involves reviewing the profession models adopted in the world community and employers' approach focused on the development of professional skills of their personnel (4).

2.1. Developing Main Curricula for the Occupations that Correspond to Professions in Occupational Standards

This function allows one, for the developed competences (4), to review a list of didactic units and to select training modules from the set of already existing ones or develop new modules for curricula of specialized educational institutions in order to cover in the widest possible way all of the didactic units. According to methodology (5), this activity is followed by conversion of competences within each training area and existing curricula.

The content of a curriculum reflects two sides of preparedness to professional activities that are related to functional and personal aspects. Therefore, the development of a curriculum is preceded by the development of the specialist's activity and determination on its basis of the specialist's personality model.

A developed model of the specialist's activity includes the following:

- a list of areas of the professional activity;
- a list of objects of the professional activity;
- a description of the main types of the professional activity;
- a list of tasks set for the professional activity;
- theoretical or applied knowledge used by the specialists in his/her activities;
- approach to solving specified problems or tasks;
- skills and training needed for obtaining the required results.

The model of the specialist's activity also contains supply of the profession to the job market the state of which significantly affects both the selection of a specific area of vocational training and re-training and the content of training (6).

The approach in which the content of training is considered as an informational model of professional activities related to specific organizational and content units of educational process requires detailing of the following items: overall mission of the specialist, functional assignment of the specialist, general qualification requirements for the specialist, structure and content of the specialist's activity, the specialist's psychological features, and terms of and limitations on the specialist's activities.

2.2. Setting Educational Modules for Curricula

Using educational modules, especially if distant learning instruments are used, is currently a de facto standard. Therefore, all elements of the curriculum content that are designed as a logically complete fragment are formalized and described as educational modules.

A main technical solution is the ability of educational modules to integrate and interact with education management systems to organize a unified integration environment and information exchange mechanisms.

In the developed system, educational modules comply with the ADL SCORM 2004 (3rd edition) standards in what regards streamlining content and navigation in the process of progressing in training. To this end, the requirements of the standard and the integration requirements specified in the previous paragraph were compared and mutually taken into account. The module itself is described using the RUS_LOM information metadata module, which is a cognate implementation of the LOM standard (7).

This development takes into account the specific features of teaching knowledge-intensive disciplines and the best practices of usage in training state-of-the-art laboratory equipment, also including tools of mathematical and virtual simulation, and remote representation of simulated objects. This requirement is fulfilled on the stage of developing TMFs in what regards practical exercises and laboratory works.

2.3. Developing of Training and Methodical Facilities of Basic and Professional Competences on the Basis of

Educational Modules

This functionality with its architectural and functional/structural solutions is intended for formalizing the process of developing TMFs. The TMFs are to provide informational support to shaping in trainees the required set of basis and professional competences specified in corresponding occupational and state educational standards. Also of importance is their organizational role as an instrument for planning a specific sequence in mastering educational materials and supervising the process by teachers and other parties concerned.

To fulfill the required goals, the TMFs feature the structure and content that correspond to their assignment, educational objectives, and the way to fulfilling those objectives. Such TMFs are built up on the competence-based approach that is focused on gaining basic and professional competences specified in the occupational and educational standards developed specifically for particular groups of professions and different levels of specialists.

The extracted educational material is integrated into a training and methodological facility thus setting its structure and content. This is only possible if the entire material to be integrated is presented in a standardized form. In the developed system, educational materials are represented in compliance with the ADL SCORM standard.

A flowchart of developing competence-based training and methodological facilities (CBTMFs) is shown in Figure 2.

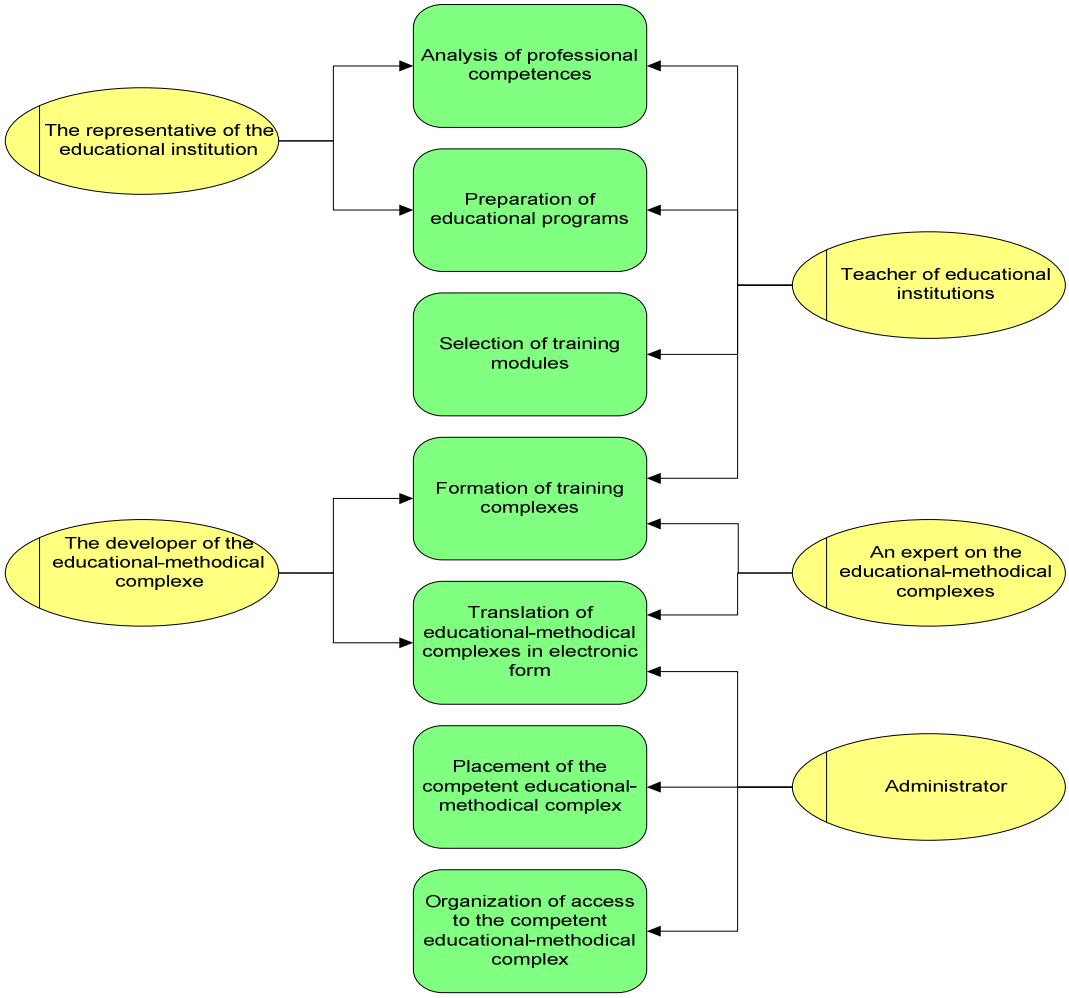

Figure 2. *Development of competence-based training and methodologi*cal facilities.

2.4. Generating Information on the Needs of an Industry in Personnel

Based on the plans for development of enterprises and market trends, representatives of enterprises and organizations (HR or personnel management departments) may distribute information about certain vacant positions linked to specific professions.

The concept of profession allows a certain level of competence to be set as a hiring prerequisite and enable applicants to assess their level of correspondence to the specific profession. In case competence is not sufficient, TMF enables one to select a plan of training, apply for training, and get training in one of available forms to be able afterward to pass tests for occupying a certain position.

2.5. Generating Information about Needs in Personnel on Marketplace

This functionality is used to forecast the number of graduates trained in a specific profession. Information about availability of professional positions is generated using the information provided by educations institutions for certain professional areas and an analysis of that information. As initial information for the analysis, the plans of educational institutions for training specialists and the number of professors and lecturers and infrastructure at educational institutions are used. This information enables one to assess supply of specialists and adjust the curricula and the number of specialist to graduate from the institution.

2.6. Analyzing Situation on Labor Market

This functionality is used for analyzing labor market and generating proposals on training specialists of enterprises and students. The system allows one to create analytic materials presenting the situation on labor market and develop recommendations regarding inclusion of specific training materials in the curriculum.

The data collected in the system are represented in a form convenient for analysis; i. e., they are aggregated according to corresponding dimensions that are employed as viewpoints for analytic processing of data. The following viewpoints are used for analyzing data:

- time;
- territory;
- professions;
- topics;
- occupations, training areas, and disciplines; and
- age.

In processing, data may be represented in the following forms:

- graphical (as plots, histograms, and charts;
- textual (as table and lists); and
- geoinformational, provided territorial viewpoint is available.

3. Technological Solutions for Designing the Systems for Managing Training and Re-Training of Personnel

The following solutions have been selected for designing and developing the system for managing training and re-training of personnel:

The system is primarily based on freeware and open-code software.

The system is open for changes and modifications, i. e., all of its components and data are formalized and specified; this also refers to the exchange interfaces and data presentation formats both in process of storing and transmission and processing (8).

The system is designed as a modular structure and allows components to be developed independently in what regards the systems intended for storing, processing, and displaying data.

The system is implemented on PHP, MySQL (another DBMS may be used) and, respectively, has platform-independent architecture, including application servers, database management systems, and operating systems.

The system, which is deployed on Intel Dual Xeon servers running under the Gentoo Linux operating system, ensures the response time of no more than 3 seconds in case of 10 concurrent queries and 1,000 connected users thus confirming that the production solutions were selected correctly.

The proposed structure of the system for managing training and re-training personnel by means of information and computer technologies is implemented using the Internet owing to which access to the system is possible from any workstation connected to the Web. A structural chart of the implementation of the system for managing training and re-training personnel is shown in Figure 3.

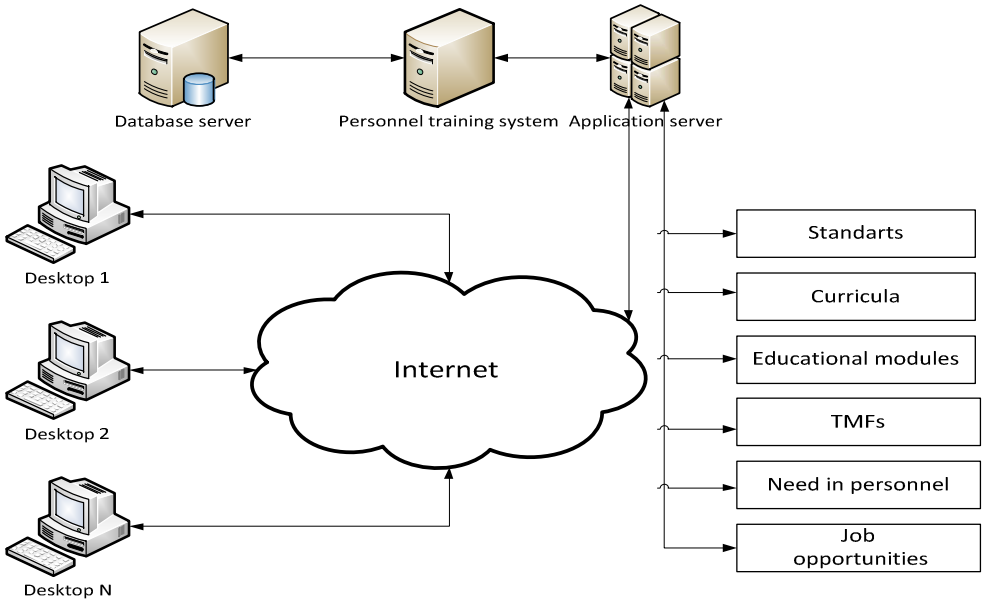

Figure3. *Structural chart of system implementation using the Internet.*

4. Criteria for Assessing the Efficiency of the Implemented System

The following criteria have been developed to assess the functionalities of the automated training system:

1. Maintaining users and user groups

These commands, which are only accessible to the system administrator, run in dialog mode; the system prompts to the administrator to select a command and fill out the fields in the form that correspond to the attributes of the User or Group object; select accessible roles; specify the default role; and set up the required configuration of rights for system objects and, for the Group object, specify a list of users.

2. Maintaining user sessions

A session is the main mechanism for maintaining communication between the user and the information system. It provides an environment for executing commands and verifying role characteristics and rights to access system objects. The user may log into the system by inputting a valid login and password. After the user is identified, a Session object is created for that user where all information pertaining to interaction of the user with the system is captured (including the start and end time of operations, the current role, the rights for system objects, environment parameters, etc.)

3. Graphical interface view

HTML is the main language for generating user interface elements. The user interface elements must support presentation of system objects in a tabular, graphical, and general form and support an option to select one or more objects for executing individual or batch commands for them.

Manipulations with the objects must be ergonomic and intuitively clear. Any operation requiring a long execution time must be accompanied with messages on the progress in execution and the estimated time of operation completion. In case an error occurs, an error message is to be displayed and possible option to remove the error must be prompted.

4. Presentation and maintenance of Web services

As far as it is possible and if it is required, any system functionality may be transformed into a service that may be accessed without using the user interface. This notwithstanding the overall mechanism of system organization is maintained via the functionality of the Session object in which the name of the user who connects to the system is to be entered. The result fully corresponds to the parameters sent using the query.

This mode differs from the regular one that is leveled through using additional Single-Sign-On (SSO) services or other options to authenticate users.

5. Transmitting messages

This functional unit supports exchange by messages between system objects including the User and Group objects. All messages that were sent are grouped, stored, and displayed to the object whenever that object is created or it calls up the functions to be executed.

6. Maintaining a hierarchy of objects

Objects may be combined into a hierarchical sequence using the tools that are external with respect to the object. A possible mechanism is to rubricate objects, i. e., assign them to hierarchical structure elements (headings). This method allows one to implement different types of links and additional functionalities without re-designing the system by simply changing the structure of links between the objects.

7. Export/import

This functional module maintains information exchange with external systems. Functionally it is focused on service architecture but assumes that there is an independent specification for the description of the transmitted information about objects. For each particular exchange case a specification is selected for the exchange format that is based on using a published standard. The main selection criterion is that the information about the object and its content is complete.

8. Maintaining a system log

The log shows the commands that were executed by the user and the impacts of running those commands.

9. Maintaining metadata of system information objects

The content of the metadata of an electronic resource must support storing any information about the electronic resource and the object that is linked to the resource. Metadata allow additional characteristics to be assigned to information objects in a flexible way without re-designing the system.

10. Search procedures

Any information object in the system is represented as a set of search attributes that are characterized by their names and the values they assume. Text attributes are included in text search for both simple (without indicating an attribute) and advanced search. Different grammar forms of words may be used.

11. Maintaining information exchange

This functional module maintains information exchange between system objects in forums, voting, and direct communications. The main mechanism consists in sending messages from a source to a recipient and generating hereditary links between messages.

12. Handling documents and maintaining their enforceability

The system maintains an option to generate electronic digital signature for the electronic documents whose enforceability is to be ensured.

13. Maintaining operations with personal data

In capturing information about an individual, that individual has to provide his/her consent for using his/her personal data for the time period specified in the query. After that time period elapses or the document no longer needs to be stored, the data are removed from the system or, at least, are de-personalized.

Any personal data captured by the system bear an

attribute allowing them to be identified; this attribute may be used for specifying the procedures for handling such data.

14. Securing copyrights and intellectual property rights

This functional module specifies a set of operations for assigning and verifying rights and for selecting the mode of operations with copyrighted information objects. The user is notified about this feature; the system also prompts a sequence of operations that correspond to the concluded license agreements.

In any case, in getting access to such objects, the user is notified about the operation mode set for handling the objects.

15. Securing the system safety

This functional module specifies a set of operations for supervising storage, distribution, and access to the information objects that contain confidential and sensible information. The system also controls the integrity of that information by protecting it against damage and deletion.

This functionality enhances the standard functionality of the system that supports restricted access to operations and system objects via mechanisms for assigning roles and rights for accessing objects to users. The list of additional measures includes password-based login, cryptographic protection, access to data allowed from only certain workstations, etc.

4.1. Assessing Efficiency of Implementing the System

The information model of the system must respond to many queries belonging to different levels. It is from this perspective that the completeness, integrity, and consistency of the information model of the systems are to be assessed (9).

The efficiency was assessed applying 15 criteria H={h1, h2, h3, h4, h5, h6, h7 h8, h9, h10, h11, h12, h13, h14 h15} (15 questionnaire items); each criterion could include several sub-criteria. All responses were reduced to a normalized scale (from 0.0 to 1.0).

The functionality indicator for the selected criterion is assessed by averaging the results of polling on each question pertaining to that criterion also taking into account the trust to the expert for all filled-in questionnaires.

$$h_i = \frac{1}{M}\frac{1}{N}\sum_{j\in M}\sum_{l\in N} K_j p_l \,, \qquad (1)$$

where pl is a coefficient that is determined on the basis of the questionnaires in a normalized scale (from 0.0 to 1.0); Kj is a coefficient of trust to the expert; N is a normalizing coefficient equal to the number of sub-criteria in the selected assessment criterion; and M is the number of experts.

The obtained set of assessments characterizes the functionality of the automated training system for each of the seven indicators for the target function under analysis.

To deduce the expert assessment of the functionality of the automated training system for the target function under analysis, summation is to be performed over all indicators in the normalized assessment scale according to the formula:

$$H_{SW} = \frac{1}{F}\sum_{i=1}^{15} h_i \alpha_i \,, \qquad (2)$$

where F is a normalizing coefficient equal to the number of assessment criteria and α_i is a factor setting the importance of indicators (it is specified by the expert/trainer in developing the algorithm for processing expert analysis results.)

To obtain generalized indicators of the functionality of the automated training system, the results of the expert analysis may be aggregated for all types of queries (target functions) using same formulas (10).

The set of the assessments obtained as a result of processing the questionnaires of the experts shows the need in the functionality of the automated training system and enables one to make conclusions regarding its most effective advantages in accordance with the target analysis function.

The results of processing the questionnaires of the experts for the given automated training systems are displayed in Figure 4.

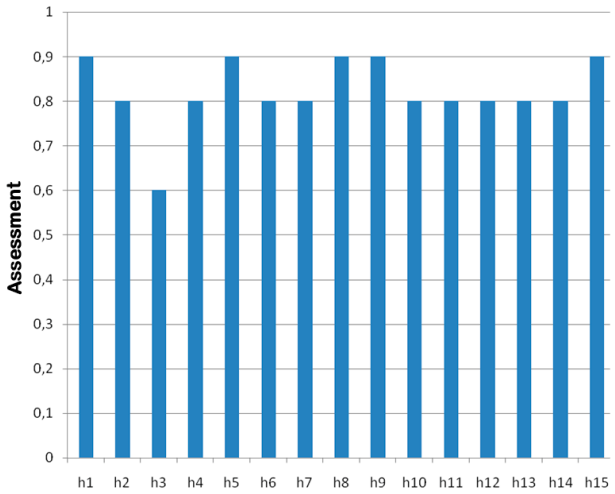

Figure 4. *Results of the expert analysis of the system.*

The results of the analysis show that the developed system is well designed and ensures the required level of quality and performance in future implementations.

5. Conclusions

The systems for managing training and re-training of personnel may be considered as the most efficient tool for creating a unified informational and educational space of an industry and a distributed information-and-analytical environment for implementing formalized activities of all the parties involved in training and re-training world-class specialists given that the system ensures unimpeded handling heterogeneous information through using a unified description of all objects belonging to the given industry. Implementation of the system may significantly affect fulfilling qualitative and quantitative target indicators in provision of

innovative industries with highly-skilled personnel that possess the required level of competences in the required areas of science and technology. Owing to the independence of the developed software from implementation platforms, it can be smoothly integrated into a functioning information system. The analysis of the expert assessment of the trial version functionality allows one to forecast that the system will be efficiently implemented in the industry.

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