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Intelligent System for Designing the Optimal Competence Model of a University Graduate

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***Abstract*—In article the problem of training the qualified specialists on the basis of competence-based approach to training in the directions of the higher education is considered. Competence-based approach to training is the main aspect in the field of the higher education and is the fundamental principle of federal state educational standards (FSES), approximate educational programs and the training materials development. Within the accepted FSES 3++ the formation of competencies on design of the main educational programs in the higher education on the basis of professional standards is declared, however the labor functions described in professional standards often demand addition and adjustment for needs of the specific employer [1]. The algorithm of forming the educational results in the form of competence-based model of the graduate taking into account requirements and additions of the employer which is a basis of an intellectual system of design of optimum competence-based model of the university graduate is presented in article. Questioning can be used for requirements of the employer definition (specification). In the process of the results of questioning analysis requirements of the employer are detected, formulated in the format «knowledge», «ability», «possession» and subsequently constitute the newly introduced professional competency (profile), one or several. The passport of competency is developed. Further the discipline (or the module) is defined in the process of studying which is achieved the formation of this competency, the matrix of competencies is formed. By drawing up a matrix it is necessary to consider levels (private weight) of competencies formation. On the basis of the matrix of competencies, a curriculum is formed that satisfies the requirements of optimality, i.e. allows to get the levels of competency development specified by the employer within the limits of academic load.**

Keywords—competence, education, educational result, educational program.

I. Introduction

Framework of information way of modern reality considerably increased value of a human factor in productions and significantly changed requirements to a set of competencies of the specialist and to their level. In the conditions of high-tech production, man began to play the role of the main resource. According to rates of development of ADP equipment, means of telecommunications, information technologies, the knowledge-intensive productions, requirements to qualification of the specialists demanded by economy change, there are new directions and specialties, new competencies are entered, professional standards change, educational technologies are improved. Development of information way in the production technology [1] caused significant changes in requirements of employers to production capabilities and labor behavior of personnel.

II. Main part

The key role in training of the qualified specialists demanded by economy is allocated for higher education. Training - purposeful process of the organization students activities for mastering knowledge, abilities, skills and competence, to acquisition of experience of activity, development of abilities, acquisition of knowledge use experience in everyday life and forming at students of motivation of education during all life. As a result, in the field of human resource management and vocational education competence-based approach was widely adopted [2]. The concepts “competence” and “competency” are the cornerstone of the specified approach [3].

Within competence-based approach the following definitions are offered:

- competency – technology or methodology, the possession of which, along with other competencies, allows a specialist to define or manage business processes within the scope of his competencies with the required level of competence;
- the competence is a measured quality of the specialist in a solution of a specific objective or to management business processes. The specialist has a certain competence in the field of its competencies;
- competence-based approach in education is understood as implementation of the educational program creating an appearance of the specialist which competence satisfies market requirements for specific labor functions execution [4].

The idea of competence-based approach in education has the following advantages:

- allows to define readiness of the university graduate for professional activity;
- gives an opportunity to quickly adjust educational programs and to provide timely training of specialists, possessing relevant competencies in dynamically changing economy and production market requirements;

- focuses attention on the results of education and this results are not just the sum of the acquired information but the ability of the person to work in different situations.

Due to the introduction of FSES 3++ approaches to the compilation of the bachelor degree (masters degree) educational program competence-based model changed, in particular, it is necessary to consider requirements of professional standards [5]. A task of the university is to develop the educational programs providing training of the graduates demanded in labor market. The educational programs curricula forming should be based on the results of the analysis of the employers needs in young professionals with a certain set of competencies.

The educational program represents a complex of the main characteristics of education (volume, content, the planned results), organizational and pedagogical conditions, certification forms which is presented in the form of the curriculum, schedule educational diagram, working programs of disciplines (modules), the practicing programs, other components and estimated and methodical materials [6].

The university provides the implementation of educational activities in accordance with the established educational program:

- the planned results of mastering the educational program - the competencies of graduates set by the educational standard and the competencies of graduates set by the organization (in case of establishment of such competencies);
- the planned results of training in each discipline (module) and practice providing achievement of the planned results of mastering of the educational program.

Professional standards are applied first of all at a design stage of educational results for the Main Educational Program (MEP) in general. Spheres of professional activity in which the university graduates who mastered MEP can carry out professional activity are listed in FSES 3++ according to numbers of the list of types of professional activity applied when developing professional standards [7].

The competence-based model of the university graduate representing educational results includes [8]:

1) universal and all-professional competencies – are given in FSES 3++;

2) professional competencies.

Professional competencies are formed on a basis of:

- the professional standards corresponding to professional activity of graduates;
- of requirement of the analysis of the requirements for professional competencies of graduates in the labor market, consultations with leading employers, industry employers' associations in which graduates are in demand.

The higher education institution has the right to define independently one or several professional competencies proceeding from orientation (profile) of the bachelors degree program on the basis of the professional standards corresponding to professional activity of graduates and to include it into the main educational program.

Application of professional standards concerns first of all the design of [9]:

- professional competencies,
- independently set professional competencies;
- the being professional competencies (knowledge, abilities and possession);
- descriptors (indicators of formation of knowledge, abilities and possession.

Descriptors - indicators of knowledge, abilities, practical experience and other components of competencies formation [10]. Descriptors are the generalized characteristics specifying and opening a formulation of competency. They can be presented in the form of training results or in the form of the specific actions performed by the graduate who mastered this competency.

Professional competencies can be set in the approximate educational program as obligatory and (or) recommended.

The educational organization includes one or several professional competencies defined independently, proceeding from orientation (profile) of the program of a bachelor degree, on the basis of the professional standards corresponding to professional activity of graduates and also, if necessary, on the basis of the analysis of other requirements imposed to graduates.

Taking into account the aforesaid design of competence-based model of the graduate includes the following stages [11]:

- requirement analysis of professional competencies claimed from the graduates in the labor market,
- carrying out in order to identify the requirements of additional knowledge and skills that a modern highly qualified specialist of a profile necessary for an employer should possess;
- development of maps (passports) of independently established professional competencies based on the analysis of the results of consultations and employers' surveys;
- determination the discipline or module required for the formation of professional and independently established professional competencies and its ranking by the level of competency formation;
- design of a matrix of compliance of competencies and the MEP components creating them (disciplines, educational blocks);
- development of the curriculum on the basis of a matrix of competencies [6].

Development of the curriculum in the direction (specialty) is carried out on the basis of a matrix of competencies taking into account a complex of relevant requirements of FSES 3++ to labor input of disciplines, the recommended academic load of the student within

educational week, the diagram of educational process for the entire period of training, etc [12].

In design of competence-based model of the graduate the main role in decision-making belongs to the expert or the group of experts [13]. Experts create a set (list) of disciplines for choice from which then the person making a decision (PMD) selects necessary disciplines for a matrix of competencies [14].

According to it there is a task: choose the set of disciplines that is optimal in terms of labor intensity and levels of competence formation, which allows the most effective implementation of the set of competencies of a university graduate (trainee in a certain direction of bachelor degree), taking into account the level of competency development and curriculum limits set by the employer. To make decisions within the framework of the task, a project is proposed for an intelligent design system for the optimal competency model of a university graduate.

Basic data are:

D – set of educational modules (disciplines, dimension N), including basic disciplines and disciplines for choice.

Discipline: $Д: \left\{D1;\ D2;\ \{D_{enter}\};\ \{K_j\};\ \{f_j\}\right\}$,

where: D1 – the name of discipline,

D2 – the labor input expressed in test units (t.u.),

{D_enter } – set of the entering (previous) disciplines, Denter ⊆ D,

{K_j } – set of the competencies created by this discipline,

{f_j } – private the weight (forming levels) of the competencies created by this discipline.

The competency is stated within a course of a subject matter (one or several) for the purpose of its forming at the trainee. Necessary level of formation of competency Z (accepts values from 1 to 3 for a bachelor degree) is defined by the requirement of the expert (employer).

For definition of the concept “level of formation of competency”, we will take the generalized system of target didactic indicators of assimilation of a training material offered in work as a basis [15].

“Zero” level (Understanding) is such level, at which the pupil is capable to understand, i.e. consciously to perceive information, new to it. Strictly speaking, it is impossible to call this level the level of assimilation of a training material on the studied subject. Actually, it is about the previous training of the pupil, which gives him the chance to understand a training material, new to it. Conditionally activity of the pupil at the “zero” level is called Understanding [16].

The first level (Knowledge) is a recognition of the studied objects and processes at repeated perception of earlier acquired information on them or actions with them, for example, selection of the studied object from a number of the shown different objects. Conditionally activity of the first level is called by Knowledge, and by knowledge, which is its cornerstone – Knowledge acquaintance.

The second level (Reproduction) is a reproduction of knowledge acquired earlier from the literal copy before application in standard situations. Examples: reproduction of information on memory; a solution of standard tasks (on the sample acquired earlier). Activity of the second level is conditionally called by Reproduction, and by knowledge which is its cornerstone – Knowledge copy.

The third level (Application) is such level of assimilation of information at which the pupil is capable to reproduce and transform independently acquired information for discussion of the known objects and its application in various non-standard (real) situations. At the same time, the pupil is capable to generate subjectively new (new to him) information on the studied objects and actions with them. Examples: a solution of non-standard tasks, the choice of a suitable algorithm from a set of earlier studied algorithms for a solution of a specific objective. Activity of the third level is conditionally called by Application, and by knowledge which is its cornerstone – Knowledge ability.

The fourth level (Creative activity) is such level of proficiency in a training material of a subject at which the pupil is capable to create objectively new information (earlier unknown to nobody). The above described taxonomy is applicable for the description of level of formation of the competencies in the process of studying the discipline (Table 1).

TABLE I. LEVEL OF FORMATION OF COMPETENCIES

Levels of the higher education	Level (description)
Bachelor degree	1 – Recognition – Knowledge acquaintance.
	2 – Reproduction – Knowledge copy.
	3 – Application – Knowledge ability.
Master’s degree	4 – Creative activity – ability to create objectively new information

It is necessary to understand the educational module (EM) (a subject matter or its part, several disciplines) creating competence at the certain level (Fig. 1) as the training object.

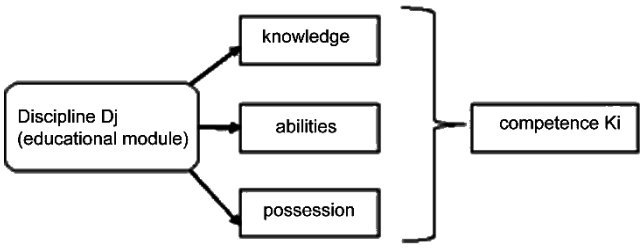

Fig. 1. Creating competence at the certain level

Let's designate a set of competencies K (dimension m):

K： {K1;K2},

where: K1 – the name of competency,

K2 – the integrated weight (level of formation of competency).

To – a set of competencies (the dimension m), includes:

1) common cultural or universal competencies (CC, UC);
2) all-professional competencies (APC);
3) professional competencies (PC);
4) PCP – professional competencies of a profile (independently set professional competencies, are entered according to a profile in the direction, requirements of the employer, a profile of department, higher education institution, etc.

It is necessary to consider the logical sequence and coherence of disciplines (previous - the subsequent disciplines) in the course of forming of competency [17].

The private weight (forming levels) we will designate f_i on components of competence so: f_1 – knowledge, f_2 – abilities, f_3 – possession.

The matrix of F (Table 2) reflects the level of competency formation which includes knowledge, abilities and possession of educational modules:

- indicator of forming of knowledge forming competency K1, f1,i → [0; 1] (1):

$$\sum_{i=1}^{n} f_{2,i}, \quad (1)$$

- indicator of forming of the abilities forming competency K2, f2,i → [0; 1] (2):

$$\sum_{i=1}^{n} f_{3i}, \quad (2)$$

- indicator of forming of the possession forming competency K3, f3,i → [0; 1] (3):

$$K2_i = \sum_{1}^{3} f_i, \quad (3)$$

- formation level (integrated weight) of the competency created by EM, one or several – the numerical coefficient accepting values from 0 to 3.

TABLE II. THE LEVEL OF COMPETENCY FORMATION

KAP / Educational module	K1			K2			Km
	K1	*A1*	*P1*	*K2*	*A2*	*P2*	…
EM1	f11	f12	f13	f14	f15	f16	…
EM2	f21	f22	f23	f24	f25	f26	…
	f31	f32	f33	f34	f35	f36	…
EM	…	…	…	…	…	…	…
EMn	fm1	fm2	fm3	fm4	fm5	fm6	…

Curriculum P (4):

$$P: \left\{\{D_m\}; \sum_{i=1}^{N} Tp\right\}, \quad (4)$$

where $\{D_n\}$; −a set of disciplines, $\sum Tp$ to the sum of requirements of FSES 3++ in the direction of training, N to the number of requirements, FSES is determined by the specific direction.

Competence-based model KM:

$$KM: \left\{\{K_j\} \rightarrow \{Z_j\}\right\}, j = \overline{1..m},$$ where Zi – the levels of formation of competencies declared the employer.

The task is as follows: develop an algorithm of design optimum on labor input and levels of formation of competencies of competence-based model of the graduate in the direction of a bachelor degree.

Restrictions:

1) Meet requirements of competence-based model (a matrix of competencies) for the direction of training;
2) Consider succession of disciplines (previous - the subsequent), i.e. the discipline of Di can be included in the curriculum if it belongs to a set of the previous disciplines (5):

$$X_i = \begin{cases} 0, & D_i \notin \{D_{\text{вход}}\} \\ 1, & D_i \in \{D_{\text{вход}}\} \end{cases}, \quad (5)$$

where Xi- binary variable (6):

$$\forall X_i = 1 \implies X_{k1} \in \{D_{enter}\}_i = 1. \quad (6)$$

Labor input of the curriculum F (7):

$$F = \sum_{i=1}^{n} X_i D2_i \rightarrow min. \quad (7)$$

The integrated weight of the competency K2j, consisting of levels of competency forming by the disciplines (8)

$$K2_j = \sum_{i=1}^{n} X_i * \Delta K_{ij}, j = \overline{1 \dots m}, \quad (8)$$

n – dimension of a set of disciplines, X_i – binary variable, ΔK_{ij} – the indicator of formation of the j-th competence by i-th discipline, should meet the requirement (9):

$$K2_j \geq Z_j, j = \overline{1..m}, \quad (9)$$

Z_j – the level of formation of competency set (employer).

The offered algorithm of design of optimum competence-based model of the graduate taking into account requirements of the employer [18]:

1) to formulate requirements of employers to the graduate of a certain direction of training of the bachelor in the language “nobility, be able, own” [19];
2) to define compliance of the formulated knowledge, abilities, possession to the competencies specified in FSES HE (3++) in the selected direction in case of need to select additional professional competencies;
3) to make a matrix of compliance of educational modules and knowledge created by them, abilities, possession, considering the logical sequence of studying of disciplines in the course of competency forming, specifying value of level of formation of the being competencies by the training modules according to FSES in this direction (the decision on the value of this metrics is made by the expert or the group of experts), to define integral the weight of competencies [20];

4) to range a matrix of compliance of competencies and educational modules on the value of integrated scales of competencies;

5) to create the list of disciplines, (considering that the educational module consists of one or several disciplines) by the principle of selection of the maximum level of formation of the corresponding competencies and/or comparisons of integrated scales of competencies with value, the defined employer (Z);

6) to analyze a matrix of compliance and considering structure of competency and the fact that the educational module consists of one or several disciplines, (depending on the contents, the purposes and tasks of the module), to create the matrix of compliance of competencies and educational modules reflecting levels of formation of competencies;

7) to correct the received list taking into account labor input of disciplines;

8) to create competence-based model which optimality is expressed in achievement of the maximum value of integrated scales of the created competencies [21](10,11):

$$\sum_{j=1}^{m} K2_i \rightarrow max, \quad (10)$$

$$max = \sum_{j=1}^{x} Z_j, \;\; x \leq m, \quad (11)$$

where Z_j – the levels of formation of competencies set by the employer, x – the number of the stated requirements of the employer, on condition of the minimum labor input of disciplines of $D_{2i} \rightarrow$ min. On the basis of the received competence-based model then the curriculum is formed.

III. Conclusion

The intelligent information system on the basis of the above described algorithm will allow the expert making a decision to project the educational result providing achievement of the goal of high-quality training of the highly skilled workers having a set of the necessary competencies meeting requirements of employers and allowing to carry out effectively professional types of activity.

References

[1] The federal law «About introduction of amendments to the labor code of the Russian Federation and Articles 11 and 73 of the federal law «About Education in the Russian Federation» of 02.05.2015 No. 122-FZ. European social research: studying of basic social, political and cultural changes in a comparative context Russia and 25 countries of Europe Analytical report of 2008 [Electronic resource] of URL: http://www.cessi.ru/fileadmin/user_upload/Analytical_report.pdf (date of the address 27.12.2012)(in Russian).

[2] Lyle M., Spencer Jr. and Sayn M. Spencer. Competencies at work. Model of maximum efficiency of work: The lane with English M.: HIPPO, 2005. 384 pages.

[3] Francoise Delamare Le Deist & Jonathan Winterton // Human Resource Development International.2005. March. Vol. 8, № 1. P. 27–46.

[4] V.I. Rykov, Makarova S.Yu. Technique of forming of model of quality management of training of the university graduate on the basis of competence-based approach taking into account requirements of production.//Virtual modeling, prototyping and industrial design: materials V of the International scientific and practical conference: in 3 t. / under a general edition of M.N. Krasnyansky; FGBOOU WAUGH «TGTU». – Tambov: TGTU VO publishing center FGBOU, 2018. – Issue 5. Volume 3. P 298-304.)(in Russian)

[5] The federal law of 29.12.2012 No. 273_FZ «About education in the Russian Federation» (with amendment and N 497-FZ additional of 25.12.2018))(in Russian)

[6] Makarova S. Yu., Martynov V.V. Development of optimum competence-based model of the graduate taking into account dynamically changing requirements of the employer. - Informatization of science and education. Scientific and methodical log «No. 4(36)/2017. Page 120-133.)(in Russian)

[7] Bespalko V. P. Pedagogics and progressive technologies of training. M.: 1995. – 336 pages.)(in Russian)

[8] V. Martynov, P. Sakál, A. Skuratov, E. Filosova, A. Zaytseva, E. Zakieva, Chapter 11: CSRP-System Design Technology of Training Information Support of Competent Professionals, In the Handbook of Research on Engineering Education in a Global Context, ed. by E. V. Smirnova and R. P. Clark, vol. 2. USA, Derry: IGI Global, 2018.)(in Russian)

[9] Jabatan Kerja Raya Competency model & dictionary [Electronic resource] URL: http://ru.scribd.com/doc/101318523/Model-Dictionary .

[10] Competence. Dictionary of terms [Electronic resource] of URL: http://www.hr-portal.ru/varticle/kompetentsiya)(in Russian)

[11] Golub G.B., Fishman I.S., Fishman L.I. Standards of third generation: what to teach also to what to check at the exit: Issues of education. - 2010. - N 3. - p. 102-114.)(in Russian)

[12] Baydenko V.I. Identification of structure of competencies of university graduates as necessary design stage of FSES HE of new generation: Methodical grant. – M.: Research center of problems of quality of training of specialists, 2006. – 72 pages.)(in Russian)

[13] Bespalko V. P. Composed pedagogical technology. M, Pedagogics,1989. 192 pages.)(in Russian)

[14] Tuzovsky A.F., Management systems knowledge (methods and technologies, Tomsk, publishing house science technical literature, 2005 page 258.)(in Russian)

[15] Azarova R.N., Zolotareva N.M. Development of the passport of competence: Methodical recommendations for organizers of project works and faculties of higher education institutions. The first edition. – M.: Research center of problems of quality of training of specialists, Coordination council of educational and methodical associations and scientific and methodical councils of the higher school, 2010. – 52 pages.)(in Russian)

[16] Learning Technologies. (2017). E-Learning Awards Categories and Criteria, Retrieve from http://www. learningtechnologies.co.uk/enter-an-award/award-categories

[17] Weinreich, H., Obendorf, H., & Mayer, M. (2008). Not Quite the Average: An Empirical Study of Web Use University of Hamburg. In Proceedings of the 15th International Conference on the World Wide Web (Vol. 2). doi:10.1145/1326561.1326566

[18] Zualkernan, I. A. (2006). A framework and a methodology for developing authentic constructivist e- Learning environments. Journal of Educational Technology & Society, 9(2), 198–212. Retrieved from http://www.ifets. info/journals/9_2/16.pdf

[19] Ning, W. (2014). The Latent Appreciation Effect of Interactive Design in Internet Communication, IEEE 11th Intl Conf. on Ubiquitous Intelligence and Computing and IEEE 11th Intl Conf. on Autonomic and Trusted Computing and IEEE 14th Intl Conf. on Scalable Computing and Communications and Its Associated Workshops (pp. 723-726). doi:10.1109/UIC-ATC-ScalCom.2014.65

[20] Intel World Ahead Program. (2009). The Positive Impact of eLearning. Retrieved from https://www.intel.la/ content/dam/www/program/education/us/en/documents/positive-impact-of-elearning.pdf Khan, B. (2005). Managing E-Learning Strategies: Design, Delivery, Implementation and Evaluation. Hershey, PA: IGI Global; doi:10.4018/978-1-59140-634-1 Learning Technologies. (2017). E-Learning Awards Categories and Criteria, Retrieve from http://www. learningtechnologies.co.uk/enter-an-award/award-categories

[21] Ping REN, Zude ZHOU, Quan LIU, An Adaptive Token Passing Algorithm Applicable to MS/TP Network International Journal of Computational Intelligence Systems, Vol. 4, No. 5 (September, 2011), 910-920