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THE DEVELOPMENT OF APPROACHES FOR OBTAINING AUTOMATED SOLUTION ON THE FORMATION OF THE CURRICULUM

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РАЗРАБОТКА ПОДХОДА ДЛЯ ПОЛУЧЕНИЯ АВТОМАТИЗИРОВАННОГО РЕШЕНИЯ ФОРМИРОВАНИЯ УЧЕБНОГО ПЛАНА

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Keywords

Competence; competence approach; curriculum; multi-criteria optimization.

Abstract

Modeling of training processes contributes to obtaining effective solutions of problems in the educational system. One of the most important tasks in the planning of the educational process is computer-aided curriculum design taking into account imposed limitations and the requirements set educational standards and institutions in accordance with the competence-based approach. Despite the considerable amount of the problem research, a systematic formulation of its solution does not exist. The approach is designed to obtain such a decision involving the relationship between disciplines, competencies and teachers. Features of the approach are connected with the formalization and generalization of semi-structured data. Its processing is possible by using the basis of modern decision-making methods with initial uncertainty. Approaches to solving these problems are proposed. Based on the received set of education profile field competences the formation model of the curriculum is constructed. This problem can be considered as an multi-criteria optimization problem.

Ключевые слова

Компетенции; компетентностный подход; учебный план; многокритериальная оптимизация.

Аннотация

Моделирование учебного процесса способствует эффективному управлению в образовательной системе. Одной из важнейших задач в планировании учебного процесса является автоматизированное проектирование учебного плана с учетом накладываемых ограничений и требований, заданных образовательным стандартом и вузом в соответствии с компетентностным подходом. Несмотря на значительное количество исследований, посвященных решению этой проблемы, системная постановка её решения отсутствует. Разработанный в статье подход к получению такого решения основан на взаимосвязи дисциплин, компетенций и преподавателей. Особенности подхода связаны с необходимостью формализации и обобщения слабоструктурированных данных, обработка которых возможна на основе современных методов принятия решений в условиях исходной неопределенности. Предложены подходы к решению этих проблем. На основе полученного набора компетенций профиля направления построена модель формирования учебного плана, являющаяся задачей многокритериальной оптимизации.

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Introduction

The curriculum formation is a key problem of the educational process of the University. Most of the research on this problem use information technology in the curriculum formation without analyzing the requirements of Federal State Educational Standards [1-11]. At the same time, the curriculum formation is characterized by a significant influence of the higher education workers contingent and, as a result, it needs a serious restructuring. This is especially true in the context of increasing requirements for the quality of training [12, 13]. A primitive curriculum with a random distribution of disciplines by modules leads to a decrease in the quality of the basic educational program. In consequence of that, there is a decrease in the quality of professional skills of graduates [14-22]. The inclusion of optimization procedures in the construction of the curriculum [23] allows us to evaluate the choice of specific disciplines that fully provide competence.

The formation of the curriculum is implemented under the condition of the fulfillment of many requirements that defined in the regulatory documents. According to the mathematical modeling, they are fuzzy. Requirements, on the one hand, can be represented as restrictions that imposed on the curriculum formation, on the other hand, can be represented as the target functions, the value of which must be maximized (minimized). As a result, the task of the curriculum formation is reduced to a class of poorly formalized problems with indistinct restrictions, incomplete and fuzzy data. The feature of this problems is that it is impossible to find the only acceptable optimal solution. These disadvantages leads to a variety of curriculum formation models. Moreover, the choice of a particular solution depends on subjective factors and during their formalization depends on the models and algorithms adopted.

Domain analysis

Imagine the process of curriculum formation in the form of:

$$UP=\{D,K,L\} \quad (1)$$

where D — is the discipline of curriculum, K – content requirements (competences) for the educational program for which the developed educational plan, L – persons, ensuring the learning and curriculum development.

Disciplines, in turn, are divided into the disciplines of the basic part, the variable, the profile (optional), practice, and GIA:

$$D=\{D_b, D_v, D_p, D_{pr}, D_a\}. \quad (2)$$

The substantive requirements include competence, which, in turn, have 3 levels: universal, general professional, professional:

$$K=\{K_u, K_o, K_p\}. \quad (3)$$

The person providing the training process and curriculum development are divided into internal and external:

$$L=\{L_{prof}, L_{doc}, L_{pr}, L_{as}\}. \quad (5)$$

Note: the feature of the new educational standards is the division of rights to the competencies formation. Specifically, universal and general professional competences are defined by the standard, and professional competences are established at the educational institutions. The paper [24] proposes an approach that determines the profile and professional competence of the basic educational program, that the most relevant for the labor market in a particular region.

The idea of the approach to developing the curriculum development

Select the main entity in the formation of the curriculum:

- disciplines;
- competences;
- teachers.

The main element in the curriculum is the disciplines. Consider the communication of disciplines competences and disciplines teachers. The organizational unit of teaching can be considered disciplines. This implies that directly it is impossible to determine which competencies are acquired as a result of studying a particular discipline. Let us formulate the following principle of formation of the curriculum with the requirements of the educational standard: the subjects of the curriculum are directly linked only with descriptors (knowledge, skills, proficiency) which, in turn, are associated with competencies. The study [25] introduces a formalized representation of competence through a tuple. It contains a set of descriptors and a set of terms. Based on this, each the curriculum entity can be represented in the descriptor space in the form of:

$$V=<S^V, D^V, T^V>, \quad (6)$$

where V is the designation of the selected entity, S^V– formulation of the selected entity in natural language, D^V – set of descriptors («knowledge», «skills»,…), T^V — set of terms.

Figure 1 presents a diagram showing the relationship of competencies, disciplines, and descriptors.

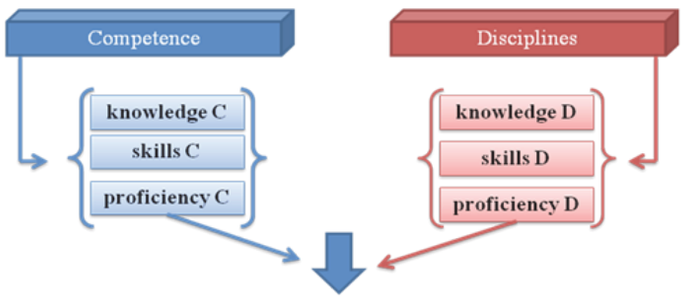

Fig. 1. Relationship between disciplines and competencies

Рис. 1. Взаимосвязь компетенций и дисциплин

We define the identifying the relationship between descriptors and competences as $k_{ij} \in [0,1]$ – close ratio of the i-th competence of the j-th discipline. After obtaining the ratio we form the set of disciplines included in the curriculum. The result is a wide variety of disciplines, each of which provides the closure of the i-th competence is not less than the α value. We build an optimization problem to obtain a set of disciplines that provide the maximum competence (section 4.1), by distributing the resulting set of disciplines in parts of the curriculum. Before proceeding to the connection of disciplines and teachers, it is necessary to decide the structure of the curriculum (determination of the studying disciplines order). In addition, at this stage there is a distribution of credits for each type of the study discipline. After that, we turn to the connection of competencies and teachers. The entity of discipline and teachers are also connected through knowledge, skills, proficiency of teachers and disciplines. And they can be represented in the descriptor space [25]. Figure 2 shows the connection between disciplines and teachers.

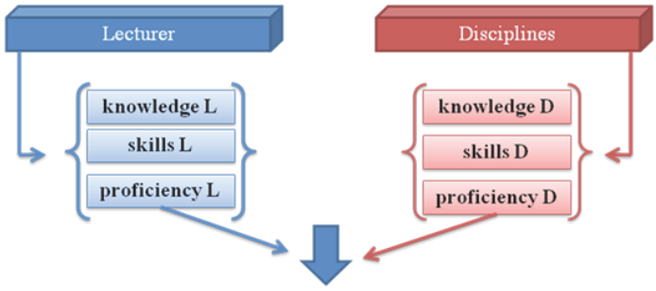

Fig. 2. Relationship between disciplines and teachers
Рис. 2. Взаимосвязь преподавателей и дисциплин

Let $h_{pj}^{s} \in [0,1]$ the connection of the descriptors of disciplines and teachers. It is the ratio profiling of the p-th teacher at the s-th type of academic work of the j-th discipline. After obtaining the coefficient of profiling we transfer to the formation of the teachers set who have the right to exercise the type of the training discipline. The result is the set of indices of teachers, the profiling which is the s-th type of academic work of the j-th discipline not less than β. At this stage, the second optimization problem of maximizing the profiling of teachers in each discipline with minimum cost is set is described.

Mathematical model of the curriculum

The resulting mathematical model of the curriculum consists of two parts:

- connection of disciplines and competencies;
- connection of disciplines and teachers.

Connection of disciplines and competences

We introduce the following notation:
i – is the number of competence, $i=\overline{1,m}$.

$I^u = \{i_1^u, i_2^u, \dots, i_{m_u}^u\}$ – is the set of indices of the universal competences.

$I^o = \{i_1^o, i_2^o, \dots, i_{m_o}^o\}$ – is the set of indices of General professional competences.

$I^p = \{i_1^p, i_2^p, \dots, i_{m_p}^p\}$ – is the set of indices of professional competence.

j – number of discipline, $i=\overline{1,n}$.

$k_{ij} \in [0,1]$ – close ratio of the i-th competence of the j-th discipline.

$J^f = \{j_1^f, j_2^f, \dots, j_{n_f}^f\}$ – is the set of indices of the fundamental disciplines (required included in pack).

$J_\alpha^i = \{j_1^i, j_2^i, \dots, j_{n_i}^i\}$, $i = \overline{1,m}$ – is the set of indices of subjects, each of which provides the closure of the i-th competence is not less than the value α.

$J_\alpha^u = \bigcup_{i \in I^u} J_\alpha^i \setminus J^f$ – is the set of indices of the disciplines involved in the closure of universal competencies.

$J_\alpha^o = \bigcup_{i \in I^o} J_\alpha^i \setminus J^f$ – is the set of indices of the subjects participating in the closure of General professional competencies.

$J_\alpha^p = \bigcup_{i \in I^p} J_\alpha^i \setminus J^f$ – is the set of indices of the disciplines involved in the closure of professional competences.

k – the number of the structural parts of the curriculum:
k = 1 – the base part of the curriculum;
k = 2 – the variable part of curriculum;
k = 3 – profile part;
k = 4 – practice;
k = 5 – GIA.

$J_\alpha^1 = J_\alpha^u \cup J^f \cup J_\alpha^o$ – is the set of indices of the disciplines involved in the formation of the basic part of the pack.

$J_\alpha^2 = J^f \cup J_\alpha^o$ – is the set of indices of the disciplines involved in the formation of the variable part of the CP.

$J_\alpha^3 = J_\alpha^o \cup J_\alpha^p$ – is the set of indices of the disciplines involved in the formation of the relevant part of the pack.

J_α^4 – is the set of indices of the disciplines involved in the formation of the part of the practitioner pack.

J_α^5 - is the set of indices of the disciplines involved in the formation of part of the GIA pack.

$\underline{V}^k$ – the lower bound credits the k-th part of the pack.

$\overline{V}^k$ – upper limit of credits k-th part of the pack.

V – limitation on total number of credits up.

v_j – the number of credits allocated to the j-th discipline.

$$x_{kj} = \begin{cases} 1, & \text{if j-th iscipline is included into в k-th part curriculum,} \\ 0, & \text{otherwise.} \end{cases} \quad (2)$$

The solution of the problem will be a matrix X of dimension 5×n. We introduce a limit on the number of credits for each structural part of the curriculum:

$$\underline{V}^k \le \sum_{j \in J_\alpha^k} v_j x_{kj} \le \overline{V}^k, k = \overline{1,5.} \quad (3)$$

We introduce a limit on the singleness of entrance of j-th in the curriculum:

$$\sum_{k=1}^{5} x_{kj} \le 1, j = \overline{1,n.} \quad (4)$$

It is necessary to maximize presence of each competence in the curriculum:

$$\sum_{j\in J_\alpha^i}\sum_{k=1}^{5} k_{ij}x_{kj} \to max, i=\overline{1,m}. \quad (5)$$

Connection of disciplines and teachers

We introduce the following notations:
p – number of teacher, $p=\overline{1,l}$.
d – the number of the qualification of the teacher:
d=1 – professor;
d=2 – associate professor;
d=3 – senior teacher;
d=4 – assistant.
$P^d=\{p_1^d,p_2^d,\dots,p_{l_d}^d\}$, $d=\overline{1,4}$ – is the set of indices of teachers d-th of qualification.
$P^{dn}=\{p_1^{dn},p_2^{dn},\dots,p_{l_{dn}}^{dn}\}$ - is the set of indices of teachers with a scientific degree Doctor of Sciences.
$P^{кn}=\{p_1^{кn},p_2^{кn},\dots,p_{l_{кn}}^{кn}\}$ - is the set of indices of teachers with a scientific degree of candidate of Sciences.
c_d – cost of one rate a teacher d-th qualification
s- type number of training activities on the discipline:
s=1 – lectures;
s=2 – practical lessons;
s=3 – laboratory work;
s=4 – contact independent work;
s=5 – exam;
s=6 – consultation on exam;
s=7 – test, $s=\overline{1,q}$.
$S^j=\{s_1^j,s_2^j,\dots,s_{q_j}^j\}, j=\overline{1,n}$ – is the set of indices of the training activities, which are part of the j-th discipline.
v_j^s – the number of credits provided for the s-th type of study j-th discipline.
$D^s=\{d_1^s,d_2^s,\dots,d_{t_s}^s\}$, $s=\overline{1,q}$ – is the set of indices of the qualifications allowed for the implementation of the s-th type of academic work.
$h_{pj}^s\in[0,1]$ – coefficient of profiling of the p-th teacher at the s-th type of academic work the j-th discipline. If $h_{pj}^1=1$, then the p-th teacher is the leader for the j-th discipline. This ratio is dependent on the education diplomas, teacher training courses, publications, personal rating, etc.
$P_\beta^{sj}=\{p_1^{sj},p_2^{sj},\dots,p_{l_j}^{sj}\}, j=\overline{1,n}, s=\overline{1,q}$ – is the set of indices of teachers, profiling of which is the s-th type of academic work the j-th discipline not less than β.
$P^s=\bigcup_{d\in D^s}P^d$ is the set of indices of teachers eligible to exercise the s-th type of academic work..
wr_{sj} – the rate provided to s-th type of training on the j-th discipline.

$$y_{ps}^j=\begin{cases}1, & \text{if p-th teacher leads s-th type of academic work the j-th}\\ 0, & \text{discipline,otherwise}\end{cases} \quad (6)$$

It is demanded to maximize the profiling of teachers in each discipline:

$$\sum_{s=1}^{q}\sum_{p\in P^d\cap P_\beta^{sj}} h_{pj}^s y_{pj}^s \to max, j=\overline{1,n}. \quad (7)$$

The total value of the discipline in the curriculum should be minimal. This requires to minimize the cost of each discipline::

$$\sum_{d\in D^s}\sum_{p\in P^d\cap P_\beta^{sj}} c_d wr_{sj} y_{sp}^j \to min, \ j=\overline{1,n}. \quad (8)$$

After analyzing the requirements of educational standards, we introduce a restriction on the share of scientific and pedagogical workers having the scientific degree:

$$\sum_{j=1}^{n}\sum_{s\in S^j}\sum_{d\in D^s}\sum_{p\in P^d\cap P_\beta^{sj}\cap(p^{kn}\cup p^{dn})} wr_{sj}y_{sp}^j \ge \gamma. \quad (9)$$

Let us introduce the conditions on the number of people from scientific and pedagogical workers, in every kind of work discipline:

$$\sum_{p\in P^s} y_{ps}^j = 1, s=1, j=\overline{1,n}. \quad (10)$$
$$\sum_{p\in P^s} y_{ps}^j \ge 1, s=2, j=\overline{1,n}. \quad (11)$$
$$\sum_{p\in P^s} y_{ps}^j \ge 1, s=3, j=\overline{1,n}. \quad (12)$$
$$\sum_{p\in P^s} y_{ps}^j \ge 1, s=4, j=\overline{1,n}. \quad (13)$$

The constraint (10) means that lectures may be read only by one teacher. Constraints (11), (12), (13) indicate that laboratory and practical contact and independent work may be provided by more than 1 person.

Conclusion

The work result is the developed approach for automated decision design of the curriculum taking into account imposed limitations and the requirements set by educational standards and institutions in accordance with the competence-based approach. A mathematical model of the curriculum, including communication of disciplines, competences and teachers is offered. The subsystem designed automated solution of the formation of the curriculum includes the discipline, requirements of the standard and the University, technology implementation of the curriculum experts who provide the educational process. The obtained results can be used to solve tasks for improving the efficiency of compiling and verifying the compliance of the curricula quality criteria.

References

[1] Gusyatnikov V.N., Bezrukov A.I., Sokolova T.N., Kayukova I.V. Information technology to assess the level of competence in the educational process. *Proceedings of the 9th International Conference on Application of Information and Communication Technologies (AICT).* Rostov on Don, 2015, pp. 473-476. DOI: 10.1109/ICAICT.2015.7338604

[2] Viriansky Z.Y., Raychuk Y.A. Quality assurance in education at the stage of curriculum development. *Proceedings of the IV Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations)*. St. Petersburg, 2015, pp. 86-87. DOI: 10.1109/IVForum.2015.7388262

[3] Rongrong R., Gang X., Linan G. A model for university counselor's competence evaluation based on GIOWA operator. *Proceedings of 2010 Chinese Control and Decision Conference*. Xuzhou, 2010, pp. 1845-1848. DOI: 10.1109/CCDC.2010.5498651

[4] Sibikina I.V., Kvyatkovskaya I.Yu. Construction of linguistic scales with the purpose of revelation of important disciplines developing the competence. *Vestnik of Astrakhan State Technical University. Series: Management, Computer Science and Informatics*. 2012; 2:182-186. Available at: https://elibrary.ru/item.asp?id=17839442 (accessed 26.09.2018). (In Russian)

[5] Viriansky Z.Y., Rauchuk Y.A., Shaposhnikov S.O. Uncertainty

account in development of the curriculum for targeted specialists. *Proceedings of 2016 IEEE V Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations)*. St. Petersburg, 2016, pp. 19-20. DOI: 10.1109/IVForum.2016.7835841

[6] Migunova L.G., Kuregyan A.L., Vorontsova E.S. Optimization of multi-educational learning paths. *Proceedings of the 11th International Forum on Strategic Technology (IFOST).* Novosibirsk, 2016, pp. 483-486. Available at: https://elibrary.ru/item.asp?id=29766307 (accessed 26.09.2018).

[7] Hrmo R., KriStofiaková L., Miština J. Building a quality system of technical and vocational education in Slovakia towards a European labour market. *Proceedings of 2015 International Conference on Interactive Collaborative Learning (ICL)*. Florence, 2015, pp. 237-243. DOI: 10.1109/ICL.2015.7318032

[8] May D., Ossenberg P. Modelling competences: Developing a holistic competence model for engineering education. *Proceedings of 2014 International Conference on Interactive Collaborative Learning (ICL)*. Dubai, 2014, pp. 936-944. DOI: 10.1109/ICL.2014.7017902

[9] Fionova L.R., Zolotova T.A. The development of the information system components for teaching management on the base of competence approach. *Informatizaciya obrazovaniya i nauki*. 2011; 4:14-28. Available at: https://elibrary.ru/item.asp?id=17280936 (accessed 26.09.2018). (In Russian)

[10] Naykhanova D.V., Dambaeva S.V. Methods and decision-making algorithms in the management of the educational process in conditions of uncertainty. Ulan-Ude: VSSTU, 2004. 163 p. Available at: https://elibrary.ru/item.asp?id=19931740 (accessed 26.09.2018). (In Russian)

[11] Lavlinskaya O.Yu., Kurchenkova T.V. Decision-making models in a problem of synthesis of the curriculum. *The bulletin of Voronezh Institute of the Ministry of Internal Affairs of Russia*. 2009; 1:136-143. Available at: https://elibrary.ru/item.asp?id=11780755 (accessed 26.09.2018). (In Russian)

[12] Sedelmaier Y., Landes D. Evaluating didactical approaches based upon students' competences. *Proceedings of 2016 IEEE Global Engineering Education Conference (EDUCON)*. Abu Dhabi, 2016, pp. 527-536. DOI: 10.1109/EDUCON.2016.7474603

[13] Pérez J., Vizcarro C., García J., Bermúdez A., Cobos R. Development of Procedures to Assess Problem-Solving Competence in Computing Engineering. *IEEE Transactions on Education*. 2017. 60(1):22-28. DOI: 10.1109/TE.2016.2582736

[14] Kernosov M.A., Mikhnova A.V., Imshenetsky D.A. Flexible set-theoretic model of curriculum for the planning and control subsystem of information and analysis system of university. *Radio Electronics, Computer Science, Control.* 2013; 1:66-71. Available at: https://elibrary.ru/item.asp?id=19397460& (accessed 26.09.2018). (In Russian)

[15] Sukhomlin V.A., Zubareva E.V. Standardization of IT-Education Based on Curriculums at the Present Stage. V. Sukhomlin, E. Zubareva, M. Shneps-Shneppe (Eds.) *Proceedings of the XI International Scientific-Practical Conference "Modern Information Technologies and IT-Education" (SITITO 2016).* Moscow, Russia (November 25-26, 2016). *CEUR Workshop Proceedings*. 2016; 1761:40-46. Available at: http://ceur-ws.org/Vol-1761/paper04.pdf (accessed 26.09.2018). (In Russian)

[16] The design of the main educational programs of the university in the implementation of the level of training on the basis of federal state educational standards. S.V. Korshunov (Ed.) M.: MIPK BMSTU, 2010. 212 p. (In Russian)

[17] Kurilova O.L. Application of Genetic Algorithm for Curriculum Optimization. *Information and Control Systems*. 2013; 3:84-92. Available at: https://elibrary.ru/item.asp?id=19082719 (accessed 26.09.2018). (In Russian)

[18] Pugachev V.M., Gazenaur E.G. The role of information technology in science and education. *Bulletin of the Kemerovo State University*. 2009; 3:31-35. Available at: https://elibrary.ru/item.asp?id=13979272 (accessed 26.09.2018). (In Russian)

[19] Friedman O.V. Analysis software for automating development of educational plans of the university. *Proceedings of the Kola Scientific Center of the Russian Academy of Sciences*. 2015; 3(29):162-175. Available at: https://elibrary.ru/item.asp?id=25794485 (accessed 26.09.2018). (In Russian)

[20] Kharitonov I.M. The study plan forming algorithm based on the study discipline formalized presentation procedure (by the example of «System Simulation» discipline). *Vestnik of Astrakhan State Technical University. Series: Management, Computer Science and Informatics*. 2011; 2:178-185. Available at: https://elibrary.ru/item.asp?id=16457508 (accessed 26.09.2018). (In Russian)

[21] Shishkanova T.A. Development of a methodology for constructing an automated learning management system. *Gorny Informatsionno-Analiticheskiy Byulleten (nauchno-teknicheskii zhurnal)* = Mining Informational and Analytical Bulletin (scientific and technical journal). 2011; S6:518-529. Available at: https://elibrary.ru/item.asp?id=17253300 (accessed 26.09.2018). (In Russian)

[22] Zykina A., Kaneva O., Krejdunova V. Optimizing learning management system in high school. V. Sukhomlin, E. Zubareva, M. Shneps-Shneppe (Eds.) *Proceedings of the XI International Scientific-Practical Conference "Modern Information Technologies and IT-Education" (SITITO 2016).* Moscow, Russia (November 25-26, 2016). *CEUR Workshop Proceedings*. 2016; 1761:64-72. Available at: http://ceur-ws.org/Vol-1761/paper08.pdf (accessed 26.09.2018). (In Russian)

[23] Zeer E.F. Competence-based approach to education. *The Education and Science Journal*. 2005; 3:27-40. Available at: https://elibrary.ru/item.asp?id=11530521 (accessed 26.09.2018). (In Russian)

[24] Zykina A.V., Kaneva O.N., Munko V.V. Algorithm of determining the competence of educational programs of higher education. *Informational Bulletin of the Omsk Scientific and Educational Center of Omsk State Technical University and the IM SB RAS in the field of mathematics and computer science*. 2018; 2(1):74-77. Available at: https://elibrary.ru/item.asp?id=35449425 (accessed 26.09.2018). (In Russian)

[25] Kaneva O.N., Akimova K.A., Sharun I.V. Development of an algorithm for finding semantic proximity between competences. *Informational Bulletin of the Omsk Scientific and Educational Center of Omsk State Technical University and the Institute of Mathematics and Siberian Branch of the Russian Academy of Sciences in the field of mathematics and computer science*. 2017; 1(1):155-156. Available at: https://elibrary.ru/item.asp?id=29860560 (accessed 26.09.2018). (In Russian)

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Список использованных источников

[1] *Gusyatnikov V.N., Bezrukov A.I., Sokolova T.N., Kayukova I.V.* Information technology to assess the level of competence in the educational process // Proceedings of the 9th International Conference on Application of Information and Communication Technologies (AICT). Rostov on Don, 2015. Pp. 473-476. DOI: 10.1109/ICAICT.2015.7338604

[2] *Viriansky Z.Y., Raychuk Y.A.* Quality assurance in education at the stage of curriculum development // Proceedings of the IV Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations). St. Petersburg, 2015. Pp. 86-87. DOI: 10.1109/IVForum.2015.7388262

[3] *Rongrong R., Gang X., Linan G.* A model for university counselor's competence evaluation based on GIOWA operator // Proceedings of 2010 Chinese Control and Decision Conference. Xuzhou, 2010. Pp. 1845-1848. DOI: 10.1109/CCDC.2010.5498651

[4] *Сибикина И.В., Квятковская И.Ю.* Оценка значимости дисциплин, формирующих компетенцию на основе лингвистического классификатора // Вестник Астраханского государственного технического университета. Серия: Управление, вычислительная техника и информатика. 2012. № 2. С. 182-186. URL: https://elibrary.ru/item.asp?id=17839442 (дата обращения: 26.09.2018).

[5] *Viriansky Z.Y., Rauchuk Y.A., Shaposhnikov S.O.* Uncertainty account in development of the curriculum for targeted specialists // Proceedings of 2016 IEEE V Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations). St. Petersburg, 2016. Pp. 19-20. DOI: 10.1109/IVForum.2016.7835841

[6] *Migunova L.G., Kuregyan A.L., Vorontsova E.S.* Optimization of multi-educational learning paths // Proceedings of the 11th International Forum on Strategic Technology (IFOST). Novosibirsk, 2016. Pp. 483-486. URL: https://elibrary.ru/item.asp?id=29766307 (дата обращения: 26.09.2018).

[7] *Hrmo R., KriStofiaková L., Miština J.* Building a quality system of technical and vocational education in Slovakia towards a European labour market // Proceedings of 2015 International Conference on Interactive Collaborative Learning (ICL). Florence, 2015. Pp. 237-243. DOI: 10.1109/ICL.2015.7318032

[8] *May D., Ossenberg P.* Modelling competences: Developing a holistic competence model for engineering education // Proceedings of 2014 International Conference on Interactive Collaborative Learning (ICL). Dubai, 2014. Pp. 936-944. DOI: 10.1109/ICL.2014.7017902

[9] *Фионова Л.Р.* Разработка компонентов информационной системы для управления учебным процессом на основе компетентностного подхода // Информатизация образования и науки. 2011. Вып. 4. С. 14 - 28. URL: https://elibrary.ru/item.asp?id=17280936 (дата обращения: 26.09.2018).

[10] *Найханова Д.В., Дамбаева С.В.* Методы и алгоритмы принятия решений в управлении учебным процессом в условиях неопределенности. Улан-Удэ: ВСГТУ, 2004. 163 с. URL: https://elibrary.ru/item.asp?id=19931740 (дата обращения: 26.09.2018).

[11] *Лавлинская О.Ю., Курченкова Т.В.* Модели принятия решений в задаче синтеза учебного плана // Вестник Воронежского института МВД России. 2009. № 1. С. 136-143. URL: https://elibrary.ru/item.asp?id=11780755 (дата обращения: 26.09.2018).

[12] *Sedelmaier Y., Landes D.* Evaluating didactical approaches based upon students' competences // Proceedings of 2016 IEEE Global Engineering Education Conference (EDUCON). Abu Dhabi, 2016. Pp. 527-536. DOI: 10.1109/EDUCON.2016.7474603

[13] *Pérez J., Vizcarro C., García J., Bermúdez A., Cobos R.* Development of Procedures to Assess Problem-Solving Competence in Computing Engineering // IEEE Transactions on Education. 2017. Vol. 60, issue 1. Pp. 22-28. DOI: 10.1109/TE.2016.2582736

[14] *Керносов М.А., Михнова А.В., Имшенецкий Д.А.* Гибкая множественная модель учебного плана в подсистеме планирования и контроля учебного процесса ИАС вуза // Математическое и компьютерное моделирование. 2013. Вып. 1. С. 66-71. URL: https://elibrary.ru/item.asp?id=19397460& (дата обращения: 26.09.2018).

[15] *Сухомлин В.А., Зубарева Е.В.* Куррикулумная стандартизация ИТ-образования на современном этапе // CEUR Workshop Proceedings. 2016. Т. 1761. С. 40-46. URL: http://ceur-ws.org/Vol-1761/paper04.pdf (дата обращения: 26.09.2018).

[16] Проектирование основных образовательных программ вуза при реализации уровневой подготовки кадров на основе федеральных государственных образовательных стандартов / Под ред. С.В. Коршунова. М.: МИПК МГТУ им. Н.Э. Баумана, 2010. 212 с.

[17] *Курилова О.Л.* Применение генетического алгоритма для оптимизации учебного плана // Информационно-управляющие системы. 2013. Вып.3. С. 84-92. URL: https://elibrary.ru/item.asp?id=19082719 (дата обращения: 26.09.2018).

[18] *Пугачев В.М., Газенаур Е.Г.* Роль информационных технологий в науке и образовании // Вестник Кемеровского государственного университета. 2009. № 3. С. 31-35. URL: https://elibrary.ru/item.asp?id=13979272 (дата обращения: 26.09.2018).

[19] *Фридман О.В.* Анализ программных продуктов для автоматизации формирования учебного плана вуза // Труды Кольского научного центра РАН. 2015. № 3(29). С. 162-175. URL: https://elibrary.ru/item.asp?id=25794485 (дата обращения: 26.09.2018).

[20] *Харитонов И.М.* Алгоритм формирования учебного плана с применением методики формализованного представления учебной дисциплины (на примере дисциплины «Моделирование систем») // Вестник Астраханского государственного технического университета. Серия: Управление, вычислительная техника и информатика. 2011. № 2. С. 178-185. URL: https://elibrary.ru/item.asp?id=16457508 (дата обращения: 26.09.2018).

[21] *Шишканова Т.А.* Разработка методики построения автоматизированной системы управления учебным процессом // Горный информационно-аналитический бюллетень (научно-технический журнал). 2011. Т. S6. С. 518-529. URL: https://elibrary.ru/item.asp?id=17253300 (дата обращения: 26.09.2018).

[22] *Зыкина А.В., Канева О.Н., Крейдунова В.В.* Оптимизация системы управления учебным процессом в вузе // CEUR Workshop Proceedings. 2016. Т. 1761. Pp. 64-72. URL: http://

ceur-ws.org/Vol-1761/paper08.pdf (дата обращения: 26.09.2018).

[23] *Зеер Э.Ф.* Компетентностный подход к образованию // Образование и наука. Известия УРО РАО. 2005. № 3. С. 27-40. URL: https://elibrary.ru/item.asp?id=11530521 (дата обращения: 26.09.2018).

[24] *Зыкина А.В., Канева О.Н., Муньков В.В.* Алгоритм определения профиля основной образовательной программы высшего образования вузе // Информационный бюллетень Омского научно-образовательного центра ОмГТУ и ИМ СО РАН в области математики и информатики. 2018. Т. 2, № 1. С. 74-77. URL: https://elibrary.ru/item.asp?id=35449425 (дата обращения: 26.09.2018).

[25] *Канева О.Н., Акимова К.А., Шарун И.В.* Разработка алгоритма нахождения семантической близости между компетенциями // Информационный бюллетень Омского научно-образовательного центра ОмГТУ и ИМ СО РАН в области математики и информатики. 2017. Т. 1, № 1. С. 155-156. URL: https://elibrary.ru/item.asp?id=29860560 (дата обращения: 26.09.2018).

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