INFORMATION TECHNOLOGIES OF FORMATION OF THE CONTENT OF DISCIPLINES AND OPTIMIZATION OF THE CURRICULUM OF THE SPECIALTY

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Abstract. The main purpose of the higher education system is the professional training of highly qualified specialists in accordance with the social order. Therefore, it is the professional activity of specialists that sets and defines the goals of studying all academic disciplines, and hence the content, structure and forms of the corresponding educational activities of students preparing for future professional work. In this context, of great importance is the formation of a variable part of the curriculum specialty. The variable part provides an opportunity to expand and (or) deepen the knowledge and skills determined by the content of the basic disciplines, allows the student to gain in-depth knowledge and skills for successful professional activity and (or) to continue professional education in the master's degree. The disciplines of the variable part of the curriculum of the specialty must meet a number of indicators: the importance of the discipline in the system of training of specialists in this profile; the content of the discipline material (scientific level, depth of presentation); methodical level of presentation (logic of material placement, clarity of presentation) and others.

Since Universities and experts of this profile of professional activity are scattered throughout Ukraine and it is not always possible to collect them in one place, proposed to use the Internet survey system to collect the necessary expert assessments with their subsequent processing.

The article proposes an approach to the formation of the content of academic disciplines of the University using a systematic approach that reflects the main didactic indicators of the educational process. The proposed approach to the formation and optimization of the variable part of the curriculum of the specialty is universal to solve such problems in various fields of human activity. There are no restrictions on the number of experts, indicators of the quality of the studied objects. The main problem is the multi-criteria nature. When a small number of criteria, this problem solved on the paired dominance of the criteria as shown in this article. With a large number of criteria proposed to use a linear convolution. At the same time, the use of the Internet survey system allows you to connect a wide range of experts to increase the confidence probability of the optimality of the results.

Keywords: *optimization, training plan, Internet survey, expert estimations, linear convolution, the Pareto set.*

Problem statement. The education system in Ukraine has entered a period of fundamental changes, characterized by a new understanding of the goals and values of education, awareness of the need to move to the widespread use of computer technology for the formation of the material of academic disciplines of the University.

According to the national program "Education Ukraine of XXI century" the main goal of the higher education system is the professional training of highly qualified specialists in accordance with the social order. Therefore, it is the professional activity of specialists that sets and defines the goals of studying all academic disciplines, and hence the content, structure and forms of the corresponding educational activities of students preparing for future professional work. That is why research aimed at the study of professional activity and the development of a "portrait" of a specialist of a particular profile are now of particular importance. The practical result of such studies was the creation of qualification characteristics of specialists with higher education. The characteristics describe the main activities of the specialist, his functional responsibilities, the requirements for his training. Preparation of qualification characteristics is an important step in solving the problem of formulating the goals of training and determining the content of his professional activity

In this context, of great importance is the problem of formation informative content of academic disciplines in the field of selected specialties. Currently, there are many works devoted to the study of this problem, in particular [1-3]. However, due to the specifics of the subjects studied, most of them are highly specialized. Nevertheless, it is possible to approach the formation of the content of academic disciplines of the University from a single system positions, reflecting the main didactic indicators of the educational process. In this sense, it is necessary to create universal targets for different subjects, forms of presentation of theoretical material and models of its assimilation, a system of criteria for objective control and evaluation of knowledge of the student. This paper proposes one of the solutions to this problem.

In addition, it is important to optimize the curriculum of the specialty. This gives the opportunity to expand and (or) deepen the knowledge, skills and abilities determined by the content of the basic disciplines, allows the student to gain in-depth knowledge and skills for successful professional activity and (or) to continue professional education in the master's degree. The disciplines of the curriculum of the specialty must meet a number of indicators, such as: the importance of discipline in the system of training of specialists in this profile; content of the discipline material (scientific level, depth of presentation); methodical level of presentation (logic of material placement, clarity of presentation) and others.

The most preferable method for the formation and optimization of such a plan is the method of expert assessments [5]. In this case, the optimal qualitative composition of disciplines curriculum will be the result of collective work of experts in the field of future activities of students of this specialty, and specialists of higher education with high competence in relation to the selected indicators of quality of academic disciplines

Since Universities and experts of this profile of professional activity is scattered throughout Ukraine and it is not always possible to collect them in one place, it is proposed

to use the Internet survey system to collect the necessary expert assessments with their subsequent processing by the method proposed below.

Form of presentation and model of learning. There are four forms of presentation of educational material corresponding to different levels of abstraction in the description:

- Phenomenological (descriptive) level;
- Analytical and logical level;
- Mathematical level;
- Axiomatic level.

The form of presentation of educational material depends on the specific subject area. However, for any of the above forms, a universal model for the development of educational material is proposed. This model of educational material shows the sequence of the study of all topics and the logical links between them [4].

At the initial stage of designing the training course, the training material planned for study divided into separate training elements.

In the model included the relationship matrix of the sequence and logical relationships of the educational elements, the sequence of learning topics, count logical links of training elements.

The construction of the model carried out in four stages:

- Formation of the matrix of priority relations of educational elements;
- Building a sequence of learning elements of educational content
- Formation of the matrix of logical connections of educational elements;
- Construction of a graph of logical connections of educational elements.

The size of the square matrix of relations of sequence and logical relations of elements equals to the number of training elements. First, empty matrices are constructed, and their rows and columns numbered according to the number of training elements (see Fig. 1 and Fig. 2). Then the matrix cells filled with zeros and ones row by row.

	1	2	3	4	5	6	7	8	9	10	Σ
1	1	1	1	1	1	1	1	1	1	1	10
2	0	1	0	0	1	1	1	1	1	1	7
3	0	1	1	0	1	1	1	1	1	1	8
4	0	1	1	1	1	1	1	1	1	1	9
5	0	0	0	0	1	0	1	1	1	1	5
6	0	0	0	0	1	1	1	1	1	1	6
7	0	0	0	0	0	0	1	0	0	0	1
8	0	0	0	0	0	0	1	1	0	0	2
9	0	0	0	0	0	0	1	1	1	0	3
10	0	0	0	0	0	0	0	1	1	1	3

Fig. 1. Relationship matrix of the sequence of training elements

	1	2	3	4	5	6	7	8	9	10
1	0	1	1	1	0	0	0	0	0	0
2	0	0	0	0	1	1	0	0	0	0
3	0	1	0	0	1	1	0	0	0	0
4	0	1	1	0	0	1	0	0	1	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	1	0	1	1	1	1
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	1	0	0	0
10	0	0	0	0	0	0	1	0	0	0

Fig. 2. Matrix of logical connections of educational elements

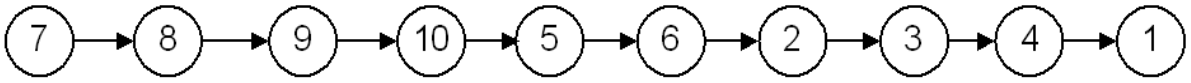

Fig. 3. Sequence of learning elements

When filling in the cells of the matrix, the sequence relationships analyze the sequence relationship between the two training elements. The unit put in the cell if the training element specified in the row number studied after the training element specified in the column number. The opposite relation of precedence denoted by zero. All cells of the main diagonal of the matrix of sequence relations filled with units. Matrix cells that are symmetric about the main diagonal must have opposite values. Therefore, the analysis of the pair sequence relations carried out only for the lower left or for the upper right triangle of the matrix, filling its remaining part on the anti-symmetry property. When filling in the matrix of logical connections we must put the unit in a cell, if the educational topic specified in the row number logically linked with the educational topic in column number. Drawing up a matrix of logical relations is convenient to conduct on the basis of the matrix of priority relations by excluding units from those cells for which there are no logical, reference links between the elements (Fig.1, Fig.2). The process of filling in the matrices is advisable to conduct, having before the eyes of the texts with educational material for all educational elements. The analysis of the content of the educational material allows reveal more objectively the pair relations of priority and logical connections between educational elements.

Not only objective but also subjective factors of the experts have an impact on the form of matrices of priority relations and logical connections, and, consequently, on the form of presentation of educational material.

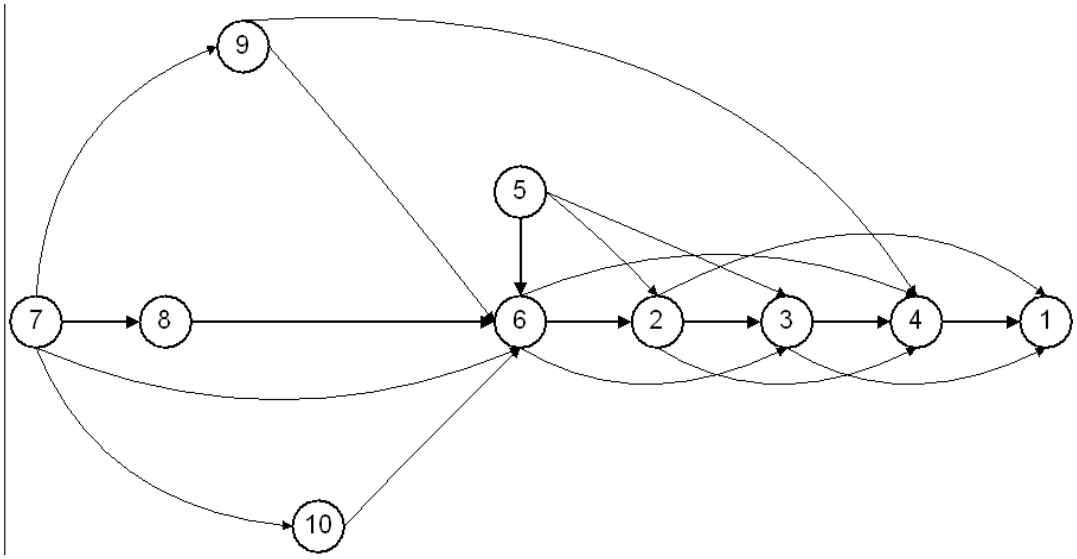

Fig. 4. Graph of logical connections

The sequence of studying the elements in the training procedure is determined in the process of processing the matrix of priority relations, summing up the coefficients of each row of the matrix. The totals recorded in the column to the right of the matrix (Fig.1). The values of the sums indicate the sequence numbers of the corresponding training elements in the list of the sequence of study of the training material (Fig.1, in Fig.3). Logical connections of educational elements displayed for clarity in the form of a directed graph (Fig. 4). A graph builds on the matrix of logical connections of educational elements.

The edges of the graph logical connections indicate the reference links between the educational elements. For example, the link between of a training element 2 and training

elements 5 and 6 (Fig.4), shows that in order to master the content of the training material from the training element 2, it is necessary to first study the material of the training elements 5 and 6. The model of development of the educational material determines the sequence of its presentation in the learning system, variants of the trajectories of its study, logical connections in the construction of hypertext. The complete graph of logical connections constructed similarly to the complete matrix of logical connections.

Optimization of curricula of specialties. Let there be N academic disciplines offered for inclusion in the curriculum of the specialty, M - the number of experts interviewed via the Internet, a specific discipline (training course) will be designated through k_i ($i = \overline{1, N}$).

We must select L disciplines ($L < N$) that meet the selected quality indicators J_k ($L < N$).

By the Internet survey system enters the experts 'assessments in the table of academic disciplines' grade grades (table. 1).

Here r_{ij}^k - rank (assessment) of the i-th discipline (*i*=1, . .,N) of j-th expert (*j*=1,…,M) by k-th quality indicator (k=1,...Q). The rank is a natural number in the accepted score scale.

Table 1

Assessments of experts

Quality indicator	J_1				…	J_Q			
Discipline / Expert	k_1	…	…	k_N	…	k_1	k_2	…	k_N
$Э_1$	r_{11}^1	…	…	r_{1N}^1	…	r_{11}^Q	r_{12}^Q	…	r_{1N}^Q
$Э_2$	r_{21}^1	…	…	r_{2N}^1	…	r_{21}^Q	r_{22}^Q	…	r_{2N}^Q
…	…	…	…	…	…	…	…	…	…
$Э_M$	r_{M1}^1	…	…	r_{MN}^1	…	r_{M1}^Q	r_{M2}^Q	…	r_{MN}^Q
The sum of the ranks	$\sum_1^1$	…	…	$\sum_N^1$	…	$\sum_1^Q$.	$\sum_2^Q$	…	$\sum_N^Q$
Average rank	$\overline{r}_1^1$	…	…	$\overline{r}_N^1$	…	$\overline{r}_1^Q$	$\overline{r}_2^Q$	…	$\overline{r}_N^Q$

The sum of ranks and the average rank are determined according to the formulas:

$$\sum_i^k = \sum_{j=1}^M r_{ij}^k \quad . \tag{1}$$

$$r_j^k = \frac{1}{M} \sum\nolimits_j^k \quad . \tag{2}$$

Without losing the generality of the result, let us assume that we have 7 academic disciplines, which as a result of ranking the experts ' assessments on the indicators of the content of the material (J_1) and the methodological level of presentation (J_2) formed the following system of inequalities relative to the average rank of the discipline:

$$J_1 : k_6 > k_1 > k_2 > k_3 > k_7 > k_5 > k_4 . \quad (3)$$

$$J_2 : k_6 > k_2 > k_1 > k_7 > k_3 > k_5 > k_4 . \quad (4)$$

The meaning of inequalities (3) and (4) lies in the pair preferences of one discipline in relation to another within the chosen quality indicator.

It known that the correctness of the expert estimates obtained during the processing depends on the consistency of the expert group. To assess the consistency of the experts, we calculate the variance coefficient of concordance for the selected quality indicators [6]:

$$W^k = \frac{12S^k}{M^2(N^3 - N) - M\sum_{j=1}^{M} T_j^k} . \quad (5)$$

where

$$S^k = \sum_{i=1}^{N}(\sum_{j=1}^{M} r_{ij}^k - r_0^k) . \quad (6)$$

r_0^k - the average rank score on the k-th indicator

$$r_0^k = \frac{1}{N}\sum \bar{r}_i^k . \quad (7)$$

T_j^k – the index of related ranks in the ranking of the j-th expert, which is defined as:

$$T_j^k = \sum_{p=1}^{H_j}(h_p^3 - h_p) . \quad (8)$$

where: $\mathrm{H_j}$ - number of groups of equal ranks of the j-th expert; $\mathrm{h_p}$ - the number of equal ranks in the p-th group of related ranks when ranked by the j-th expert.

If $\overline{\mathrm{W}}^{\mathrm{k}} \geq 0.7$ the expert group considered to be working in a coordinated manner. Otherwise, the group of experts must restructure.

In addition, it is useful to distinguish between experts by the degree of competence and the importance of their views, i.e. it is necessary to rank the experts themselves. When ranking, each of them is assigned a rank of significance from 1 (the most influential expert) to M (the least influential expert). The opinion of each expert is taken in the calculations with a coefficient proportional to1/m_j, where m_j - the rank of the j-th expert ($j = \overline{1, M}$).

To assess the relationship of ranked disciplines of training courses, we calculate the Spearman rank correlation coefficient [7]:

$$\rho = 1 - \frac{6S}{N^3 - N}. \quad (9)$$

If the value is close to one, it characterizes the linear average relationship between the rankings on the indicators under consideration.

For the two indicators considered in our case, this suggests that the disciplines that have received a high assessment of the content, are highly rated on the methodological level.

Then we perform the ordering of subjects on two quality indicators, the highlighting from the inequalities (3) and (4) consistently dominating subset of (Pareto set). For clarity, we give a graphical interpretation of this approach. For ratios (3) and (4) in Fig. 5 academic disciplines are presented according to table. 1. with a central point, the coordinates of which are determined by the place of the discipline among the disciplines under consideration, according to its average rank.

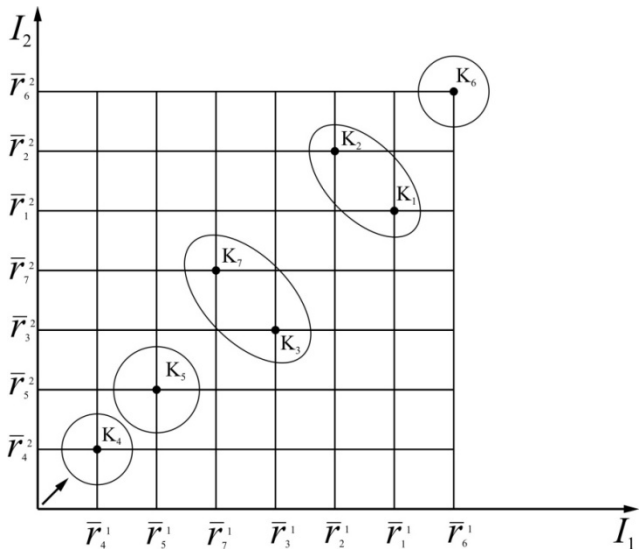

Fig. 5. Graphic interpretation of rank correlation of academic disciplines

Assume that the quality indicators J_1 and J_2 are equal, i.e. the total quality indicator is defined as:

$$J = J_1 + J_2. \quad (10)$$

In this case, the vector of change $\overline{J}$ in the quality index passes at an angle 45^0 (Fig. 5). Then, as can be seen from fig. 5, the Pareto set for the whole set of disciplines includes only one discipline k_6. Excluding discipline from consideration, we again highlight the set of Pareto, which includes two discipline each of these is more effective than any other in both respects, but they are incomparable, because for J_1 $k_1 > k_2$, but for J_2 $k_2 > k_1$.

Continuing this procedure, we get the following chain of preferences of academic disciplines:

$$k_6 > (k_1 k_2) > (k_3 k_7) > k_5 > k_4. \quad (11)$$

Hence, if, for example, we need to choose 5 out of 7 academic disciplines, the disciplines k_5 and k_4 excluded from consideration. If you need to select 4 courses, in addition k_5 and k_4 , we must exclude one of the k_3 or k_7 that can be done by the introduction of an additional indicator. It should note that with this approach, with a large number of indicators and disciplines, the task of forming the optimal variable part of the curriculum of the specialty is significantly complicated, which is associated with the analysis of the hyperspace of quality criteria.

In the case of a multi-purpose problem, it is necessary to find a solution that belongs to the intersection of sets of optimal solutions to all one-objective problems. However, this intersection is usually an empty set, so we should consider the so-called negotiating set of effective solutions (Pareto optimality). The optimality criterion of the Italian economist V. Pareto used in solving such problems, when optimization means improvement of some indicators, that others do not get worse.

We can distinguish the following main methods for solving multi-criteria optimization problems:

1) Optimization by one criterion, which recognized as the most important, while other criteria play the role of additional restrictions;

2) Convolution of many criteria to one by introducing expert weights for each criterion in such a way that the more important criterion gains higher weight;

3) Ordering of a given set of criteria and sequential optimization for each of them (this approach is the basis of the method of successive concessions) [8].

The most common of these methods is the second method, which uses a linear convolution of criteria at each level of the hierarchy. In our case, we can distinguish two levels of hierarchy. At the lower level is formed on the basis of table 1 criterion of assessment by experts of the i-th discipline on the k-th criterion. Let's denote it as E_{ik}. Table 1 shows, what $E_{ik}= \overline{r_i^k}$. Then the criterion of the upper level for the evaluation of the i-th discipline on the set of criteria of the lower level will have the form:

$$J_i = \sum_{k=1}^{Q} \lambda_{ik} E_{ik} . \qquad (12)$$

where λ_{ik} –weight coefficients of importance of the k-th criterion in the evaluation of the i-th discipline, which from table 1 are defined as

$$\lambda_{ik} = \frac{(\sum_{k=1}^{Q} \overline{r_i^k})}{(\sum_{i=1}^{N}\sum_{k=1}^{Q} r_i^k)} . \qquad (13)$$

with

$$\sum_{k=1}^{Q} \lambda_{ik} = 1, \lambda_{ik} \geq 0 . \qquad (14)$$

Taking into account the integer ranking of criteria, which leads to a large range of estimates spread, it is proposed to use a convolution of the relative values of the criteria of i-th disciplines relative to their maximum and minimum values for a more accurate assessment [7,9]. The convolution method consists in solving the problem of minimization of a linear combination with non-negative weighting coefficients denoting the importance of the k-th criterion and satisfying the condition (13):

$$j_i = \sum_{k=1}^{Q} \lambda_{ik} \frac{(E_{ik\max} - E_{ik})}{(E_{ik\max} - E_{ik\min})}. \quad (15)$$

Further, according to the obtained (12) values of the upper level criteria, we rank the list of disciplines in descending order and select the specified number of disciplines in the variable part of the curriculum of the specialty.

Conclusion. This article propose to approach the formation of the content of academic disciplines of the University with a single system positions, reflecting the main didactic indicators of the educational process. In this sense, it is necessary to create universal targets for different subjects, forms of presentation of theoretical material and models of its assimilation, a system of criteria for objective control and evaluation of knowledge of the student. The paper propose a universal approach to optimizing the curriculum of the specialty, based on the methods of expert assessments, and which can be used to solve such problems in various fields of human activity. At the same time, there are no restrictions on the number of experts, quality indicators and studied objects. The main problem is the multicriteria nature of the problem solved. With a small number of criteria solved on the pair dominance criteria as shown in this article. With a large number of criteria proposed to use a linear convolution. At the same time, the use of the Internet survey system allows you to connect a wide range of experts to increase the confidence probability of the optimality of the results.

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ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ ФОРМУВАННЯ КОНТЕНТУ НАВЧАЛЬНИХ ДИСЦИПЛИН І ОПТИМІЗАЦІЇ НАВЧАЛЬНОГО ПЛАНУ СПЕЦІАЛЬНОСТІ

Анотація. Основною метою системи вищої освіти є професійна підготовка фахівців вищої кваліфікації в відповідності з соціальним замовленням. Тому, саме професійна діяльність фахівців задає і визначає цілі вивчення всіх навчальних дисциплін, а значить і зміст, структуру і форми відповідної навчальної діяльності студентів, які готуються до майбутньої професійної роботи. У цьому контексті велике значення набуває формування варіативної частини навчального плану спеціальності. Варіативна частина дає можливість розширення та (або) поглиблення знань, умінь і навичок, визначених змістом базових дисциплін, дозволяє студенту отримати поглиблені знання і навички для успішної професійної діяльності та(або) для продовження професійної освіти в магістратурі. Дисципліни варіативної частини навчального плану спеціальності повинні відповідати цілому ряду показників, таких як: важливість дисципліни в системі підготовки фахівців даного профілю; змістовність матеріалу дисципліни (науковий рівень, глибина викладу); методичний рівень викладу (логіка розміщення матеріалу, ясність викладу) та інші.

Оскільки Вузи, де є дана спеціальність, і фахівці-експерти даного профілю професійної діяльності розкидані по всій Україні і не завжди є можливість зібрати їх в одному місці, пропонується використовувати систему Інтернет-опитування для збору необхідних експертних оцінок з наступною їх обробкою.

У статті пропонується підхід до формування контенту навчальних дисциплін вузу з єдиних системних позицій, що відображають основні дидактичні показники навчального процесу. Запропонований підхід до формування та оптимізації варіативної частини навчального плану спеціальності носить універсальний характер і може бути використаний для вирішення подібних завдань в різних сферах діяльності людини. При цьому немає обмежень на кількість експертів, показників якості та досліджуваних об'єктів. Головна проблема полягає в багатокритеріальності розв'язуваної задачі. При невеликому числі критеріїв вона вирішується на основі парної домінантності критеріїв так, як це показано в даній статті. При великому числі критеріїв пропонується використовувати лінійну згортку. При цьому використання системи Інтернет-опитування дозволяє підключити широке коло фахівців-експертів для підвищення довірчої ймовірності оптимальності отриманих результатів.

Ключові слова: *оптимізація, навчальний план, Інтернет-опитування, експертні оцінки, лінійна згортка, множина Парето.*

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ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ ФОРМИРОВАНИЯ КОНТЕНТА УЧЕБНЫХ ДИСЦИПЛИН И ОПТИМИЗАЦИИ УЧЕБНОГО ПЛАНА СПЕЦИАЛЬНОСТИ

Аннотация. Основной целью системы высшего образования является профессиональная подготовка специалистов высшей квалификации в соответствии с социальным заказом. Поэтому, именно профессиональная деятельность специалистов задает и определяет цели изучения всех учебных дисциплин, а значит и содержание, и структуру, и формы соответствующей учебной деятельности студентов, готовящихся к будущей профессиональной работе. В этом контексте большое значение приобретает формирование вариативной части учебного плана специальности. Вариативная часть дает возможность расширения и (или) углубления знаний, умений и навыков, определяемых содержанием базовых дисциплин, позволяет обучающемуся получить углубленные знания и навыки для успешной профессиональной деятельности и(или) для продолжения профессионального образования в магистратуре. Дисциплины вариативной части учебного плана специальности должны отвечать целому ряду показателей, таких как: важность дисциплины в системе подготовки специалистов данного профиля; содержательность материала дисциплины (научный уровень, глубина изложения); методический уровень изложения (логика размещения материала, ясность изложения) и другие.

Поскольку ВУЗы, где есть данная специальность, и специалисты-эксперты данного профиля профессиональной деятельности разбросаны по всей Украине и не всегда есть возможность собрать их в одном месте, предлагается использовать систему Интернет-опроса для сбора необходимых экспертных оценок с последующей их обработкой.

В статье предлагается подход к формированию контента учебных дисциплин ВУЗа с единых системных позиций, отражающих основные дидактические показатели учебного процесса. Предложенный подход к формированию и оптимизации вариативной части учебного плана специальности носит универсальный характер и может быть использован для решения подобных задач в различных сферах деятельности человека. При этом нет ограничений на количество экспертов, показателей качества и исследуемых объектов. Главная проблема состоит в многокритериальности решаемой задачи. При небольшом числе критериев она решается на основе парной доминантности критериев так, как это показано в данной статье. При большом числе критериев предлагается использовать линейную свертку. При

этом использование системы Интернет-опроса позволяет подключить широкий круг специалистов-экспертов для повышения доверительной вероятности оптимальности полученных результатов.

Ключевые слова: *оптимизация, учебный план, Интернет-опрос, экспертные оценки, линейная свертка, множество Парето*

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