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Scientifically Grounded Determination of Physics Course Content for Technical Universities

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***Abstract*—The article suggests an approach to designing a physics course content meant for technical universities ensuring objectification of educational subject syllabus structure which is aimed at obtaining final educational results in a specific field of study. Logical matrix method and expert opinion survey method serve as instruments for the conducted research. The used methodology enables quantitative grounding for selection of learning materials which are most significant to students for successful adoption of professionally oriented disciplines and formation of universal and general professional competences of a graduate.**

Keywords—technical university, physics course, course content, logical matrix method, expert estimates.

I. Introduction

The quality of contemporary higher education is evaluated through professional competence which reflects an educational program graduate's capability of successful performance of professional activities, active adaptation for rapidly changing conditions, solving difficult issues that might arise and constant self-improvement.

Educational purposes are set by the Federal State Educational Standards (FSES) in the form of universal, general professional and professional competences. Successful formation of these competences and mastering of basic professional activities are largely associated with the increase of the fundamental physics knowledge level of physics students and bachelors.

II. Urgency of the Issue and Objectives Setting

Research results and experience of training in physics at technical universities allow for determination of the basic factors affecting the quality of physics education adversely:

– discrepancy between the level of applicants' knowledge of physics and mathematics and the admission requirements of the higher education system;

– physics course content poorly focused for successful adoption by the students of professionally oriented disciplines within a specific educational program which is even more significant given the reduction of class hours of physics.

A series of publications was devoted to the problem of improving the methods of physics teaching in higher education institutions, including technical universities, in particular researches on implementation of the principle of fundamental education in physics (G.A. Bordovskiy, A.D. Gladun, O.N. Golubeva, A.D. Sukhanov et al.) [1–3] and professional direction of physics education (A.E. Aizentson, I.A. Mamayeva, L.V. Maslennikova, E.B. Petrova et al.) [4]. However, there remain some issues that have not been sufficiently studied concerning designing of physics course syllabuses for bachelors of specific educational directions based on the methods of quantitative estimation of educational content elements significance, allowing for grounding of the corresponding level of their achievement. The urgency of this task becomes more acute given implementation of new-generation FSESs according to which the syllabus of educational disciplines blocks can be unified solely by approximate programs and determined by universities that develop and update professional educational programs themselves.The urgency of this task becomes more acute given implementation of new-generation FSESs according to which the content of educational disciplines blocks can be unified solely by approximate programs and determined by universities that develop and update professional educational programs themselves.

Thus, there is a necessity of scientifically grounded differentiation of content elements recommended by reference syllabuses of “Physics” educational discipline which are most significant for achieving the declared competences of a student and a graduate at a specific field of engineering training. Such differentiation presupposes analysis and selection of the most significant and necessary educational content sufficient for the students' achievement in professionally oriented disciplines and formation of professional competence of educational programs graduates.

III. Methodology and Results of the Research

As the leading idea of the conducted research meant to improve the quality of education in Physics at a technical university we take the following statement: the syllabus of the educational material and the achievement levels differentiated by the quantitative estimation of the syllabus elements significance should be more clearly and definitely oriented for successful adoption of principal disciplines of the educational program by the students and for formation of universal and professional competences of a graduate.

New integrative methods, models and technologies corresponding to the maximum to the existing conditions and situations can appear and be used for pedagogical purposes as a

result of synthesis of systematic and technological approaches [5]. Sharing this opinion, we have developed an approach to designing of a syllabus of training in physics meant for technical universities ensuring objectification of educational program structure which is aimed at consistency and achievement of final educational goals in a specific training field. The essence of this approach consists in the quantitatively grounded selection of the most significant and necessary educational materials sufficient for successful adoption of professionally oriented disciplines and formation of the declared competences of a graduate. The following procedures are implemented within the framework of this approach:

1. A reference educational program for a physics course for technical training fields is analyzed using the logical matrix method [6, 7]. We will explain this using the example of a matrix of logically linked elements of the physics course syllabus (see Fig. 1).

	1	2	3	4	5	6	…	17	18	19	20	21	…	44	45	F
1	•	1	1	1	1	1				1						0.27
2		•	1	1	1	1				1						0.25
3			•	1		1										0.05
4				•	1	1						1				0.31
5					•											0
6						•										0.03
…							…									…
17								•								0
18									•	1	1	1				0.18
19										•		1				0.07
20											•					0.04
21												•				0.08
…													…			…
44														•		0
45															•	0
RF		1	1	1	0.75	0.8	…	0.13	0.06	0.28	0.11	0.2	…	0.02	0.09	

Fig. 1. A fragment of the matrix of logically linked physics course syllabus elements.

The educational material is divided into topics, content elements, and a number is assigned to each of them as determined by the discipline topics studying sequence. The content elements numbering predetermines numbering of columns and rows of the logical matrix. Next, an expert puts figure "1" at the crosspoint of a column and a row (a_{ij} = 1, where i is a row number, j is a column number), if the topic cannot be perceived and adopted without the corresponding degree of understanding and adoption of the topic of the row, or figure "0" if there is no link between the topic of the row and that of the column. The elements of the main diagonal of the matrix (a_{ii}) are not determined as they reflect the logical dependence of the topic on itself.

After the matrix is filled in, the quantitative characteristics of the content elements significance are determined that allow for determination of the educational material which is the most significant for successful studying of physics.

Summed up, figures "1" of the matrix row show the degree of importance of such topic for adoption of the educational discipline content elements shown in the matrix columns. Given that understanding and the adoption degree of the topic in a matrix drawn for a specific and logically set discipline can only depend on the previously studied topics, quantitative reflection of a row topic significance is determined by the sum of all figures "1" of the row divided by the number of the rows following this row (n–i). We call this ratio "frequency" (F) of usage of the topic of this row:

$$\mathrm{F} = \frac{\sum_{i=1}^{n} a_{ij}}{n-i}.$$

For example, the frequency of usage of "Particle Dynamics. Newton's Laws" content element shown in the second row of the matrix makes 0.25 and indicates to a designer and a tutor its relatively high significance for the purpose of educational material adoption (the average frequency value is 0.1). This syllabus element, in particular, is fundamental for topics "Particles System Dynamics", "Law of Conservation of Momentum, Mechanical Energy", "Variable mass body movement", "Rigid Body Dynamics", "Magnetic Field Action on Charges and Currents" positioned in columns 3, 4, 5, 6 and 19 respectively.

The sum of figures "1" in a column determines the number of the content elements which are to be adopted for perception of the topic corresponding to this column of the matrix. In case of a logically set discipline matrix the quantitative characteristic is determined by dividing the sum of figures "1" by the number of the rows preceding the number of the column, i.e. by j–1, where j can vary from 2 to n – total number of content elements shown in the matrix:

$$\mathrm{RF} = \frac{\sum_{i=1}^{n} a_{ij}}{j-1}.$$

This value is called "reference frequency". This value determines the "cost" – expenses required for adequate perception and understanding of a column topic.

The obtained quantitative characteristics of the content elements significance allow for grounded determination of the educational material which is the most significant for successful studying of physics.

2. Interdisciplinary links of the physics course are set and fixed based on construction of matrices of logical links between physics and professionally oriented disciplines. As a result, physics content elements are determined which are fundamental for principal disciplines of the educational program.

3. Based on construction of matrices of logical links between content elements of physics and those of mathematics some educational elements of mathematics can be determined which are the most significant ones for perception and successful adoption of notions, principles and laws.

4. Opinion polls are conducted among the leading tutors of principal chairs of higher technical educational institutions and professional physicists. Based on the polls, expert estimates of significance of the fundamental content of the syllabus of the

course of physics are obtained for the purpose of professional and worldview studies.

The research results represent an objectified basis for design and improvement of educational programs for “Physics” discipline meant for specific fields of training for bachelors of engineering. Superposition of subsets of professionally oriented and fundamental topics of physics with the highest expert estimates, analysis of product spaces (with consideration of frequency values taken from logical matrices) make it possible to differentiate fundamental and application components of the educational content, that is to determine the set of educational elements which will work in respect of professionally oriented and worldview aspects.

IV. Conclusion

A distinctive feature of the educational content of physics selected according to the suggested approach is a quantitatively grounded combination of fundamental and professionally significant material therein alongside with maintaining logical integrity of a course. The obtained results enable:

– objectified differentiation of levels of educational content elements adoption, optimization of educational information volume compulsory for adoption during practical studies and students' individual work at the stage of designing educational programs for a course of Physics for specific directions of bachelors training;

– improvement of contents of study guides on physics and means of assessment of compliance of the knowledge level of students studying specific educational programs with educational standards requirements.

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