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Qualimetric Approach to Assessment Educational Achievements of Graduates

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ABSTRACT
Introduction. Socio-economic transformations in Russia and the urgent need to meet the inevitable new demands of society and employers in ensuring technological safety associated with human factors have given priority to the problem of increasing the degree of formation of professional competencies of university graduates. The personal professional level of university graduates is objectively a socially significant quality of its readiness for effective and flexible work in the conditions of technical, technological, environmental, economic, managerial and educational changes to ensure the achievement of the main goals of safe and sustainable development of society. There is an obvious need for the definition and justification of scientifically based organizational and pedagogical conditions for the qualimetric assessment of control and measuring materials for educational achievements of university graduates.
The goal is to present the results of a study of organizational and pedagogical conditions that contribute to increasing the reliability of the obtained results of test diagnostics of knowledge, skills and the degree of formation of professional competencies of university graduates.
Methodology and research methods. The work was carried out based on the provisions of modern approaches and models of qualimetric monitoring (V.G. Gorb, L.N. Davydova, N.F. Efremova, N.A. Kulemin, A.N. Mayorov, D.Sh. Matros, M.M. Potashnik, A.I. Pulbere, E.I. Sakharchuk, etc.) educational achievements of students of educational organizations. The main research methods were a theoretical analysis of materials published in the scientific literature on the problem of assessing the degree of formation among students, primarily practice-oriented professional competencies, their level structuring, as well as a generalization of the monitoring features of practice-oriented professional competencies of university graduates. The main sources of development of pedagogical tools for assessing the degree of formation of professional competencies of university graduates were the domestic experience of professional training of masters in the areas of training "Management (human capital management)" and "Professional training (by industry)."
Results. The conditions for conducting an expert assessment and modeling the degree of influence of such factors of pedagogical tests as their content S, representativeness of the structure R and latency L on the value of the "objectivity" of pedagogical tests are described.
Scientific novelty consists in a qualimetric assessment of the degree of influence of the factors of pedagogical tests S, R and L on the value of the "objectivity" of pedagogical tests using mathematical modeling by scientifically based application of objective statistical methods.
The practical significance lies in the fact that the need for a qualimetric approach is justified in providing a more accurate and adequate assessment of the professional training of university graduates in the face of overcoming the objective difficulties of continuous and rapidly occurring changes in all areas of society.
Keywords*: qualimetric approach, pedagogical testing, educational achievements, expert assessment, mathematical modeling*

1. INTRODUCTION

The socio-economic transformations taking place in Russia today, as a result of the transition to market relations, and the urgent need to satisfy the inevitably new demands of society, employers and university graduates themselves objectively put forward the number of priority issues in improving the quality of training for professional cadres with a higher degree of professional competencies in the field of safe and sustainable development [1–5]. An analysis of the conformity of the vocational training of graduates convincingly indicates not so much about the

insufficient, fragmented coverage of the subject area of the needs of the modern post-information society, but about the “chronic” lag behind its urgently needed needs [6–8], the requirements of professional standards in terms of degree of compliance professional competencies, the sixth level of the National Qualifications Framework of the Russian Federation [9–11]. The aforementioned is confirmed by the fact that the problem of ensuring safe and sustainable development by 70% is associated with the human factor [12] and unsatisfactory training of personnel for effective and flexible work under the conditions of technical, technological, environmental, economic, managerial and educational changes [13–16].

2. PROBLEM STATEMENT

The current situation of total digitalization of public processes actualizes the problem of developing innovative principles for the professional training of specialists. A methodically competent assessment of the degree of conformity of professional competencies is the key to an effective response to the requests of the public, employers and students themselves, for whom it is also important to know the criteria by which they will be evaluated their readiness for the profession as a whole, and for the qualitatively efficient performance of their work in a particular workplace, the ability to quickly respond to changes in different areas of public life. The problem is largely due to the objective need to develop innovative pedagogical tools for an objective quantitative assessment of the degree of conformity of the professional competencies of university graduates as a set of interconnected tools (methods, techniques, techniques and tools) of the pedagogical interaction of subjects and objects of the educational process [19-20]. Training based on the conceptual principles and methods of pedagogy, measurements, mathematical modeling and mathematical statistics of the qualimetric approach with widespread use of ICT allows you to study and analyze the influence of various factors on the learning process, choose the optimal strategies, teaching methods and methods of generating educational trajectories [1; 21-23]. In the light of this approach, the special importance of the qualimetric approach to assessing students 'educational achievements is updated by conceptual studies within the framework of the "Program for International Student Assessment (PISA)" [8] and the development of innovative methods of pedagogical control of the degree of compliance of graduates' professional competencies universities proposed by I.D. Stolbovoy and A.N. Danilov, D.G. Miroshin [24–26], O.F. Shikhova and Yu.A. Shikhov [27], M.V. Potapova [19].

3. MATERIALS AND METHODS

The research materials were modern approaches, algorithms and models of qualimetric monitoring (V.G. Gorb, L.N. Davydova, N.F. Efremova, N.A. Kulemin, A.N. Mayorov, D.Sh. Matros, M .M. Potashnik, A.I. Pulbere, E.I. Sakharchuk, etc.) educational achievements of students of educational organizations. The main research methods were the theoretical analysis of materials published in the scientific literature on the problem of assessing the degree of formation among students, first of all, practice-oriented professional competencies, their level structuring, as well as a generalization of the monitoring features of practice-oriented professional competencies of university graduates, since at present the first plan for employers is the ability to freely own potential candidates with different behaviors Skim the skills to successfully interact with others, including the ability to work in a virtual team, timely information processing and flexible response to changes in the environment, as well as those of their quality as a cross-cultural, transdisciplinary, and adaptive thinking [27-28].

The main sources of development of pedagogical tools for assessing the degree of formation of professional competencies of university graduates were the domestic experience of professional training of masters in the areas of training "Management (human capital management)" and "Professional training (by industry)"; theoretical concepts reflecting the current level of development of professional teacher education; practical experience in the formation of practice-oriented professional competencies of university graduates.

To achieve an objective assessment of the real preparedness of university graduates to the modern demands of society, employers and students themselves, it is not enough fragmentary and unsystematic monitoring of students' academic achievements, which prevents the activation of the most important educational sources for mastering professionalism and improving their subjective properties that are professionally significant. Obtaining complete and objective information for taking reasonable measures to improve the quality of education, aligning the level of professional education and the needs of the modern labor market largely depends on the correctness of expert estimates of the difficulty level of test tasks, their objectivity due to the use of weighting factors for each of the evaluated factors when using the method of prioritization in accordance with the necessary requirements for the content of tests for their high scientific validity and representativeness, first of all [29], as well as validity, latency, cognitiveness, discriminativity and, in general, reliability (determining the reproducibility of test results, their accuracy), the answers to which, in many cases, still abound with significant difficulties [30–31]. The main goal of the pedagogical measurement as an applied theory of scientific pedagogy [32] is to develop tests of objective control of the preparedness of students. According to the results of the study [33–35], qualitatively made, qualimetrically verified tests with pre-designed technologies of standardized procedures for conducting, processing and analyzing the results [36], unlike a set of control tasks, allow solving the problem of objectification of pedagogical measurements and, on this basis, improving modern education through the direct connection of

controlling methods and teaching aids with training and education [30]. Conclusions about the "magnitude of the measurement error" of the level of knowledge, skills, rationality of various testing systems (for example, SAT, ACT, APP), formats of test tasks "multiple choice", "free response", use of the conversion of "raw points" to "true" scores using the Item Response Theory models [37–38] can only be made on the basis of experimental data analyzed using objective mathematical and statistical methods.

4. THE RESULTS OF THE STUDY

Obtaining complete and objective information for taking reasonable measures to improve the quality of education, aligning the level of professional education and the needs of the labor market largely depends on the correctness of expert assessments of the difficulty level of test tasks, their generalizing indicator, called the "objectivity" of pedagogical tests [39]. The results of expert assessments, as the practice of recent decades shows, can be significantly improved by applying mathematical statistics and a systematic approach that implements, as V.M. Glushkova [40], the translation of a problem into a structured category, to the solution of which the apparatus of mathematical modeling and the selection of optimal solutions are scientifically based [41].

At the first stage of the research, eight experts, whose consensus was previously determined by calculating the Kendall concordance coefficient (multiple rank correlation W), were asked to rank the factors selected from literature based on the analysis of the opinions of researchers according to the degree of their influence on the value of objectivity of the pedagogical tests [37– 39], namely, such factors of pedagogical tests as their content S, representativeness of the structure R, and latency L [39]. As a result of applying the method of group expert assessment, which makes it possible to increase the level of objectivity of estimates and judgments of a certain number of expert experts (more than two) using the procedures of bringing individual opinions to a single, group, taking into account differences in the knowledge, competence and objectivity of experts with real leveling their "inequality" and statistical processing of the results of surveys of independent experts at extreme values of the "importance" coefficients ci, i = 1, 2, 3 factors S, R and L pedagogical tests, the values of the degree of their influence on the value of PT are obtained: $0,67 \le S \le 0,85$; $0,73 \le R \le 0,87$; $0,60 \le L \le 0,70$. At the same time, the final (group, collective) assessment was defined as the weighted average competence of expert preparedness:

$$Xi = qj\,X11 + qj\,X12 + qj\,X13 + \cdots . + qj\,Xij \quad (1)$$

where: Xi - the final group assessment of the ranking of the i-th factor of pedagogical tests;

Xij - an individual ranking ranking of the i-th factor of pedagogical tests by the j-th expert;

qj - competence, preparedness of the j-th expert.

It is convenient to write down the conditions of the planned experiment to identify the degree of influence of the S, R, and L factors on the indicator ò in the form of a fractional matrix 23-1 (Table 1), where the rows correspond to different experiments, and the columns correspond to the values of the statistical processing of the results of surveys of independent experts of three variable factors.

Table 1 Plan for fractional factorial experiment 2^{3-1} and the results of the study of the value of the indicator ò

Experience number	Content *S*		Representativeness of the structure *R*		Latency *L*		Values (õi), i = 1,2,3,4 for importance coefficient levels:		
	Coded value	Natural value	Coded value	Natural value	Coded value	Natural value	Lower (–1)	Middle (0)	Top (+1)
1	+1	0,85	+1	0,87	+1	0,70	0,900	0,876	0,852
2	+1	0,85	–1	0,73	–1	0,60	0,857	0,833	0,809
3	–1	0,67	–1	0,73	+1	0,70	0,783	0,744	0,706
4	–1	0,67	+1	0,87	–1	0,60	0,805	0,767	0,728

The coefficients of the mathematical model in the form of a linear equation for the regression of the exponent ò for various intervals of variation of the coefficients of "importance" of factors S, R and L (table 2) were statistically verified by the values of asymmetry (A), Wilcoxon and Cochren criteria with the calculation of confidence intervals. As a result, their adequacy and ability to use in the development, as well as testing, certification and implementation of pedagogical tests, are shown. The developed mathematical models based on clear formalized rules allow you to: a) minimize the error of the experiment by selecting and applying objective plans for the implementation of experiments; b) evaluate the influence of control factors.

To study the degree of influence of the factors of pedagogical tests S, R and L depending ò = ò (S, R, L), we used mathematical design of the experiment according to the type of Latin 4x4 square (table 3). Each of the three factors S, R and L was assigned at four (and not two, as before) levels, which is why planning is called by the type of Latin 4x4 square. The levels of variation of the S-factor of pedagogical tests (bi = 0.67; ..., 0.85) correspond to the rows of table 3, the columns correspond to the levels of the R-factor of the structure of the PT (ai = 0.73; ...; 0.88); The L-factor of pedagogical tests varied from ci = 0.59 to ci = 0.71 (in the cells of table 3). The final values ò of pedagogical tests are also presented in the cells of table 3: ò = 0.721; .... 0.855.

Table 2 Coefficients of the linear equation of regression of the exponent ò

Interval changes c_s	**The coefficients of the equation**				**Confidence interval $\pm\Delta d_i$, i = 1,2,3**
	d_0	d_1	d_2	d_3	
0,43 – 0,51	0,836	0,042	0,016	0,005	0,0018
0,51 – 0,59	0,805	0,005	0,016	0,005	0,0013
0,59 – 0,67	0,774	0,057	0,016	0,005	0,0015

Table 3 The plan and results of the study ò the type of Latin square 4x4

S(b_i)	**R(a_i)**				$\tilde{o}_j$	$\tilde{o}_k$ **at** c_i
	a_1 = 0,73	a_2 = 0,78	a_3 = 0,83	a_4 = 0,88		
b_1=0,67	c_1 = 0,59	c_2 = 0,63	c_3 = 0,67	c_4 = 0,71	0,745	c_1 = 0,59
	ò = 0,721	ò = 0,737	ò = 0,752	ò = 0,768		$\tilde{o}$ = 0,788
b_2=0,73	c_2 = 0,63	c_1 = 0,59	c_4 = 0,71	c_3 = 0,67	0,779	c_2 = 0,63
	ò = 0,758	ò = 0,766	ò = 0,789	ò = 0,801		$\tilde{o}$ = 0,792
b_3=0,79	c_3 = 0,67	c_4 = 0,71	c_1 = 0,59	c_2 = 0,63	0,811	c_3 = 0,67
	ò = 0,798	ò = 0,811	ò = 0,810	ò = 0,826		$\tilde{o}$ = 0,798
b_4=0,85	c_4 = 0,71	c_3 = 0,67	c_2 = 0,63	c_1 = 0,59	0,844	c_4 = 0,71
	ò = 0,832	ò = 0,840	ò = 0,847	ò = 0,855		$\tilde{o}$ = 0,800
$\tilde{o}_i$	0,777	0,789	0,800	0,813	ő =	0,795

The average values of the indicator ò of pedagogical tests calculated from the corresponding columns, equal to 0.777; ...; 0.813, reflect the degree of influence of the R-factor of the structure of pedagogical tests on the value of the indicator ò. By the values of j, as the result of calculating by rows, one can judge the degree of influence of the S-factor of pedagogical tests: $\tilde{\tilde{}}$ j, equal to 0.745; ...; 0.844. In the rightmost column are the values of the indicator ò for various latencies L of pedagogical tests: õk, equal to 0.788; ...; 0,800.

To conduct a variance analysis of the research results, a design scheme common to this type of planning was applied (table 4).

Table 4 Analysis of variance of the results of studies of ò in the framework of plan of a model experiment on the type of Latin square 4x4

Dispersion source	**Number of degrees of freedom**		**Sum of squares**		**Average square**	
	Formula	**Value**	**Formula**	**Value**	**Formula**	**Value**
Lines b - S content of pedagogical tests	n–1	3	$s_b^2 = s_2^2 - s_5^2$	0,681	$s_b^2/(n-1)$	0,227
Columns a - representativeness of the structure R of pedagogical tests	n–1	3	$s_a^2 = s_3^2 - s_5^2$	0,662	$s_a^2/(n-1)$	0,221
Letters C - Latency L Pedagogical Tests	n–1	3	$s_c^2 = s_5^2 - s_4^2$	0,660	$s_c^2/(n-1)$	0,220
Variance error	$(n-1)\cdot(n-2)$	6	$s^2_{ост}=s^2_{общ} - (s_a^2+s_b^2+s_c^2)$	0,221	$s^2_{ост}/(n-1)\cdot(n-2)$	0,037

In this case, the number of degrees of freedom is n = 4, since the variation of factors is carried out at four levels for each of the estimated factors: S, R and L = var. The calculation was reduced to the calculation of such quantities as: the sum of the squares of all experiments $s1^2$; the sum of the squares of the row totals divided by the number of elements in each row $s2^2$; the sum of the squares of the column totals divided by the number of elements in each column $s3^2$; the sum of the squares of the results of the successive summation of $s4^2$ for k = 1, 2, 3, 4, divided by the number of elements corresponding to each index and the correcting term $s5^2$; equal to the square of the total divided by the total number of experiments.
From comparing the mean square values according to the F-criterion, it follows that the S-factor of pedagogical tests has a greater influence on the value ò: FS = 0.227 / 0.037 = 6.16 > F critical. 0.05 (3; 6) = 4.76. Significantly, the influence of the R-factor of the structure of pedagogical tests should be recognized: FR = 0.221 / 0.037 = 6.00 and latency L of pedagogical tests: FL = 0.220 / 0.037 = 5.97. An analysis of the changes shows that it significantly increases with increasing values of the S-factor, while the influence of the R- and L-factors of pedagogical tests is less than the influence of the factor S more than 2.5 times for R and 15 times for L pedagogical tests. To obtain reliable results of the test control, first of all, attention should be paid to their content S in conjunction with the representativeness R of the structure of pedagogical tests: the most reliable results of the test control should be expected precisely when the pedagogical tests meet precisely the requirements for the completeness and weight of these parameters.

5. DISCUSSION AND CONCLUSION

Planning the test control of pedagogical tests significantly increases the reliability of the results of diagnosing knowledge, skills, and the degree of formation of students' professional competencies [42-50, etc.]. The revealed correlations of the factors of pedagogical tests S, R and L are the starting points for determining and scientific substantiation of the organizational and pedagogical conditions for the qualimetric assessment of the professional achievements of future specialists in the context of an environmentally and economically safe sphere of activity to ensure the achievement of the main goals of sustainable development of society.

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