З метою забезпечення достовірності результатів оцінювання та контролю якості продукції, послуг, процесів, знань та інших об'єктів запропоновано методику розрахунку невизначеності результатів вимірювання, здійснених експертними методами. Методику апробовано шляхом дослідження невизначеності експертних вимірювань у системі управління якістю вищої освіти. Сформовано рекомендації для нормування характеристик персоналу з оцінювання якості

Ключові слова: оцінювання невизначеності, результати експертних вимірювань, якість експертів, рекомендації для стандартизації

В целях обеспечения достоверности результатов оценивания и контроля качества продукции, услуг, процессов, знаний и других объектов предложена методика расчёта неопределённости результатов измерения, осуществлённых экспертными методами. Методика апробирована путём исследования неопределенности экспертных измерений в системе управления качеством высшего образования. Сформированы рекомендации для нормирования характеристик персонала по оцениванию качества

Ключевые слова: оценивание неопределённости, результаты экспертных измерений, качество экспертов, рекомендации для стандартизации

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A STUDY OF UNCERTAINTY OF EXPERT MEASUREMENT RESULTS IN THE QUALITY MANAGEMENT SYSTEM

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1. Introduction

The process of determining the quality indices (QIs) of products and services is accompanied with uncertainties provoked by different causes that can essentially affect the final assessment of the object quality. To secure a unified QI assessment, it is necessary to establish rigid requirements for the calculation accuracy of those indices that are often derived from application of expert methods.

The quantitative estimate of the measurement accuracy is an uncertainty of the measurement results. A well-established apparatus [1, 3] for calculating the QI measurement results is known to be widely used today. Particularly, as is mentioned in [2], "Due to the expanding range of the use of measuring data processing and the possibility of the use of new instruments and procedures, the problem of the assessment of the accuracy of the experimental determination of statistical characteristics (particularly, the arithmetic mean) of correlated data was and still remains topical." Besides, the methods of uncertainty evaluation are rapidly developing and adapting to specific computational tasks as in [3]: "This practical case shows an example of how a powerful tool can be metrology for engineers, not only for validation of models but also providing better knowledge of the parameters that have a greater influence on both the model and the experiment. The designer is thus aware of the aspects that can be improved to minimize the difference between the model and experiments or the limits he cannot surpass in using the model according to the design criteria." Nevertheless, many QIs are identified by applying expert measurement methods with appropriate peculiarities.

High reliability of the results of such measurements is a pledge of an effective functioning of the quality management system. Therefore, the development of a methodical apparatus to determine and assess uncertainty of expert measurements is of topical significance.

2. Analysis of previous studies and statement of the problem

There are no generally-adopted conventional recommendations for managing uncertainty of expert evaluations.

Some authors suggest evaluating separate properties of expert measurement, which could not be treated as an exhaustive estimate of its quality. One of the most widespread properties is a coefficient of an expert's opinion coordination [4, 5]. So the dominating criterion of expert group quality estimation is a degree of the reached consensus, which is the basis of important managerial decisions [6]. Other authors [7] find the main attributes of expert estimation in the "completeness and speed of its conduction as well as in actualization of partial statements and conclusions," which does not reflect all the components that influence the quality of expert evaluation.

Nowadays, expert systems that are based on experts' knowledge and experience are being developed [8], which again highlights the importance of accuracy (uncertainty measurement) of research results and such systems' functioning.

The fact that an expert quality assessment problem has not been tackled yet is obvious from the absence of a systematic approach to its solution. To identify the expert quality, above all, means to know the properties with which it is associated. In scientific literature [5, 9, 10], a limited number of quality options is given without regard to their stipulation and interaction. For example, in one study, competence, impartiality and objectivity stand for the main properties; the other studies recognize just one or two of them. As to the expert's competence per se, it is frequently defined as a reliability and rationale of the applied indices, or as some informative content and unfaltering judgement. In addition to those most frequently mentioned properties, it is also recommended to take into account the expert's participation interest, ability to operate a relationship scale as well as attention to a number of scaled gradations [11]. Results of expert measurement are often used not only for factual estimations but also for predicting certain phenomena. In the latter case, the prediction accuracy and estimation impartiality are determined with the help of statistical methods and regression analysis [12], whose classical usage is complicated with uncertainties. Therefore, when determining the estimates, the authors of studies [13–16] prefer to apply fuzzy mathematics, in particular, fuzzy regression models, which is just a partial solution to the problem of assuring the needed reliability and accuracy of expert research.

It is worth noticing that some scholars suggest estimating the accuracy of expert measurement by contrasting its results against those gained by other methods. So the author of [17] suggests comparing the findings of expert and sociological research of the same objects. In an emergency case, this approach can be implemented, but it does not reflect the impartial estimate of accuracy and uncertainty of expert measurement results.

Thus, absence of a method for assessing expert measurement quality and its results' uncertainty with regard to modern international requirements necessitates further research in this direction.

3. Research objectives and tasks

The intended objective is to work out a methodical approach to the application of the uncertainty concept [1] in assessing the quality of expert measurements. To reach this goal, the following tasks were set and solved:

– to analyze the sources of the expert measurement result uncertainty;

– to suggest methods of calculating the uncertainty of expert measurement results;

– to recommend and rationalize standards for determining the quality indices of experts' quality assessment;

– to test the suggested methods in estimating the uncertainty of the results of expert measurement of importance degrees of student activity components in a higher education institution for the purpose of assuring an efficient functioning of its quality management system.

4. Materials and methods of the research on uncertainty of expert measurement results

4. 1. An analytical study of the sources of uncertainty of expert measurement results

To stipulate the authorial methods of estimating the uncertainty of expert measurement results, an analytical study of its sources [4–11] has been primarily conducted to stratify the expert measurement process and to reveal the main reasons for any emerging uncertainty related to the experts' imperfection, an undue choice of their number, and the conditions of making the assessment (Fig. 1).

Expert imperfection. Based on the analysis of special literature [4–20] and on previous experience, there appears an opinion that expert quality indices should be classified into four groups: namely, competence, motivation, impartiality, and reliability (Fig. 2), following which an expert's imperfection degree that leads to uncertainty of an expert measurement result seems to be interpretable. For these indices, we have developed recommendations on how to choose the practices of their defining (Fig. 2). Expert's competence should be extended both to the object of quality assessment (professional competence) and the evaluation methodology (qualimetry competence).

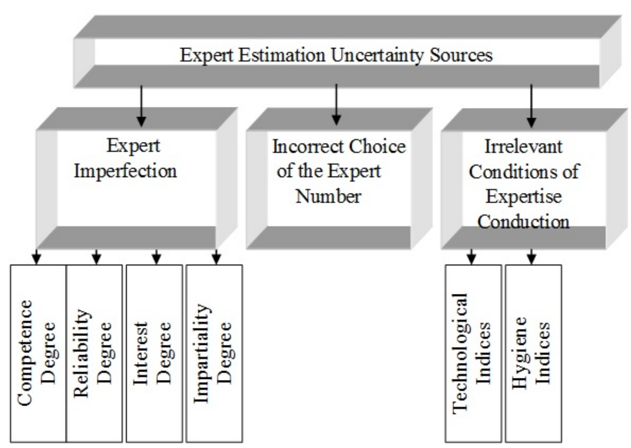

Fig. 1. Sources of expert measurement uncertainties

Professional competence covers knowledge of the following aspects: the evaluated object development history (alteration in its properties and quality indices); the object creation process (research, design, and manufacturing); the QI values of various object modifications, including the best analogues; development perspectives; scientific research results and patent materials leading to the improvement of quality properties and indices; and consumer needs, their conditions and nature.

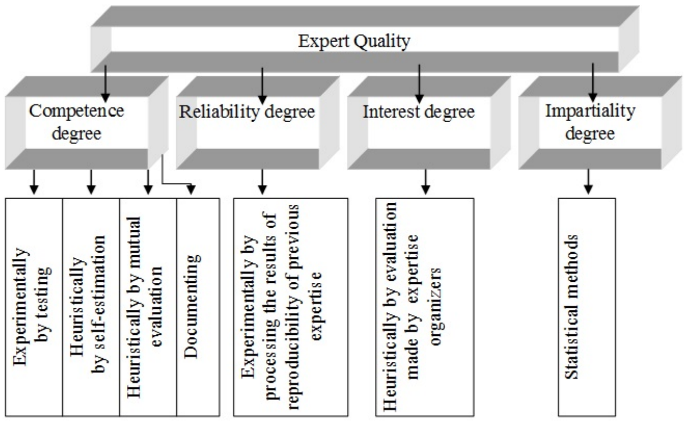

Fig. 2. Systems of expert QIs and methods of their defining

Qualimetry competence provides: the expert's clear understanding of the approach towards quality assessment; efficient use of quality assessment methods, especially those of expert nature; and abilities to apply different types of estimation scales while distinguishing between a number of gradations. Extra information necessary to improve qualimetry competence could be communicated to an expert in the process of the preparation work. However, a comparatively short term of the preparation stage complicates perception, which in its turn leads to a decrease in the expert's efficiency. The expert's interest in the assessment results depends on a number of factors: the degree of the expert's being overloaded with his or her main work, regularly combined with the mentioned assessment; the possibilities of using the obtained results; the assessment goals; the nature of conclusions possible on gaining quality assessment results; and the individual expert's peculiarities.

As to impartiality, it could be regarded as an ability to consider only information sufficient for evaluating the satisfaction of the needs for a product, service or process. Partiality of an expert consists in an overestimation or underestimation of the product quality on the basis of factors unrelated to quality itself, such as impossibility of resisting most experts' opinion due to the lack of self-confidence (conformism). Partiality of an expert could be revealed also in another situation. The matter is that expert evaluation refers to the type of a product (for example, weight coefficients and quality indices assessment) or to its concrete pattern (organoleptic estimation of aesthetic and ergonomic quality indices). Thus, partiality of an expert tends to be revealed mainly in the second case, during estimation of the real patterns – for instance, when an expert overestimates the aesthetical and ergonomic indices of a product manufactured by an enterprise with which the expert has certain dealings.

The expert's reliability degree is judged by the stability of his or her opinion. Therefore, its extent can be estimated through the reproducibility of the results on the same product quality estimation in time (during several rounds of evaluations made periodically).

Methods of the expert QI evaluation

There exist many methods among which we could discern the following:

– heuristic, in which estimates are made by a person (self-estimation, mutual experts' estimations, and estimations by assessment organizers); they are supposed to be used for identification of the experts' competence level and interest degree;

– experimental, in which estimates are obtained as a result of special experiments conducted by experts; it is expedient to consider them for identifying an expert's competence and reliability level;

– statistical, in which estimates result from elaboration of experts' opinions on the considered object as well as their comparison against an average expertise; they are supposed to be used for identifying an expert's impartiality degree;

– documental, in which estimates are based on the analysis of documental legends of experts; they could be used for identifying the experts' competence degree.

The regarded methods could be combined in different ways, and the resulting estimates might be pooled in while considering their weight. Moreover, it is possible to obtain a combined estimate C_{comb}.

Further, it seems to be relevant to study the methods of experts' QI identification in terms of their application correctness.

Heuristic evaluation is based on the formation of:

(a) a self-estimate (Q_{se}), when an expert independently evaluates his or her professional competence, i. e. the level of different sides of familiarity with the object, involving a questionnaire [21]. The degree of an expert's self-estimate C_{se} could be identified as a sum of the expert's self-estimation parameters, with considering their weight coefficients. Consequently, the degree of an expert group self-estimation could be determined as an average self-estimate of all group members;

(b) mutual estimates (Q_{mt}), when in order to decrease impartiality, the competence estimate of each expert C_{mt} could be determined as an average of grade points attributed by the other experts;

(c) the assessment organizers' estimates Q_{eo}, when the characteristic of an expert's interest in the assessment partaking and his or her concentration during an interview are provided in a quantified form. It is recommended to represent the parameter values C_{se}, C_{mt}, and C_{oe} on a 10-point scale.

Experimental estimates are gained as the results of special tests on the expert's proficiency:

(a) the expert's competence (Q_{ec}), when the level of theoretical knowledge and practical skills is determined;

(b) the expert's disposition to conformism, which can be determined by a «false group» method: the person passing a test and the group of some false experts who are in agreement with the experimenter are shown the same object of interest. The level of his or her proximity to the collective opinion characterizes the readiness to conformism. To simplify the expert's conformism level, we can use the expression:

$$C_{cl} = P_{indp} - P_{grp}, \quad (1)$$

where P_{indp} and P_{grp} are the respective numbers of the expert's mistakes during the independent judgement practice and those made collectively with the false group, and (c) the results reproducibility (Q_{rp}). The reproducibility estimation (on the 10-point scale) testifies to the reliability degree of a certain expert. It can be based on the Spearman coefficient of range correlation between two identical expert rounds (e. g., the weight coefficient ranging), reproduced by each j-th expert:

$$C_{(rp)j} = 10 \cdot r_j, \quad (2)$$

$$r_j = 1 - \frac{6\sum_{i=1}^{n} d_{ij}^2}{n^3 - n}, \quad (3)$$

where d_{ij} is a difference between the ranges attributed by the j-th expert (C_{expert} is the number of the experts) to the i-th weight coefficient (n is the number of the evaluated objects) in the first and the second questioning rounds.

Using the method of deviation from the average (one round of an expert assessment), the expression for the calculation of the r_j could be as follows:

$$r_j = \frac{1}{2} \cdot \sum_{i=1}^{n} \left[\bar{M}_i - M_{ij} \right], \quad (4)$$

where M_{ij} is a value of a weight coefficient for the i-th object, derived by the j-th expert; $\bar{M}_i$ is an average value of weight coefficients calculated on the basis of estimates of all the experts for the given object.

As compared to heuristic estimation, the method requires extra time for repeating interviews and extended calculation, but it seems to be more impartial.

Statistical estimation is based on evaluating the expert's opinion deviation from the average viewpoint of the group of experts and on the use of:

(a) a method of ranging the estimated values (calculation of a concordance coefficient, i.e. the experts' opinions coordination) (Q_{vr}), when the genuine value is an average expert's estimate. Correspondently, the lower the deviation value of an expert's individual opinion from the collective one, the larger the concordance index of the experts' opinions. The coefficient of the concordance W for the C_{expert} of experts is determined as:

$$W = \frac{\sum_{i=1}^{n} d_i^2}{\frac{1}{12}\left[C_{expert}^2 \cdot \left(n^3 - n\right) - C_{expert} \sum_{j=1}^{N} T_j \right]}, \quad (5)$$

here

$$d_i = S_i - \frac{\sum_{i=1}^{n} S_i}{n}, \quad S_i = \sum_{j=1}^{C_{expert}} R_{ij}, \quad T_j = \sum_{l=1}^{L} \left(t_l^3 - t_l\right),$$

where L is a quantity of groups of equal ranges; t_l is a quantity of related ranges in each group; the value R_{ij} denotes ranges suggested by each j-th expert for each i-th object.

Since $0 \le W \le 1$, then at W=0 among N experts there is no concord at all, and on the contrary: W=1 represents a complete agreement. The method requires considerable time spending to conduct the whole set of calculations, for example, in comparison with a priori heuristic estimation. While estimating the coordination of experts' thoughts, it is important to determine the extent to which each expert influences the generalized concordance of the group. For this purpose, one expert is taken gradually out of research, and a concordance coefficient is calculated without considering the excluded expert's thought. If during the deduction of an expert's opinion the W increases, it is viewed as a negative characteristic; if the W falls, the estimation seems to be positive. To convert the W_j into a 10-point system, it is recommended for any expert to accept that: if W_j=W, then W_j is equal to 5 points; if W_j –W=+max (the maximum of the positive values of the difference W_j–W), then for this expert W_j=5–5=0; if W_j –W=+min (the minimum of the positive values), then W_j= 5–1=4, and the intermediate values that are between +max and +min are calculated as proportional points;

(b) determination of the quantitative expression of the estimated values (Q_{qe}) based on the notion of a distance between the estimates. This method does not require considerable expenses;

(c) impartiality estimates (Q_{imp}), for which it is necessary to develop special methods of evaluating the experts' impartiality; however, estimates of a deviation from the average are also made in this respect.

Documental estimates (Q_{doc}) are based on the analysis of documental impartial data on expert characteristics and can be used in line with other methods of expert QI determination. Uncertainty in this case can be related to the partial availability of information on the expert's merits. $C_{(do)j}$ is a coefficient of a documental estimate of the j-th expert that could be evaluated as a sum of parameters of documental expert estimation with regard to weight coefficients. Then the degree of documental estimation of an expert group is determined as an average value of documental estimates of all experts in the group. Like in previous cases, it is expedient to use a 10-point scale.

The results of analyzing the methods of expert QI estimation are given in the table below, where the juxtaposition of the methods is conducted through the evaluating criteria of their advantages, disadvantages, and usability degree.

The data in Table 1 help make the right choice of the optimum methods of expert QI estimation while deducing a combined evaluation. In a general case, provided that all the expert QIs are considered, the combined quality index of a j-th expert could be represented according to the expression:

$$Q_j = \frac{Q_{sej} + Q_{mtj} + Q_{oej} + Q_{ecj} + Q_{rpj} + Q_{vrj} + Q_{qej} + Q_{impj} + Q_{docj}}{q}, \quad (6)$$

where q is the number of the components considered during calculating the combined quality index of the j-th expert.

Table 1

Comparison of the methods of expert QI assessment

Methods	Advantages	Disadvantages	Maximal application
Heuristic Q_{se}, Q_{mt}, and Q_{eo}	high technological indices of the method preparation and realization, in particular, low time and labour consumption as well as a substantial informative content	judgement impartiality	evaluation of an expert's competence and interest degree
Experimental Q_{ec} and Q_{rp}	a sufficient level of impartiality, i.e. lower uncertainty of an evaluation result, which could be estimated by a standard deviation	long-lasting realization and labour-consuming processing of the obtained results	evaluation of an expert's competence level and reliability
Statistical Q_{vr}, Q_{qe}, and Q_{imp}	high impartiality	high labour and time consumption for the preparation work and the method realization	evaluation of an expert's impartiality degree
Documental Q_{doc}	impartiality, substantiation, and a high technological realization of the method	the results of documental evaluation depend on an expert's competence field	an expert's competence evaluation

If any quality index component could be reflected in points (on a 10-point scale), then $1 \le Q_j \le 10$ (unless it is assumed that $Q = \sum_{j=1}^{C_{expert}} Q_j = 1$).

Wrong choice of the number of experts. To assess and eliminate uncertainty related to the incorrect choice of the number of experts, it is important to consider the statements of the probability theory (namely, the expression of an error confidence level) [22, 23] and represent the evaluation of the expert number C_{expert} at the given confidence probability P within the range of values inherent in metrology – namely, from 0.9 to 0.99 with the error Δ. Using the expression for calculating a confidence interval, the formula for calculating C_{expert}, which is a prototype of the number of observations, could be written as follows:

$$C_{expert} = \frac{t^2 \cdot S^2}{\Delta^2}, \tag{7}$$

where t is the Student's coefficient for the given confidence probability; S is the standard deviation in the quality assessment.

If S is unknown (for example, the assessment is made for the first time), the error Δ is supposed to be set prior to the evaluation as part of S by the following ratio:

$$\Delta_1 = \frac{\Delta}{S}. \tag{8}$$

Then expression 7 acquires the form of

$$C_{expert} = \frac{t^2}{\Delta_1^2}; \tag{9}$$

consequently,

$$\Delta_1 = \frac{t}{\sqrt{C_{expert}}}. \tag{10}$$

The values of the errors Δ_1, calculated according to (10) for a different number of experts C_{expert},, and the confidence probability of the expert estimation P are tabulated in Table 2. It seems obvious that starting from the number of experts equal to 7 the given estimation error Δ does not exceed S and constitutes its part. Thus, the minimum number of experts should not be less than 7.

Table 2

Error values $\pm\Delta_1$ for a different number of experts C_{expert} and the confidence probability of the expert estimation P

Number of experts / P, in %	2	3	4	5	7	10	15	20	30	40
90	4.50	1.75	1.80	1.00	0.73	0.58	0.45	0.39	0.31	0.26
95	8.98	2.48	1.59	1.24	0.93	0.71	0.55	0.47	0.37	0.31

Thus, the data given in Table 2 should be used for calculating a Type B uncertainty based on an insufficient number of experts; this value should be considered as a component of total standard uncertainty of a QI expert estimation result.

Conditions of assessment. Since special rooms are provided for a qualimetry assessment, their state and climate characteristics should comply with health and safety regulations. Thus, while making an expert assessment, the expert remains in conditions of limited motion ability within a closed space, which can result in unfavorable influences on the final estimate and thus provoke uncertainty due to the following factors:

– deviation from the normative characteristics of the microclimate in the working area;
– increased levels of noise and vibration;
– insufficient lighting of the working area;
– absence or lack of natural light;
– increased light brightness;
– increased or decreased air humidity;
– increased or decreased pressure;
– excessive use of labour and time.

4. 2. Methods of calculating the uncertainty of QI expert measurement results

To calculate uncertainty caused by the experts' quality and quantity, it is recommended to involve both uncertainty types – A and B. Particularly, a Type A uncertainty should be calculated through a standard deviation of the experts' estimates from the average both for equal-point (a prototype of convergence for equal-point observations in metrology) and unequal-point (a prototype of reproducibility for unequal-point observations in metrology) expert measurements. So an expert's estimate is regarded as a prototype of an observation result received through measuring.

Convergence of the experts' estimates in the case of a certain evaluated object could be calculated under condition that expert QIs are practically the same. Then the Type A uncertainty for the i-th evaluated object is calculated according to the formula:

$$u_{Ai} = \sqrt{\frac{\sum_{j=1}^{C_{expert}} (x_{ij} - \overline{x}_i)^2}{C_{expert} \cdot (C_{expert} - 1)}}, \tag{11}$$

where x_{ij} is a result of expert estimation, i. e. an estimate of a j-th expert for an i-th object; $\overline{x}_i$ is an average value of the expert's estimates of all C_{expert} experts for the i-th object.

Correspondently, the standard uncertainty of an expert group, evaluating a series of objects of the same designation, is calculated as follows:

$$u_A = \sqrt{\sum_{i=1}^{n} u_{Ai}^2}, \tag{12}$$

where n is the quantity of objects studied by an expert group.

Under the condition that combined expert QIs are not the same, we deal with unequal-point observations [24] for which the estimation of each expert has its own weight coefficient Q_j that is calculated according to expression (6). Then formula (11) is transformed into the expression:

$$u_{Ai} = \sqrt{\frac{\sum_{j=1}^{C_{expert}} (Q_j \cdot (x_{ij} - \overline{x}_i)^2)}{Q \cdot (C_{expert} - 1)}}, \tag{13}$$

where

$$\overline{x}_i = \frac{\sum_{j=1}^{C_{expert}} (Q_j \cdot x_i)}{Q} \text{ and } Q = \sum_{j=1}^{C_{expert}} Q_j, \tag{14}$$

where x_{ij} is a result of expert estimation, i. e. an estimate of the j-th expert for the i-th object; $\overline{x}_i$ is an average value of the expert's estimates of all C_{expert} experts for the i-th object; Q_j is a weight coefficient of the j-th expert.

For the parameters characterizing the conditions of making an assessment, there are standardized indices the deviation from which is a reason for the Type B uncertainty.

Thus, the total standard uncertainty of expert measurement u_c makes the following:

$$u_C = \sqrt{\sum_{i=1}^{n} u_{Bi}^2 + \sum_{j=1}^{m} u_{A_j}^2}. \tag{15}$$

Then the extended uncertainty U makes the following:

$$U = c \cdot u_C, \tag{16}$$

where c is a coverage coefficient for the given confidence probability P.

Based on the value of an extended uncertainty decision regarding the accuracy of expert research and the need for an additional study, the results of an uncertainty evaluation can be based on a comparison of several similar studies regarding their authenticity.

5. Results of the research of expert measurement uncertainty

The methods used for estimating the uncertainty of expert measurement results were tested to ensure efficient functioning of a quality management system in the higher education institution. The expert research was conducted on the significance degrees of components of such student activities as study combined with scientific, methodical, and social work as well as self-improvement. Such investigations in higher education institutions are necessary to modernize the processes of quality management in the spheres of educational services; therefore, it is very important to estimate the uncertainty of their evaluation results. A questionnaire was developed for this study, and 40 teachers were involved as experts in expert measurement. The results of the questionnaire processing reflect the rating of the importance of student activity components in points on a 10-point scale (Fig. 3).

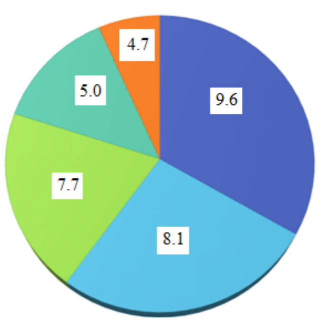

Fig. 3. The measured values of importance degrees of student activity components: 9.6 is study activity, 8.1 is self-improvement, 7.7 is scientific activity, 5.0 is methodical activity, and 4.7 is social activity

To calculate the absolute values of a standard uncertainty of this expert research (Table 4) according to the methods suggested in this study, the expert weight coefficients Q_j (Table 3) were calculated according to a 10-point scale. These coefficients were introduced into the formula for the calculation of the Type A standard uncertainty – (13) and (14). The weight coefficients were statistically determined while considering such components as: the degree of impartiality according to the concordance coefficient (5); the degree of confidence with regard to the reproducibility of expert evaluation in time, which was made in two rounds – (2) and (3); the degree of competence, defined by the documental method on the basis of objective data; and the degree of the expert's interest, established heuristically by the research organizers.

The relative values of the uncertainties in Tables 4, 5 were calculated by the division of the correspondent values of absolute uncertainties by the measured values of importance degrees of student activity components (Fig. 3); they are represented in percentage.

Table 3

Combined expert QIs (weight coefficients Q_j) and their components

Expert	The expert's impartiality degree, in points	The expert's reliability degree, in points	The expert's competence degree, in points	The expert's degree of interest, in points	A combined expert quality index, Q_j, in points
Expert 1	7.0	10.000	6.5	10.0	8.375
Expert 2	7.3	9.917	7.3	8.0	8.129
Expert 3	10.0	10.000	10.0	10.0	10.000
Expert 4	9.0	10.000	7.3	10.0	9.075
Expert 5	7.0	9.917	7.2	8.0	8.029
Expert 6	6.0	10.000	8.0	10.0	8.500
Expert 7	7.0	9.917	6.3	8.0	7.804
Expert 8	9.0	9.917	6.5	8.0	8.354
Expert 9	6.0	9.75	9.2	6.0	7.738
Expert 10	6.0	9.834	7.2	7.0	7.508
Expert 11	6.0	10.000	7.2	10.0	8.300
Expert 12	6.0	9.834	6.5	7.0	7.334
Expert 13	7.0	9.917	6.5	8.0	7.854
Expert 14	9.0	9.917	10.0	8.0	9.229
Expert 15	9.0	9.917	6.5	8.0	8.354
Expert 16	7.0	9.834	8.0	7.0	7.958
Expert 17	6.0	9.917	6.5	8.0	7.604
Expert 18	7.3	9.834	3.5	7.0	6.908
Expert 19	7.3	9.917	3.2	8.0	7.104
Expert 20	9.0	9.917	6.3	8.0	8.304
Expert 21	7.3	9.5	7.2	5.0	7.250
Expert 22	9.0	9.917	3.8	8.0	7.679
Expert 23	6.0	10.000	9.2	10.0	8.800
Expert 24	9.0	9.917	7.2	8.0	8.529
Expert 25	7.0	9.917	6.5	8.0	7.854
Expert 26	10.0	10.000	2.5	10.0	8.125
Expert 27	7.0	9.917	9.2	8.0	8.529
Expert 28	6.0	9.917	6.5	8.0	7.604
Expert 29	7.3	9.917	4.2	8.0	7.354
Expert 30	9.0	9.917	6.5	8.0	8.354
Expert 31	7.3	9.917	5.5	8.0	7.679
Expert 32	7.3	10.000	7.0	10.0	8.575
Expert 33	10.0	9.917	4.5	8.0	8.104
Expert 34	7.0	9.834	5.6	7.0	7.358
Expert 35	7.0	9.917	6.0	8.0	7.729
Expert 36	10.0	10.000	6.5	10.0	9.125
Expert 37	7.3	10.000	6.5	10.0	8.450
Expert 38	7.0	9.917	4.8	8.0	8.529
Expert 39	7.3	9.917	9.2	8.0	8.604
Expert 40	7.0	9.917	3.5	8.0	7.104

Table 4

Standard uncertainty of the Type A of the results of expert measurements of the importance degrees of student activity components

Name of the student activity component	Absolute value of the standard uncertainty u_A, in points	Relative value of the standard uncertainty u_A, in %
Study	0.2770	2.88
Self-improvement	0.1937	2.39
Scientific activity	0.2130	2.77
Methodical activity	0.5487	10.97
Social activity	0.6046	12.86

In the course of the research, the conditions of the experiment met the established standard, and the 40 experts was a sufficient number (Table 2) to support a high degree of the expert measurement result reliability. Thus, the calculation of an extended uncertainty (Table 5) of expert research results according to (16) was the final stage in the method realization.

Table 5

The extended uncertainty of expert measurement results of student activity component importance for P=95 %

Name of student activity component	Absolute value of the extended uncertainty U, in points	Relative value of the extended uncertainty U, in %
Study	0.5595	5.82
Self-improvement	0.3913	4.83
Scientific activity	0.4646	5.60
Methodical activity	1.1084	22.16
Social activity	1.2213	25.98

The data in Table 5 prove the different uncertainty degree during expert measurement of the importance degree of student activity components.

6. Discussion of research results and suggestion of recommendations

The results of the expert measurement have helped establish the importance degrees of student activities. They could be represented by a range set from the most important to the least important item – namely, study, self-improvement, scientific, methodical and social activities. For the expert measurement of the importance degree of each component, uncertainty values were calculated. Moreover, the smallest uncertainty values were obtained for the components "self-improvement", "scientific work", and "study", which proved the high reproducibility degree of the results of these components' importance degree in expert measurement. The largest uncertainty values were revealed for the components "methodical activity" and "social activity". It was expedient to make decisions on the realization of the repeated expert measurements with another expert set.

Expert weight coefficients were determined to calculate the uncertainty (Table 3). It is worth noticing that the expert's impartiality degree values ranged from 6 to 10 points, the reliability degrees – from 9.5 to 10 points, the competence degrees – from 3.2 to 10 points, and the interest degrees – from 5 to 10 points.

For the purpose of the experts' attestation, the study standardized the expert quality indices by establishing the lower limit of an admissible value. Based on the results of the expert research, these standards have been formulated and represented in Table 6.

Table 6

Recommendations for standardizing the QIs of specialist experts on quality assessment

Standardization type / Index title	The upper limit of the threshold value
Competence index, calculated according to the results of the introspection Q_{se}, the mutual evaluation Q_{mt}, the documental evaluation Q_{doc}, and the experimental evaluation Q_{ev}	3 points
Interest index, calculated according to the results of the organizer's evaluation Q_{oe}	5 points
Impartiality index, calculated according to the results of the statistical data processing through the concordance coefficient Q_{vr} for each expert	5 points
Reliability index, calculated according to the results of the experimental testing through the coefficient of the results' reproducibility Q_{rp}, received in several rounds	5 points

Thus, for the purpose of a successful experts' attestation, their quality indices should be quite high. Moreover, the lower limit of the admissible values of their quality indices should not be below the correspondent limit indicated in Table 6.

7. Conclusion

1. The analysis of the principle stages of expert measurement has revealed the main reasons of the resulting uncertainty of the latter. The uncertainty reasons are: experts' imperfection, wrong choice of the number of experts, and assessment conditions.

2. The study has suggested the methods of calculating the uncertainty of expert evaluation results that can help adjust the process of accuracy evaluation of such parameters to international requirements (namely, to represent the results of expert measurement based on the uncertainty concept). The system of expert quality indices and the methods of expert quality evaluation have been developed in the study to help deduce the weight coefficients while calculating a Type A uncertainty of expert measurement. The method of considering a Type B uncertainty has also been suggested. It was ascertained that the reasons for its appearance are an insufficient quantity of experts and the conditions of carrying out expert measurement.

3. Recommendations have been formulated to standardize the quality indices of specialist experts by setting the lower limit of the admissible values (within a 10-point scale): namely, it has been recommended to attribute to the competence index 3 points, whereas the interest, impartiality and reliability indices are suggested to have 5 points each. This approach helps standardize the expert characteristics and improve the process of their attestation. Besides, standardization of expert quality indices is an important component of the expert measurement coherence.

4. The results of the conducted expert research on the estimation of the student activity components importance level and the calculation of the components' evaluation uncertainty according to the suggested methods are specified in the work. They have proved that the most important component of student activities is the study process, and the least ponderable one is social activity. Moreover, we have calculated the values of the result uncertainty of the expert measurement. The least value was obtained for the component "self-improvement", and the largest – for the component "social activity".

The research results are supposed to be topical in all activity spheres where expert measurements are normally made, since their accuracy is crucial for the support of efficient functioning of a management system in organizations.

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