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APPLICATION OF THE PROVISIONS OF THE GENERAL THEORY OF MEASUREMENTS WHEN SOLVING SELECTION PROBLEMS

Abstract. The impetus for this publication was an article on the possibility and need to use the general theory of measurement in judicial practice based on considerations of the state and prospects of judicial decisions by the judiciary, as they solve the problem of choice (punishment or justification) as a result expert evaluation in conditions of uncertainty. The article discusses the possibility of disseminating methods and tools for decision-making in the field of metrology as a result of measurement and expert evaluation in conditions of uncertainty in such areas as pedagogical and general qualimetry. To solve the problem, it is proposed to use in educational practice to assess the level of learning (level of acquisition of knowledge, skills and abilities) of subjects of learning four-point scales of the order. Their compatibility with the stobal rating scale and the corresponding ESTC scale is shown. The corresponding nomogram is given, the logarithmic four-point scale of which is obtained on the basis of the probabilistic-information approach. The procedure of data processing of expert assessment (measurement) in pedagogical qualimetry is considered, which can be partially used for processing the characteristics of objects of comparison (OC) in qualimetry. The possibility of applying traditional and improved four-point scales and elements of fuzzy mathematics in qualimetry in the construction of OC models. As directions of implementation of the principles of the general theory of measurements and procedures of expert estimation (measurement) at the decision of problems of a choice it is offered to improve legal, normative, directive and other documents on metrological activity concerning concrete subject area and objects of comparison, and distribution of their scope.

Keywords: metrology; qualimetry; uncertainty; order scales.

Introduction

Searching for information on the subject of the article in the Google Scholar search engine did not return any results.

In the article [1] the directions of improvement of scientific, methodical and organizational bases of the general theory of measurements (GTM) for the purpose of their application at an expert estimation in various branches are considered. The impetus for its publication was the article [2], which deals with the possibility and need for the use of GTM in judicial practice, as the judiciary makes a court decision as a result of the results of expert evaluation in conditions of uncertainty. The considerations of the publication [2] concern the comparison of different levels and means of decision-making in metrology and jurisprudence and are extended [1] to such areas as pedagogical and general qualimetry (table 1).

Objects of comparison (OC) and basic objects (BO) of comparison mean products (products, services, etc.) or subjects of study (SS).

Table 1 – **Levels and means of decision-making in metrology and other fields**

Metrology	Judicial practice	Pedagogical qualimetry	General qualimetry
State standards (Gosstandart)	Laws (Supreme Court)	Education standards (from a certain field of knowledge)	Legislative (regulatory) documents
Working standards	Courts of second instance	Fundamental printed works (monographs, textbooks, etc.) and their sections	List of properties of BO
Measuring instruments	Courts of first instance	Expert teacher (group of experts) and assessment tools SS-OC	Expert (group of experts) and means of evaluating / measuring the properties of OC

Presentation of the main material

In [3] the use of a four-point scale and an improved four-point scale (IFS) of the order in the system of assessment of the level of learning (level of acquisition of knowledge, skills and abilities) of SS, which makes the use of ten- and twelve-point scales is impractical. The indicator of learning (preferably integrated) shows the intermediate or final learning outcome. The Bologna Declaration recommends for use in educational practice the rating scale (RS), the corresponding ESTC-scale and the control procedure, "tied" to the division of the entire scope of a particular discipline into blocks of content modules (BCM) and content modules (CM), and the accumulation of points obtained during the control. Probabilistic-information approach to the evaluation procedure [4] allowed to obtain an expression for determining the evaluation on any logarithmic L-score scale:

$$Q_L = N_i + log_2[- 2^L /((2^L - 1)q - 2^L))], \qquad (1)$$

where N_i *i*s the initial mark of the scale; $L = |N_e - N_i|$ – scale length; N_e is the end mark of the scale.

In Fig. 1 shows a graph of the dependence of the estimates Q of two-, three-, four-, ten- and twelve-point scales, the beginning of which is combined with zero, on the share q of the returned SS information during control.

Here q – the share of information returned by the subject of training during testing, written or oral survey

– the numerical result of the assessment of learning for CM, BCM or in general for the discipline:

$$q = n_c / n_t, \quad (2)$$

where n_c – the number of correct answers, decisions; n_t – the total number of questions, tasks, tasks that determine the content of knowledge of the subject area.

The value of $q = 1$ is an exemplary result. We emphasize that the presence of a sample (standard, in terms of metrology) involves measuring on a scale of relations. This procedure in pedagogical qualimetry can be implemented based on the concept of information entropy, but this issue needs a separate discussion.

Analysis of functional dependences (Fig. 1) shows that the scatter of the values of estimates increases with increasing length of the scale L, especially sharply for values of $q > 0.8$.

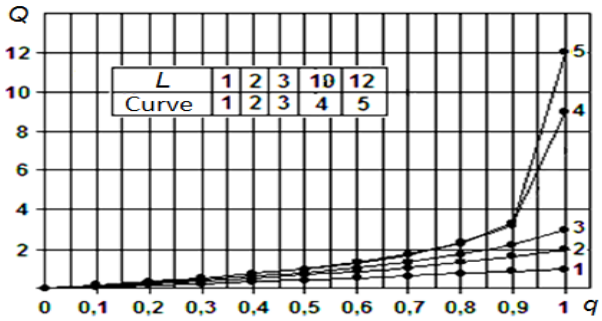

Fig. 1. Graphs of dependences $Q = f(q)$

Thus, it is logical to assume that the use of logarithmic scales longer than three does not make sense, and the use of traditional and advanced four-point scales as the basis for expert evaluation (in particular, the level of study) will be justified. Scores on a logarithmic four-point scale (LFS):

$$Q_{LFS} = 2 + log_2[-8/(7q - 8)]. \quad (3)$$

Approximation $Q_{LPS} = f(q)$ three lines (Fig. 2) in the range of estimates 2.00-3.00; 3.00-4.00; 4.00–5.00, which correspond to the values of q in the ranges 0–0.57; 0.57–0.86; 0.86–1, does not change the "logarithmic essence" of the approximated logarithmic four-point scale (ALFS), but allows to simplify the calculations of estimates.

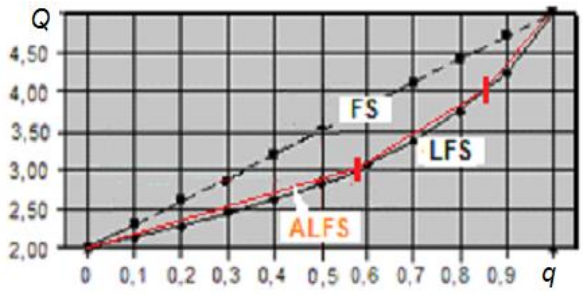

Fig. 2. Graphs of dependences $Q_{FS} = f(q)$

In Fig. 2 shows graphs of four-point advanced (traditional), logarithmic and approximate scales. We emphasize that the values of ALFS estimates differ from the corresponding LFS values, but their relative position does not change, which is decisive. The maximum given errors of estimates in the approximation intervals are 1/57, 1/29 and 1/14 of the score, respectively. Nomogram (Fig. 3), which combines IFS, RS, ALFS and ESTC-scale, allows you to use these scales to assess the level of study of SS in any combination without additional calculations, and the end result is presented in a predetermined scale or as a coefficient of compliance in the range of normalized values from zero to one, or as a percentage (actually – on a rating scale).

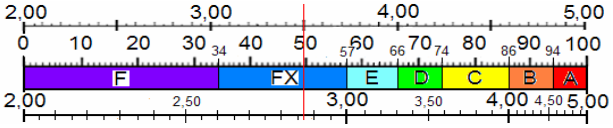

Fig. 3. Nomogram of assessments of scales of pedagogical qualimetry

As the example shows (see fig. 3), a fixed score of 3,50 on the advanced four-point scale corresponds to a score of 50 on the stem scale (or a coefficient of conformity of 0,50), FX on the ESTC scale, and 2,83 on the approximated logarithmic four-point scale.

Note that the introduction of RS was accompanied by "voluntarism" by higher education institutions (HEIs), as shown in Table 2 for generalized data [5] and universities of authors and others.

Table 2 – **Scores on different scales of order**

Score on a four-point scale	Rating ECTS	Grades on the stem scale		
		declared	calculated	applied
Vidminno	A	94-100	94-100	81-100
Dobre	B	86-94	86-94	74-89
	C	74-86	74-86	61-75
Zadovilno	D	67-74	66-74	50-74
	E	57-67	57-66	35-60
Nezadovilno	FX	34-57	34-57	22-59
	F	0-34	0-34	0-34

The practical convergence of the declared and calculated by formula (3) estimates for RS in the ranges of the FS and ECTS scale suggests that the Bologna Declaration proposed the use of the system of stem rating assessment is based on the concept of probabilistic-information approach. This approach is acceptable for test control (in particular, using a computer with special software as a means of assessing SS), focused on "covering" the total number of questions (tasks, tasks) of a certain amount of educational material taken as a sample.

Thus, the procedure for processing expert evaluation data in pedagogical qualimetry consists of a sequence of the following actions:

- formation of sets of results of assessment of knowledge, skills and abilities of subjects of training in one of two ways: in an absolute scale as a share of the returned SS information at control; in a traditional four-point scale or an advanced four-point scale;
- calculation of average grades in an improved four-point scale;
- the expression of average grades in a form acceptable for the construction of the rating list in the two-point, logarithmic four-point, rating scale and the corresponding ECTS scale or otherwise.

The quality of products (services, etc.) is usually assessed by comparing products with each other or with the base object.

Any basic object (BO) is characterized by a set of its quantitative and qualitative properties, which consists of experts who attribute the scores of the FS according to the rules associated with the statements "Yes" – 5, "Rather yes, than no" – 4, "Rather no, than yes" – 3, "No" – 2 in response to questions such as "Is the property inherent in the base object or not?" The result of this procedure is an information model of the basic object (actually – a sample – an analogue of the standard or working standard) in the thesaurus (dictionary) and the alphabetical index of the properties of the BO.

Quantitative characteristics of the properties of the object of comparison are obtained by measurements by appropriate methods (techniques). Uncertainty-based measurement results can be provided as membership functions.

Qualitative characteristics of the OC are evaluated by the same method of assigning points, as described above, for judgments such as "Does this property match the object of comparison and BO?" The obtained data of non-numerical nature are used to construct the resulting characteristic membership function (RCMF). Fasification of RCMF using the method of center of gravity [6] gives the desired result - an integral indicator of the quality of OP as an arithmetic mean, which does not contradict the theory [7] and confirmed by calculations [8].

Conclusion

The extension of the principles of GTM to the areas of activity where decisions are made on the basis of expert assessment / measurement requires:

- improvement of legal, scientific, methodological, organizational principles and evaluation (measuring) procedures;

- finalization of normative (directive, guiding, administrative and other) documents on metrological activities related to a specific subject area and specific objects of comparison, and expansion of their scope.

Establish the possibility of using different types of scales to solve the problem of comparing objects of comparison.

REFERENCES

1. Dehtyarʹov O.V., Dubrovina V.V. , Kozlov V.Ye. , Kozlov Yu.V. Zahalʹna teoriya vymiryuvanʹ yak osnova ekspertnoho otsinyuvannya [General theory of measurements as a basis for expert evaluation]. *Systemy obrobky informatsiyi*. – Kharkiv: KHUPS, 2015. – Vyp. 10 (135). – P. 178-181. (in Ukrainian).
2. Shishkin I.F. Justice de jure and de facto [Pravosudye de-yure y de-fakto]. Available at: ttp: // ria-stk. ru.
3. Kozlov V.Ye. , Kozlov Yu.U. V. , Kobzyev V.G. , Moshchenko I.O. Metod otsinyuvannya rivnya vyvchenosti subʺyekta navchannya [Method of assessing the level of study of the subject of education]. *Information systems and technologies IST-2020: materials of the 9th International*. November 17-20, 2020 - Kharkiv, Ukraine. - Kharkiv: Printing House Madrid, 2020. - P. 160-162. (in Ukrainian).
4. Kozlov V.Ye., Olenchenko V.T., Yuzʹkov I.O. Modelʹ podannya otsinnykh funktsiy vykladacha [Model of representation of evaluative functions of the teacher]. *Systemy obrobky informatsiyi*. – Kharkiv: KHU PS, 2009. – Vyp. 6(80). – P. 233–236.
5. Varhalyuk V., Derkach T. Analiz rezulʹtativ pedahohichnoho eksperymentu z vprovadzhennya shkaly ECTS u VNZ Ukrayiny [Analysis of the results of a pedagogical experiment on the implementation of the ECTS scale in Ukrainian universities]. *Informatyka ta informatsiyni tekhnolohiyi v navchal'nykh zakladakh*. №2, 2007. P. 66-70. (in Ukrainian).
6. Kozlov V.Ye, Novikova O.O. Teoretyko-mnozhynnyy metod ekspertnoho otsinyuvannya [Theoretical-multiple method of expert evaluation]. *Systemy obrobky informatsiyi*. - Kharkiv: KHU PS, 2012. – Vyp. 9(107). – P. 291-293. (in Ukrainian).
7. Orlov A. I. Ekonometrika. [Econometrics], Rostov-na-Donu, Feniks, 2009. 572 p. (in Russian).
8. Horelyshyev S.A., Iokhov O.Yu., Novykova O.O. Teoretyko-mnozhynnyy metod profesiynoho vidboru [Theoretical-plural method of professional]. Systemy obrobky informatsiyi. – 2011. – Vyp. 2(92). – P. 188-190. (in Ukrainian).

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Застосування положень загальної теорії вимірювань при розв'язанні задач відбору

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Анотація. Поштовхом до публікації стала стаття про можливість і необхідність використання загальної теорії вимірювання в судовій практиці, виходячи з міркувань стану та перспективи судових рішень судовими органами, оскільки вони вирішують проблему вибору (покарання чи виправдання) як результат експертної оцінки в умовах невизначеності. У статті розглядаються можливості поширення методів та засобів прийняття рішень у сфері метрології за результатами вимірювань та експертного оцінювання в умовах невизначеності в таких сферах, як педагогічна та загальна кваліметрія. Для вирішення проблеми пропонується використовувати в освітній практиці для оцінювання рівня навченості (рівня засвоєння знань, умінь і навичок) суб'єктів навчання чотирибальні шкали порядку. Показано їх сумісність зі стобальною шкалою оцінок і відповідною шкалою ESTC. Наведено відповідну номограму, логарифмічну чотирибальну шкалу якої отримано на основі імовірнісно-інформаційного підходу. Розглянуто процедуру обробки даних експертної оцінки (вимірювання) у педагогічній кваліметрії, яка може бути частково використана для обробки характеристик об'єктів порівняння у кваліметрії. Можливість застосування традиційних та вдосконалених чотирибальних шкал та елементів нечіткої математики в кваліметрії при побудові моделей об'єктів порівняння. В якості напрямів реалізації принципів загальної теорії вимірювань і процедур експертного оцінювання (вимірювання) при вирішенні проблем вибору пропонується удосконалити законодавчі, нормативні, директивні та інші документи з метрологічної діяльності щодо конкретної предметної галузі та об'єкти порівняння та розподіл їх сфери.

Ключові слова: метрологія; кваліметрія; невизначеність; замовлення ваги.