COMPARATIVE ASSESSMENT OF PROFESSIONAL COMPETENCIES OF EDUCATIONAL STANDARDS OF INFORMATION AND MEASUREMENT TECHNOLOGIES SPECIALTY

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Abstract. National education standards are documents that define expected educational achievements, knowledge, skills, and competencies. These standards may vary between countries and regions, but they are important to ensure the quality of education and comparability between different education systems. An important element of each education standard is the definition of professional competencies to be acquired. The formation of such competencies should be carried out with the involvement of the main stakeholders. To evaluate professional competencies according to the standards of bachelor's and master's education in information and measurement technologies, their group expert evaluation was carried out by stakeholder specialists using the averaging of indicators and the Rasch model. The results of assessment by both methods and their comparison are considered. The obtained results showed their convergence. The analysis of the results obtained according to the multivariate Rasch model showed that the measurement data according to this model allows calculating established statistics both for the competencies under consideration and for the involved experts. The Rasch model can be a useful tool for assessing the importance of established professional competencies for different levels of higher education in different specialties. Experts had the most doubts about the competence of a bachelor in the ability to develop a regulatory and methodological framework for quality assurance and technical regulation and to develop a scientific and technical basis for quality management systems and certification tests, as well as the competence of a masters in the ability to manage projects and startups and evaluate their results. Therefore, these competencies require special attention during the next revision of education standards for greater balancing of the relevant competency set.

Key words: Comparative assessment, professional competence, information and measurement technologies, scale ranking, Rasch model.

1. Introduction

The initiative introduced to promote cooperation and standardization of higher education in the countries of the European continent is called the European educational space. The main characteristics of this space include the Bologna Process; a three-level system of higher education in universities; the use of a special credit system; recognition of qualifications; cooperation in the field of research, etc. [1–4].

In many European countries, great attention is paid to the quality of higher education. Education is carried out based on educational programs – a structured set of educational materials, tasks, and content, which are developed and used in the educational process to achieve specific educational and educational goals. Educational programs are determined by specific educational needs and standards, taking into account the interests of stakeholders.

National education standards are documents that define expected educational achievements, knowledge, skills, and competencies [5]. These standards may vary between countries and regions, but they are important to ensure the quality of education and comparability between different education systems. An important element of each education standard is the definition of professional competencies to be acquired. The formation of such competencies should be carried out with the involvement of the main stakeholders [6].

2. Drawbacks

Basic scientific publications on improving approaches to the development of professional and communicative competencies [7–9], offering special tools for evaluating competencies are well-known [10]. The authors investigated the issue of perception and evaluation of the listener's competence [11, 12], the processes of formation of competencies and learning outcomes based on professional standards and spheres of activity [12, 13], methods of checking and evaluating the acquired competences of students of technical specialties related to production engineering at bachelor's and master's levels [14], the importance of applied competencies and learning outcomes in the standards of higher education for obtaining the degree of higher education "bachelor" and "master" [15, 16]. At the same time, there are no scientific publications on the issues of evaluated results of professional competencies for a specific specialty, which remains an urgent task.

3. Goal

The purpose of the research is a comparative assessment of professional competencies according to the educational standards of information and measurement technology specialty using several methods.

4. Expert assessment of professional competencies with averaging of indicator

A group expert assessment of professional competencies and his learning results was carried out with the involvement of 13 professionals of the SE "UKRMETRTESTSTANDARD" (Kyiv), including 3 doctors and 5 candidates of technical sciences. This organization is one of the largest stakeholders of university graduates in the information and measurement technology specialty (code 175) in the National Metrological Service of Ukraine. A special questionnaire has been developed to assess the professional competencies of bachelors (10 competencies from C13 to C22) and masters (14 competencies from C11 to C24). The chosen scale for assessment: from 1 (least important indicators) to 9 (most important indicators) scores.

Processing of the received questionnaire data was carried out according to the next algorithm with averaging of indicators:

- Analysis of collected data from experts and formation of a matrix of received estimations;
- Carrying out a simple averaging of received estimations from experts for each professional competence;
- Ranking of total expert estimations of professional competencies from the most essential (greater than the average value of all scores) to the least essential (less than the average value of all scores);
- Formation of recommendations regarding the importance of professional competencies based on the analysis of the received estimations.

Results of expert assessment of professional competencies with averaging of indicators for bachelor and master are shown in Fig. 1-2, respectively in scores. The dashed line on those figures shows the average value of all scores.

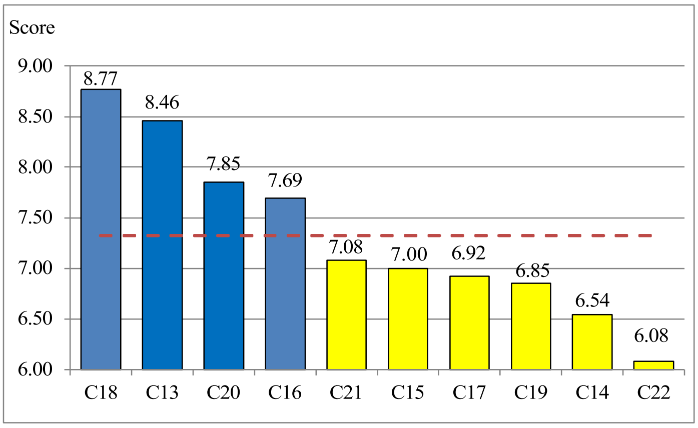

Fig. 1. Ranking of professional competencies for bachelors

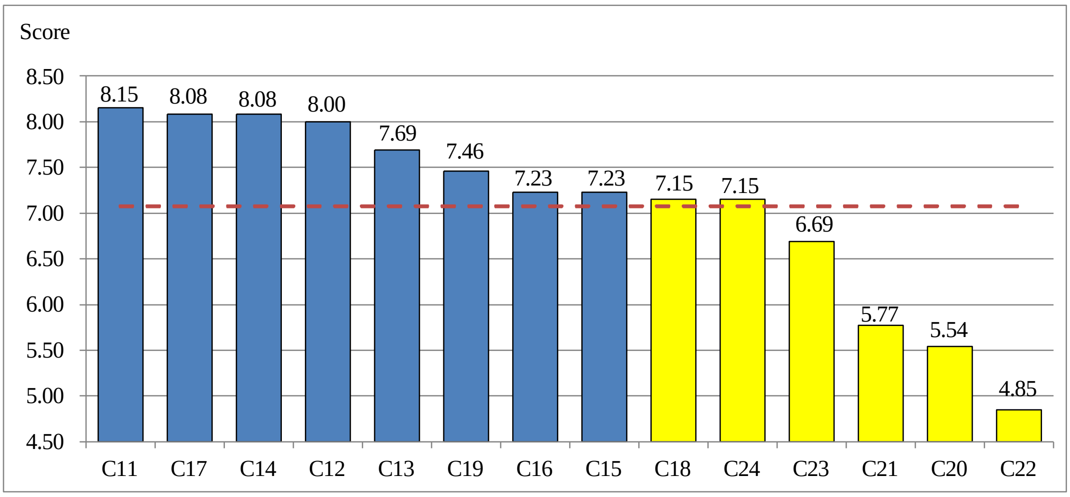

Fig. 2. Ranking of professional competencies for masters

Ranking of the most important professional competencies for a bachelor (bars with a darker filling in Fig. 1): C18 (8.77 scores), C13 (8.46), C20 (7.85), and C16 (7.69), and the least important (bars with a light filling in Fig. 1): C22 (6.08), C14 (6.54), C17 (6.92). The ranking of the most important professional competencies for a master (bars with a darker filling in Fig. 2): C11 (8.15 scores), C17 (8.08), C14 (8.08) and C12 (8.00), and the least important (bars with a light filling in Fig. 2): C22 (4.85), C20 (5.54), C21 (5.77) and C23 (6.69).

1. Expert assessment of professional competencies using the Rasch model

A group expert assessment of professional competencies was conducted with the participation of the same participants according to their estimations and according to the same scale.

The Rasch model is a statistical methodology used to analyze data obtained on a certain rating scale of objects. This model helps to make assessment more objective, accurate, and efficient and allows obtaining information about the tasks being analyzed in different contexts, which is of great importance for decision-making. The Rasch model has some advantages over other methods: objectivity; adaptability; differentiation of tasks; efficiency; data modeling; and comparison of groups [17, 18].

For Rasch model uses a special numerical characteristic – the logit, which is the logarithm of the ratio of the probability of correct assessment to the probability of incorrect assessment of the task. It is used to convert the probability of a correct estimate ("*p*") into the appropriate scale. In this space, the Rasch model becomes linear, which simplifies the analysis of the obtained data and the solution of various problems related to the assessment of task parameters and the criticality of experts' assessment [19].

The Infit and Outfit statistics are the most widely used descriptive Rasch model statistics. The Infit stat is more critical when the item's scale is close to the subject's scale, and the Outfit stat is more critical when the metrics at the end of the scale are not the subject's metric.

Charts and tables of the Rasch model using normalized unweighted averages so that the graphs are symmetrical centered on zero [17, 20, 21]:

– Mean-square statistic (MNSQ) is the level of randomness of the results or the discrepancy between the data of the measurement model;

– z-statistics (ZSTD) is the probability of a Root-Mean-Square Statistic expressed as a z-statistic (Root-Mean-Square Deviation, RMSD).

For MNSQ, the most expected values are around 1.0, and the most qualitative values are in the range of 0.5 to 1.5. Values below 1.0 indicate that the data are either too predictable or excessively predictable, above 1.0 – too unpredictable data, less than 0.5 – "information overload" of the element, more than 1.5 – uncertainty and excessive unpredictability of the data or "noise". MNSQ values between –2.0 and +2.0 are acceptable, and a module greater than 2.0 is inconsistent with the measurement model and cannot be used in the analysis of results. The analysis starts with the higher MNSQ value for the objects under consideration. For probability $p \le 0.05$ with two-sided distribution ZSTD > |1.96|.

The measurement error using the Rasch model is the estimated value that, when added and subtracted from the logit measurement, gives the minimum distance before the difference becomes significant.

Processing of the received questionnaire data was carried out according to the next algorithm with the Rasch model:

- Analysis of collected data from experts and calculations of total scores and measurement errors for all professional competencies;
- Calculations of Infit and Outfit statistics (MNSQ and ZSTD) for all professional competence;
- Ranking of total expert estimations of professional competencies from the most essential to the least essential;
- Formation of recommendations regarding the importance of professional competencies based on the analysis of the Rasch model.

The obtained primary data on experts were processed using the WINSTEP 4.4.7 software [11], which implements the Rasch model. The results of the transformation of the input primary data by professional competencies in the Rasch dimension are shown in Table 1 for bachelors and Table 2 for masters.

The obtained MNSQ values for professional competencies (Table 1) for bachelors the Infit statistic range from 0.45 to 2.02 and for the Outfit statistic from 0.49 to 1.59. This indicates that all these values are acceptable for Rasch model analysis. Only for the C20, C13, and C22 competencies are the values of Infit and Outfit statistics, and additionally, for C18 competence the values of Outfit statistics have a value greater than 1.5, which indicates the presence of "noise" in the input data. Ranking for Rasch model measurement of the most important professional competencies for a bachelor: C18 (-2.18), C13 (-1.20), C20 (-0.22), and C16 (-0.06), and the least important: C22 (0.95), C14 (0.73), C19 (0.56).

The obtained MNSQ values for professional competencies of masters (Table 2) for the Infit statistic range from 0.40 to 2.88 and for the Outfit statistic from

0.38 to 2.02. This indicates that all these values are acceptable for Rasch model analysis. Only for the C19 competence the value of Infit and Outfit statistics have a value greater than 1.5, which indicates the presence of "noise" in the input data. At the same time, although the Infit statistic value is 2.88 for the C12 competency, the Outfit statistic value is 2.02 and does not exceed the established limits. Ranking for Rasch model measurement of the most important professional competencies for a master: C11 (-0.94), C17 (-0.83), C14 (-0.83), and C12 (0.72), and the least important: C22 (1.23), C20 (0.96), C21 (0.87) and C23 (0.42).

Table 1. Results of the data transformation on professional competences of bachelors

Professional competence	Total scores	Measure-ment	Measurement error	Infit statistics		Outfit statistics	
				MNSQ	ZSTD	MNSQ	ZSTD
C18	114	-2.18	0.61	1.06	0.31	1.59	0.86
C13	110	-1.20	0.42	1.80	1.41	1.58	1.02
C20	102	-0.22	0.30	2.02	1.66	1.52	1.07
C16	100	-0.06	0.28	0.81	-0.18	0.70	-0.52
C21	92	0.43	0.22	0.52	-1.06	0.49	-1.22
C15	91	0.47	0.22	0.82	-0.26	0.81	-0.29
C17	90	0.52	0.21	0.69	-0.61	0.66	-0.69
C19	89	0.56	0.21	1.13	0.42	0.91	-0.05
C14	85	0.73	0.20	0.45	-1.47	0.62	-0.82
C22	79	0.95	0.19	1.53	1.17	1.51	1.13
Averaging	95	0.00	0.28	1.08	0.10	1.04	0.10
RMSD	11	0.93	0.13	0.51	1.00	0.43	0.80

Table 2. Results of the data transformation on professional competencies of masters

Professional competence	Total scores	Measure-ment	Measurement error	Infit statistics		Outfit statistics	
				MNSQ	ZSTD	MNSQ	ZSTD
C11	106	-0.94	0.34	0.86	-0.17	0.82	-0.26
C17	105	-0.83	0.33	0.91	-0.05	0.72	-0.54
C14	105	-0.83	0.33	0.87	-0.14	0.84	-0.23
C12	104	-0.72	0.32	2.88	2.88	2.02	1.92
C13	100	-0.36	0.28	1.45	1.01	1.41	0.98
C19	97	-0.14	0.26	1.74	1.43	1.72	1.49
C16	94	0.50	0.24	1.37	0.85	1.23	0.63
C15	94	0.50	0.24	1.24	0.63	0.94	0.00
C24	93	0.11	0.24	0.40	-1.47	0.38	-1.70
C18	93	0.11	0.24	0.92	0.00	0.76	-0.44
C23	87	0.42	0.21	1.17	0.50	0.91	-0.07
C21	75	0.87	0.18	0.98	0.80	0.69	-0.72
C20	72	0.96	0.18	0.77	-0.53	0.83	-0.33
C22	63	1.23	0.17	0.72	-0.71	0.57	1.15
Averaging	92	0.00	0.26	1.16	0.30	0.99	0.00
RMSD	13	0.67	0.06	0.58	1.00	0.44	1.00

2. Discussion of the assessment of the professional competencies

A comparison of the results of the assessment by both methods showed their convergence. This made it possible to form a list of the most and least important professional competencies of bachelor's and master's based on the analysis of the obtained grades.

The following most important professional competencies of the bachelor were established:

C18 is the ability to perform technical operations during testing, verification, calibration, and other operations of metrological activity;

C13 is the ability to analyze error components according to their essential features, operate with error/ uncertainty components following measurement models;

C20 is the ability to carry out technical measures to ensure metrological traceability, correctness, repeatability, and reproducibility of measurement and test results according to international standards;

C16 is the ability to use modern engineering and mathematical packages to create models of devices and measurement systems.

The following least important professional competencies of the bachelor were established:

C22 is the ability to develop a regulatory and methodological framework for quality assurance and technical regulation and to develop the scientific and technical basis of quality management systems and certification tests;

C14 is the ability to design information and measurement equipment and describe the principle of their operation;

C19 is the ability to provide metrological support for technological processes and certification tests.

The following most important professional competencies of the master were established:

C11 is the ability to choose and apply suitable mathematical methods, computer technologies, as well as approaches to standardization and certification to solve tasks in the field of metrology and information and measurement technology;

C17 is the ability to apply a comprehensive approach to solving experimental tasks using information and measurement equipment and application software;

C14 is the ability to apply a systematic approach to solving scientific and technical tasks of metrology and information and measurement technology;

C12 is practical skills in solving complex tasks and problems of metrology, information and measurement technology, and standardization in evaluating product quality.

The following least important professional competencies of the master were established:

C22 is the ability to manage projects and start-ups and evaluate their results;

C20 is the ability to develop software, hardware, and metrological support of computerized information and measurement systems;

C21 is the ability to take into account the requirements for metrological activity in the field of technical regulation, due to the need to ensure sustainable development;

C23 is the ability to comply with legal and ethical norms on intellectual property issues.

3. Conclusions

To evaluate professional competencies according to the standards of bachelor's and master's education in information and measurement technologies, their group expert evaluation was carried out by stakeholder specialists using the averaging of indicators and the Rasch model.

The analysis of the results obtained according to the multivariate Rasch model showed that the measurement data allow calculating established statistics both for the competencies under consideration and for the involved experts. The Rasch model can be a useful tool for assessing the importance of established professional competencies for different levels of higher education.

Experts doubt the competence of a bachelor in the ability to develop a regulatory and methodological framework for quality assurance and technical regulation and to develop a scientific and technical basis for quality management systems and certification tests as well as the competence of a master in the ability to manage projects and startups and evaluate their results. Therefore, these competencies require special attention during the next revision of education standards for greater balancing of the relevant competency set.

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