METROLOGY, QUALITY, STANDARDIZATION AND CERTIFICATION

EXPERT ASSESSMENT OF THE COMPETENCIES AND RESULTS OF BACHELOR'S STUDY ACCORDING TO THE STANDARD OF HIGHER EDUCATION IN INFORMATION AND MEASUREMENT TECHNOLOGIES

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Abstract. The article establishes the relevance of researching the importance of applied competencies and learning results in the standard of higher education for obtaining the bachelor's degree in the specialty "Information and measurement technologies". To achieve the goal, the description and requirements of competencies and learning results were analyzed, and an algorithm for group expert assessment of their importance was proposed and substantiated. Based on the assessment, the priority of professional competencies and learning results was established. The most important competencies and learning results that can significantly influence the quality of education in the specialty are determined. Competences and learning results with the least impact on the quality of education in the specialty have been identified, which may indicate their formal nature. To better balance the system of competencies and learning results, it is necessary to pay special attention to those that have the least influence during the next revision of the standard of higher education for the training of bachelors in the specialty "Information and measurement technologies". The changes to the description of competencies and learning results proposed by the experts take into account the current trends in the development of the industry, provisions of current legislation, regulatory documents, and established terminology in the field of metrology and information and measurement technologies.

Key words: expert assessment; competence; learning results; bachelor's degree; information and measurement technologies.

1. Introduction

The main goals of the European Higher Education Area (EHEA) are to facilitate the mobility of students and teachers, to improve the quality of higher education, to increase the competitiveness of European universities on the world stage, and to ensure greater accessibility of higher education [1]. The main characteristics of the EHEA include the Bologna process and a three-tier system, which provides for the introduction of the following levels of higher education in universities: bachelor's, master's, and doctoral. EHEA uses the European Credit Transfer and Accumulation System (ECTS), which allows students to transfer and accumulate credits in different universities and countries, facilitating international mobility [2]. The EHEA regulates the recognition of higher education qualifications between countries, helping to increase the international recognition and comparability of degrees. One of the major aims of the EHEA is to increase opportunities for students and teachers to study and work in different European countries. The EHEA also promotes collaboration between universities and national research programs to create an enabling environment for scientific research and innovation.

Ukraine began its accession to the EHEA in 2005. During this time, several legislative and regulatory documents were adopted in the country, and the necessary institutions were created. The list of fields of knowledge and specialties for which higher education students are trained in Ukraine is currently not fully aligned with the International Standard Classification of Education (ISCED) [3]. The latter was developed by UNESCO as a comprehensive statistical description of national education systems and a methodology for evaluating national education systems compared to comparable international levels. The main unit of the ISCED classification is educational programs (EP), and the classification of EP it- self is carried out according to fields of knowledge, orientation, and purpose of EP. National fields of knowledge and specialties are maximally equated to the international classification [4]. Following the latest changes, the code and name of the specialty 152 "Metrology and information and measuring technology" was changed to 175 "Information and measuring technologies" and assigned to the field of knowledge 17 "Electronics, automation, and electronic communications".

Ukraine is integrated into the EHEA and continues to implement the features of European education at

the national level. Most students start with a bachelor's degree, after which they can choose further studies. Students usually choose their specialization or major at the time of undergraduate admission. More emphasis is placed on academic research, so many universities emphasize research, and students can participate in research projects even during their undergraduate studies.

Many universities actively support exchange programs for students that allow them to study or work in other countries. It promotes cultural diversity and international cooperation. Universities use the ECTS credit system, which allows students to transfer their credits from one university to another and facilitates international exchange. Many universities actively support the education of foreign students, there are various scholarship and support programs for students from other countries.

In Ukraine, as in Europe, great attention is paid to the quality of higher education. Almost all universities are accredited and evaluated by independent organiza- tions to ensure a high standard of education. In Ukraine, this function is performed by the National Agency for Quality Assurance of Higher Education (NAQAHE). Education standards are important to ensure the quality of education and the possibility of comparison between different education systems. They help teachers, stu- dents, parents, and education authorities to understand what can be expected from a particular level of educa- tion and how to assess the performance of pupils or stu- dents. National education standards may vary in different countries and regions.

In Ukraine, a standard of higher education has been adopted and is in force to achieve the level of high- er education "bachelor" for the specialty 152 "Metrology and information and measuring technology" [5], which is applicable for specialty 175 "Information and measuring technologies". The standard transfers the graduate's recognition of integral, external, and special (professional) competencies for the specialty. At this point, at least 50 % of the EP volume is directed toward ensuring the provision of general and special (professional) competencies for the specialty. Taking into account to continue the process of adaptation of Ukraine with EHEA and harmonization with ISCED, the provisions of the standard of higher education for the creation of the level of higher education "bachelor" for specialty 152 are irrelevant, require the renovation and bringing it to today's conditions. Such research can be a reference point for universities in designated procedures and areas for improvement, which will allow better to agree on initial plans, development of competencies, and final learning results, as well as determine the relevance and necessity of carrying out special investigations in this direction.

2. Disadvantages

Basic scientific publications on improving approaches to the development of professional and communicative competencies [6, 7], offer special tools for evaluating competencies [8]. The authors studied the issue of perception and evaluation of the listener's com- petence [9], methods of testing and evaluation of the acquired competencies of students of technical special- ties related to production engineering at the bachelor's and master's level [10], expert methods of evaluating EP quality criteria for the field of measuring technology [11, 12]. At the same time, there are no scientific publications on the issues of professional and communicative compe- tencies for a specific subject area and specialty, which remains an actual task.

3. Goal

The goal of the study is to develop a method of group expert assessment of the importance of professional competencies and learning results for a bachelor in the specialty 175 "Information and measurement technologies". To achieve the set goal, the following tasks must be solved: analyze the composition and requirements of professional competencies and learning results, propose and justify an algorithm for group expert assessment of the importance of professional competencies and learning results; establish the priority of professional competences and learning results based on the conducted assessment.

4. Professional competencies and learning results for the bachelor's level of education

A standard of higher education is a document that defines the expected educational achievements, knowledge, skills, and competencies that pupils or students should obtain after completing a specific level of education. Education standards are established by national or regional educational authorities and serve as qualitative criteria for assessing the quality and level of education.

The main characteristics of higher education standards include:

– the main educational goals and tasks that must be achieved at a certain level of education, which involves the acquisition of specific knowledge, the development of skills and abilities, the formation of values, etc.;

– the content of education for a certain level of education, which involves the description of topics, issues, and concepts that should be included in educational programs;

– specific expected learning outcomes, which can be specified in terms of skills, critical thinking ability, level of knowledge, etc.;

– methods of assessment and measurement of educational achievements, which may include evaluation criteria, tools used to determine the level of learning and a system of evaluations;

– deadlines for achieving learning results;

– specific needs of specialties or educational contexts.

The formulation of integral competence for the bachelor's level of education consists of the ability to solve complex specialized tasks in a certain field of professional activity. The list of general and professional competencies should be correlated with the description of the corresponding qualification level of education. Achieving the learning results defined by the higher education standard is provided for by the EP, which includes a single set of educational components: educational disciplines, individual tasks, practices, control measures, etc., which gives the right to obtain a specified educational or educational and professional qualification.

Special (professional) competencies that are relevant to a specific subject area and important for successful professional activity in the specialty "Information and measurement technologies" for the bachelor's qualification level deserve special attention. No less important are the learning results, which determine the normative content of training within this specialty and must be correlated with the specified list of general and special (professional, subject) competencies.

In the standard of higher education there are only 10 professional competencies (Fig. 1) and 18 learning results (Fig. 2) for a bachelor's degree in the specialty "Information and measurement technologies" [5].

In [13, 14], group expert evaluation algorithms are proposed, which can be used to evaluate professional competencies and learning results in the field of information and measurement technologies. The competence of each of the experts involved in conducting such an assessment plays a major role, as it can increase the credibility of such an assessment. Therefore, the selection of experts was carried out taking into account the availability of a scientific degree in a specialty or significant work experience in the specified field, in particular in managerial positions. It can be assumed that the competence of all involved experts is high, therefore, taking into account their competence cannot lead to significant shifts in the obtained estimates.

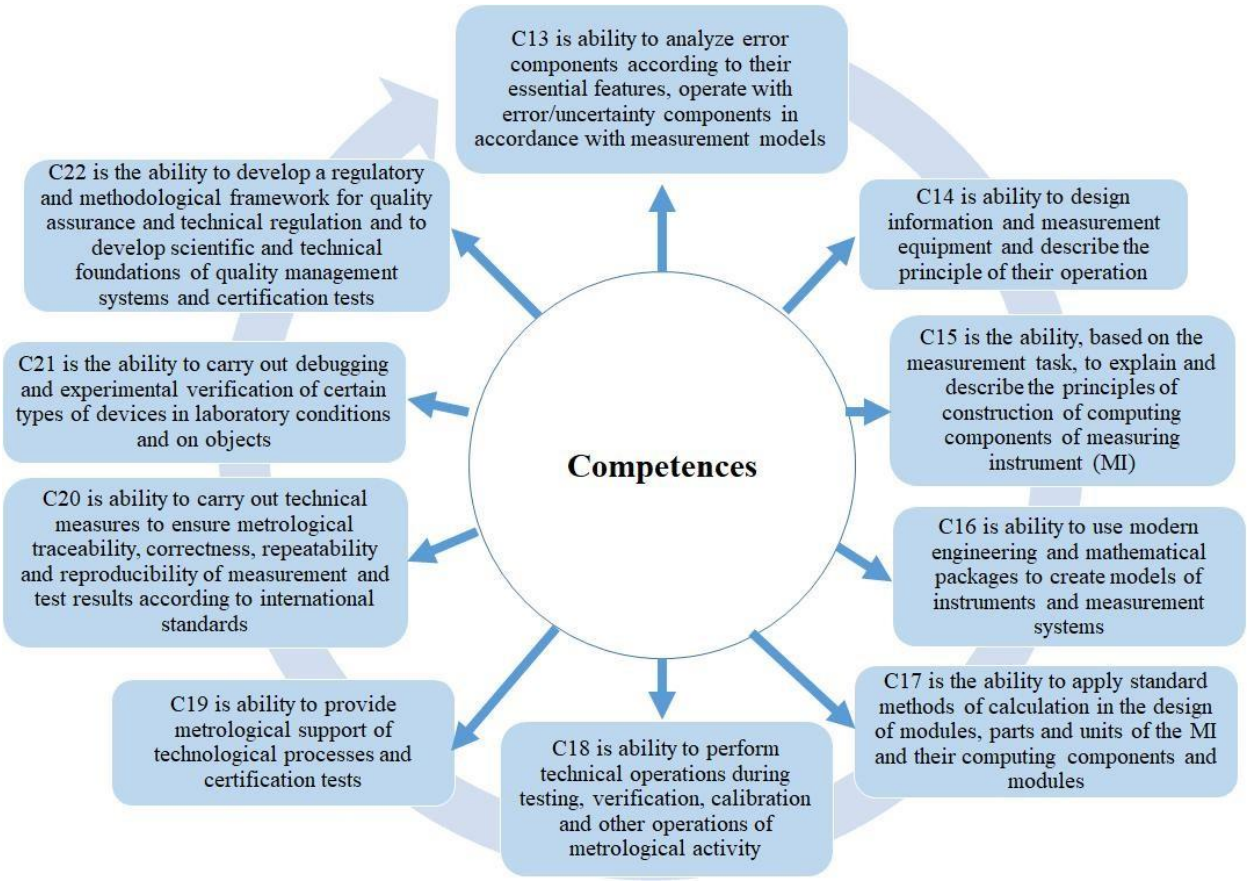


Fig. 1. Professional competencies of bachelor for specialty "Information and measurement technologies"

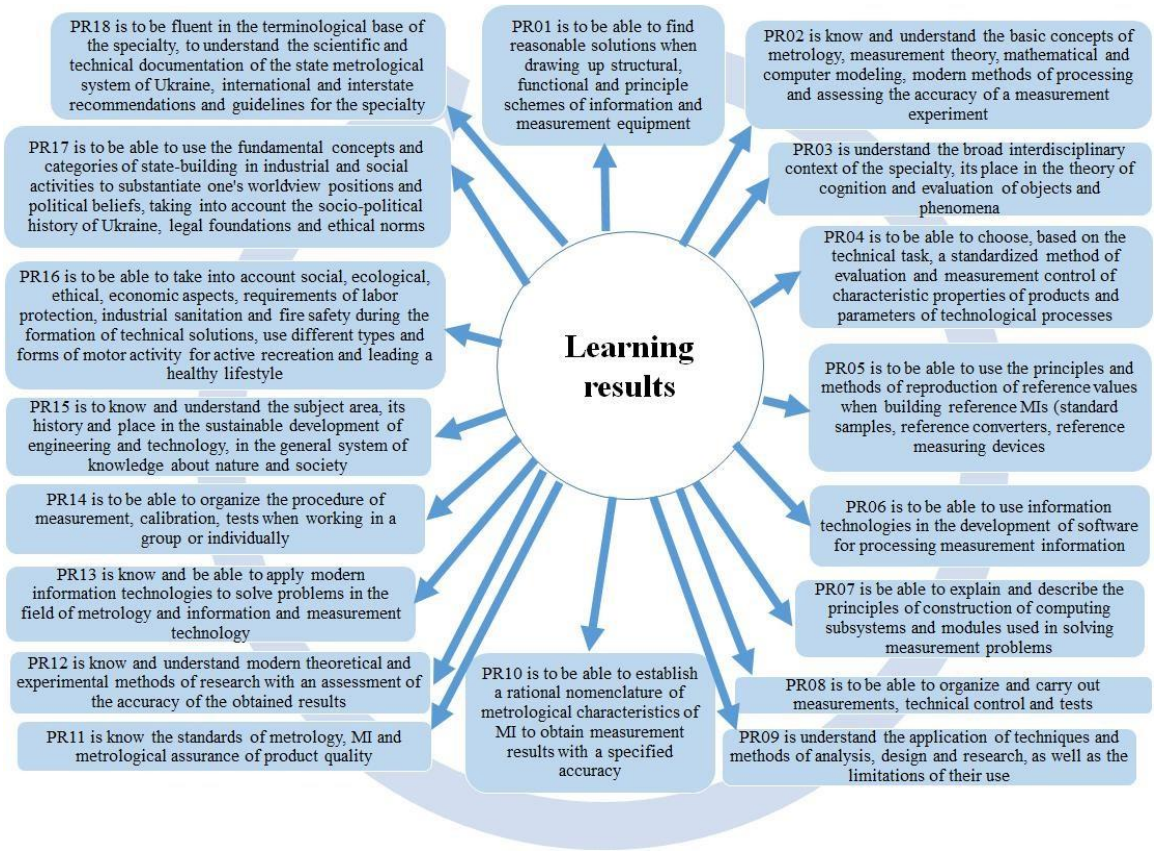


Fig. 2. Learning results of bachelor for specialty "Information and measurement technologies"

The necessary calculations were made using such basic indicators as the average score for each of the *N* professional competencies and learning results, taking into account the specific assessments of all *M* experts who participated in the assessment; the average value of the expert assessment for all professional competences and learning results as a simple average value (in scores), as well as the ranking of the obtained values for each professional competence/learning results in the or- der of decreasing points received. The weighting crite- rion for professional competencies and learning results is exceeding the obtained average score for all professional competencies or learning results. The application of such a criterion made it possible to form a list of the most important professional competencies and learning results. For clarity of the obtained results, their graphic presentation in the form of corresponding histograms was applied.

5. Group expert assessment of professional competencies and learning results for a bachelor

A group expert assessment of professional competencies and learning results for the bachelor was carried out with the involvement of 18 experts: scientific employees of the SE "UKRMETRTESTSTANDART" (Kyiv, Ukraine) as one of the largest stakeholders in Ukraine and teachers of the Gheorghe Asachi Technical University of Iași (Iași, Romania). In particular, 5 doctors of science and 8 candidates of science in the specialty 05.01.02 "Standardization, certification, and metrological provision" and other technical specialties related to information and measurement technologies took part in the evaluation. For this purpose, a special questionnaire was developed and distributed among research staff to assess both professional competencies and learning results. The chosen scale for evaluation: from 1 (least important) to 9 (most important) points. Processing of the received questionnaire data was carried out according to the proposed algorithm [13].

Fig. 3 and 4 present assessments of professional competencies and learning results for a bachelor (red dashed line – medians of the given values of assessment of professional competencies and learning results, respectively).

The sequence of importance of professional competencies are: C18, C13, C20, C16, and the sequence of the least important professional competencies are: C22, C14, C17, C15, C19.

The sequence of importance of learning results are: PR02, PR10, PR14, PR08, PR13, PR12, PR11, and the sequence of least important learning results are: PR17, PR16, PR03, PR15, PR01, PR05.

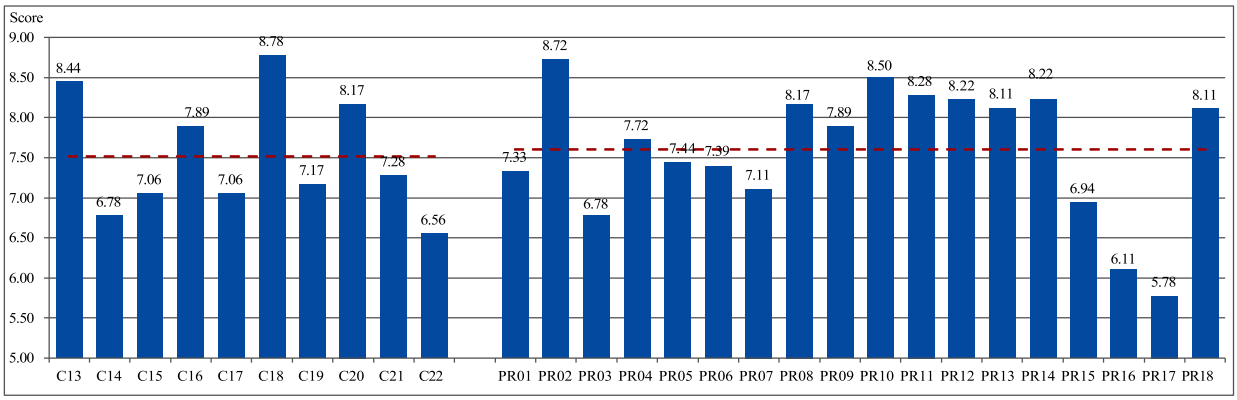
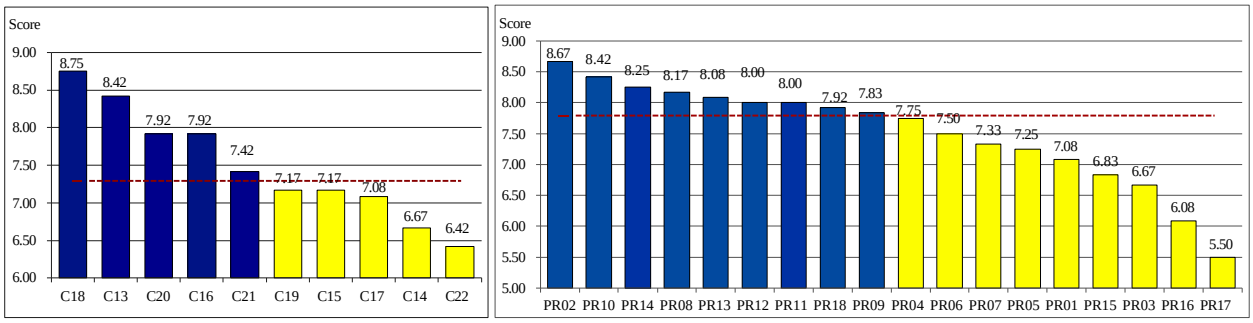


Fig. 3. Expert assessments of professional competencies and learning results for a bachelor's degree in scores



a *b*

Fig. 4. Ranking of professional competencies (a) and learning results (b) for a bachelor's degree by weight in scores

6. Discussion of the results of the assessment of professional competencies and learning results for the bachelor

In total, 4 (out of 10–40 %) professional competencies and 10 (out of 18–55 %) learning results were allocated.

The most important professional competencies (scores above the average level is 7.26) are the following (from 8.75 to 7.42 scores) regarding the ability to: perform technical operations during testing, verification, calibration, and other operations of metrological activity (C18, 8.75 scores); analyze error components according to their essential features, operate with error/uncertainty components following measurement models (C13, 8.42); use modern engineering and mathematical packages to create models of devices and measurement systems (C16, 7.92); implement technical measures to ensure metrological traceability, correctness, repeatability and reproducibility of measurement and test results according to international standards (C20, 7.92).

According to experts, professional competencies (scores below the average level is 7.26) have the least influence on the quality of education as follows (scores from 7.17 to 6.42) regarding the ability to: develop a regulatory and methodological base for quality assurance and technical regulation and develop scientific – technical principles of quality management systems and certification tests (C22, 6.42 scores); to design means of information and measurement equipment and to describe the principle of their operation (C14, 6.67); apply standard calculation methods in the design of modules, parts and units of MI and their computing components and modules (C17, 7.08); based on the measurement task, to explain and describe the principles of construction of the computing components of the MI (C15, 7.17).

The identification of deficiencies in some professional competencies in most cases indicates that such competencies are formal. Therefore, the specified competencies (C22, C14, C17, C15) require special attention during the next revision of the set of competencies for greater balancing of their system.

The most important learning results (scores above the average level is 7.75) are as follows (from 8.67 to 7.83 scores): to know and understand the basic concepts of metrology, measurement theory, mathematical and computer modeling, modern methods of processing and assessing the accuracy of measuring experiment (PR02, 8.67 scores); to be able to establish a rational nomenclature of metrological characteristics of measuring instruments to obtain measurement results with a specified accuracy (PR10, 8.42); to be able to organize the proce-

dure of measurement, calibration, tests when working in a group or individually (PR14, 8.25); to be able to organ- ize and carry out measurements, technical control and tests (PR08, 8.17); know and be able to apply modern information technologies to solve problems in the field of metrology and information-measuring technology (PR13, 8.08).

According to experts, the following learning results (scores below the average level is 7.75) have the least influence on the quality of education (from 7.75 to 5.5 scores): to be able to use the fundamental concepts and categories of state formation in industrial and social activities to justify one's own worldview positions and political beliefs, taking into account the socio-political history of Ukraine, legal foundations and ethical norms (PR17, 5.5); to be able to take into account social, ecological, ethical, economic aspects, requirements of labor protection, industrial sanitation and fire safety during the formation of technical solutions, use different types and forms of motor activity for active recreation and leading a healthy lifestyle (PR16, 6.08); understand the broad interdisciplinary context of the specialty, its place in the theory of cognition and evaluation of objects and phenomena (PR03, 6.67); to know and understand the subject area, its history and place in the sustainable development of engineering and technology, in the general system of knowledge about nature and society (PR15, 6.83); to be able to find reasonable solutions when drawing up structural, functional and principle diagrams of information and measurement equipment (PR01, 7.08).

The identification of deficiencies in some learning results in most cases indicates that they are formal. Therefore, the specified learning results (PR17, PR 16, PR 03, PR 15, PR 01) require special attention during the next review of their set for greater balancing of the learn- ing results system.

During the evaluation of professional competencies and learning results, some experts paid attention to the relevance and clarity of their formulation, as well as provided their comments and suggestions, which are shown in Fig. 5 and 6. In total, it is proposed to change the description of 6 professional competencies (C13– C16, C19, C22) and 4 learning results (PR10, PR15, PR1, PR18).

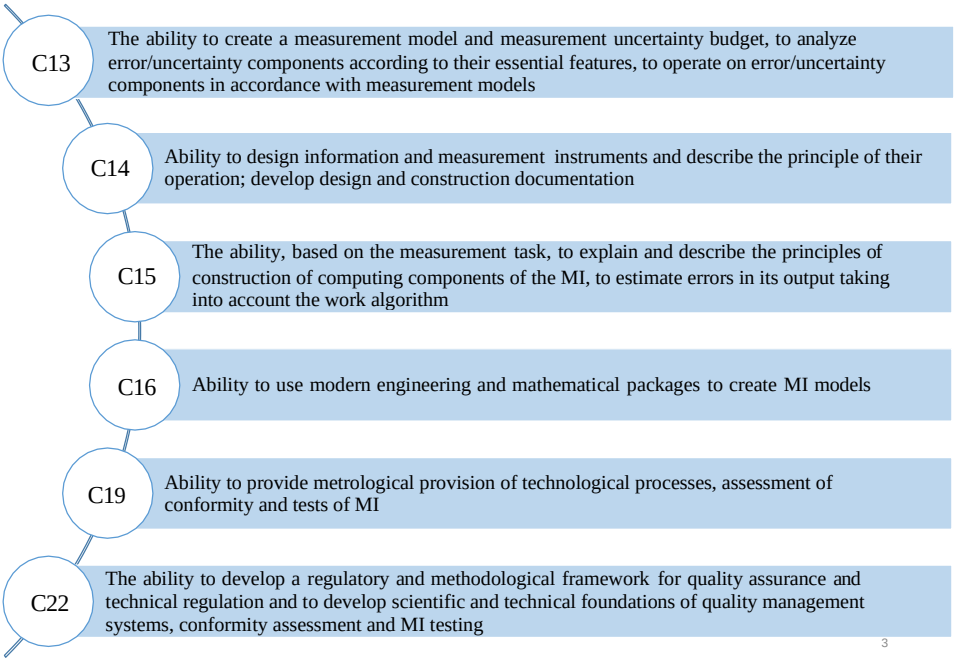


Fig. 5. Changing the description of professional competencies for a bachelor

The analysis of the training results showed that some of them do not sufficiently take into account the trends in the development of the specialty following modern practices in the specified field and need to be revised. Thus, PR18 provides "... to understand the scientific and technical documentation of the state metrological system of Ukraine, international and interstate recommendations and guidelines by specialty". According to the current legislation in the field of metrology and metrological activity, since 2014, the provisions regarding the "state" metrological system of Ukraine have not been applied, as new provisions regarding the "metrological system of Ukraine" have been introduced. Also, all "interstate" regulatory documents have lost their validity on the territory of Ukraine, so this concept does not apply.

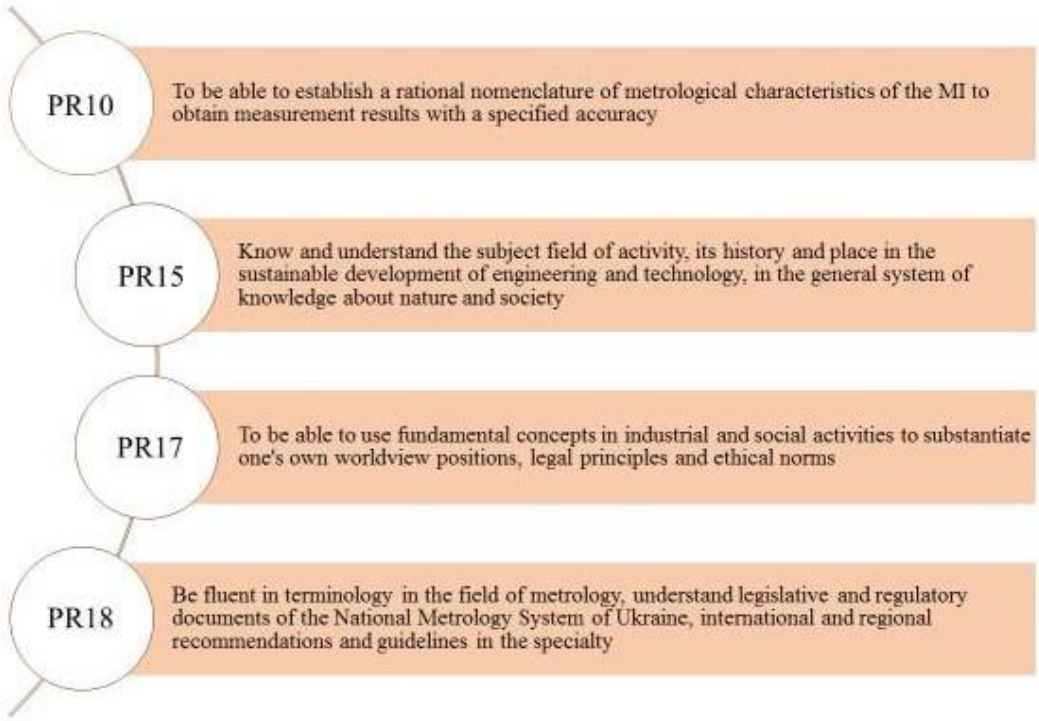


Fig. 6. Changing the description of learning results for the bachelor

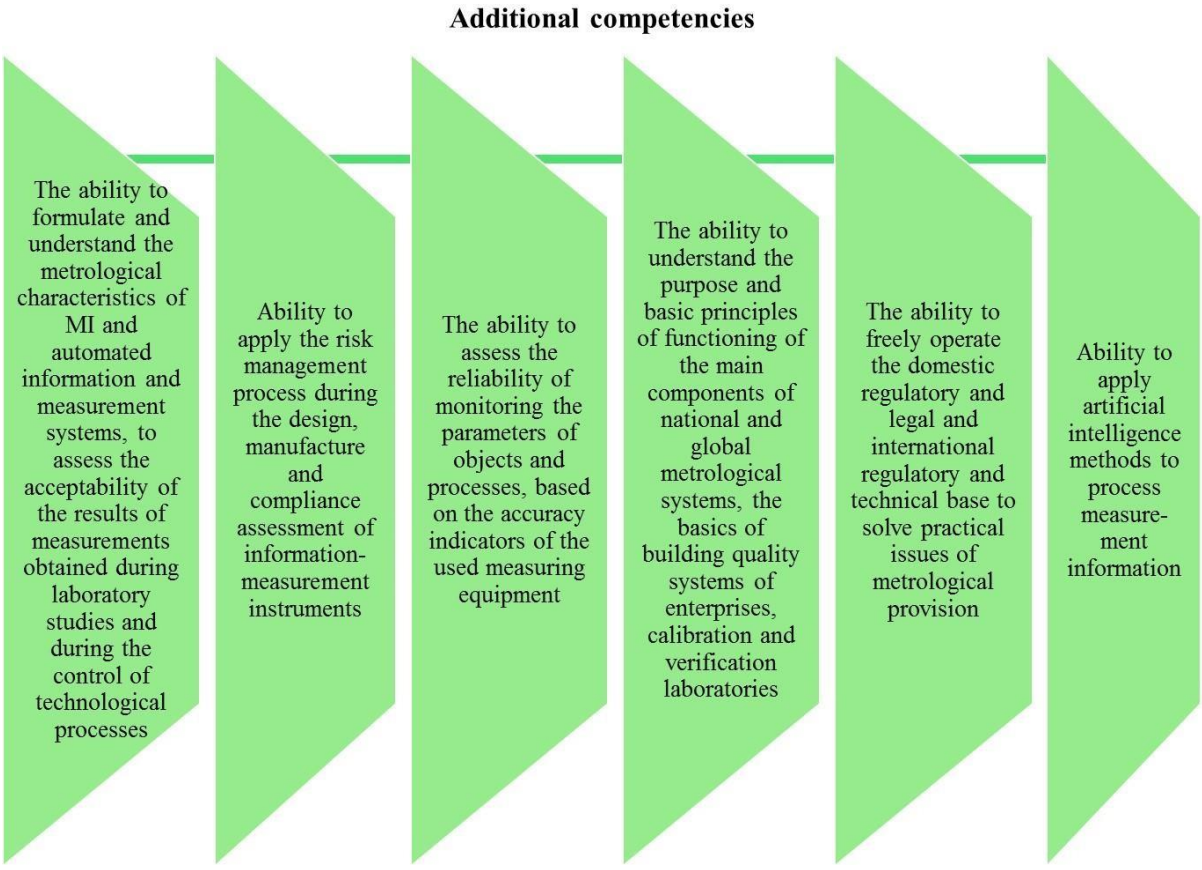


Fig. 7. Addition of professional competencies for a bachelor

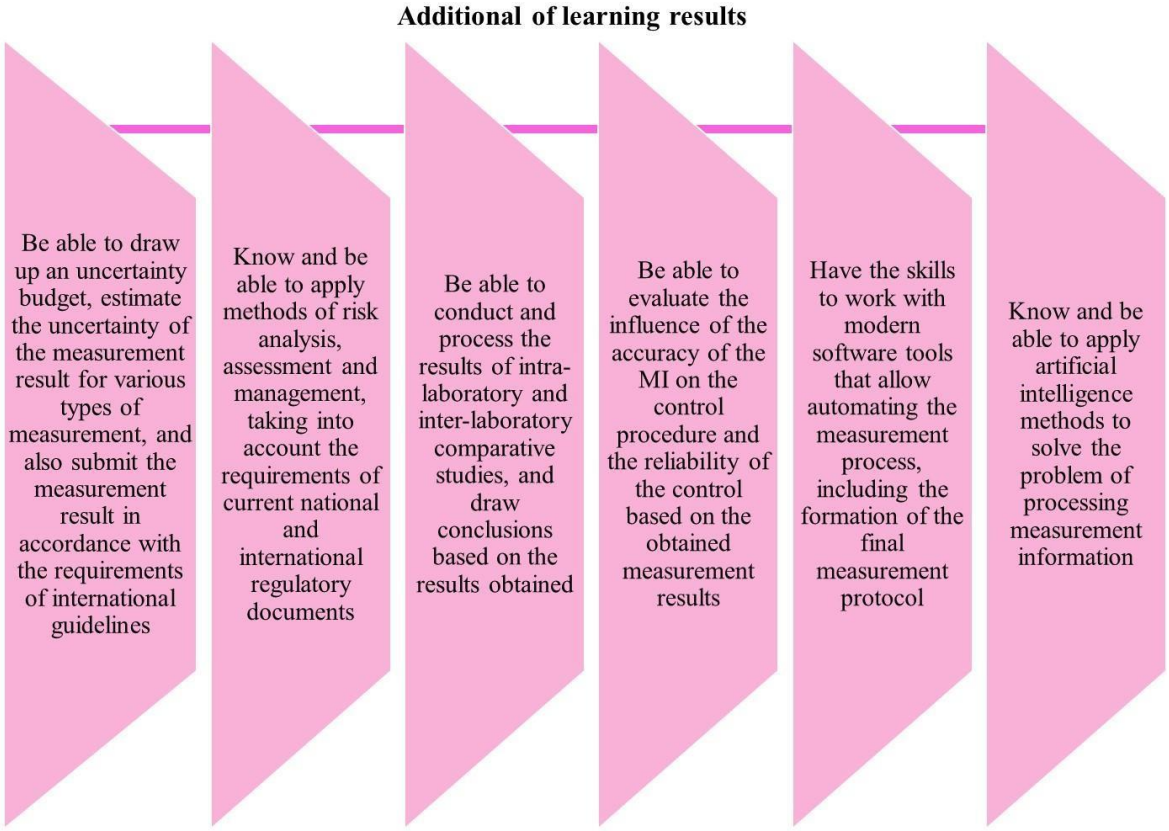


Fig. 8. Addition of learning results for a bachelor's degree

In addition, the experts considered it expedient to expand the list of available competencies and learning results for bachelor and proposed 6 new professional competencies and 6 new learning results, shown in Fig. 7 and 8 accordingly.

For specialists in the field of information and measurement technologies, it is important to be able to make an uncertainty budget when evaluating the uncertainty of the measurement result for various types of measurement, as well as to submit the measurement result following the requirements of international and national guidelines. At the same time, the specialist should assess the influence of the accuracy of the MI on the control procedure and the reliability of the control based on the obtained measurement results. Skills in the application of methods of analysis, assessment, and risk management, as well as methods of artificial intelligence to solve the problem of processing measurement information, are important. Metrologists should have the skills to conduct and process the results of intra-laboratory and inter-laboratory comparative studies, as well as be able to draw conclusions based on the results obtained. At the same time, the skills of working with modern software tools are important, which mostly allows not only to automation of the measurement process but also to form of the final measurement protocol.

During the formation of proposals for changes to the description of competencies and learning results, experts took into account modern trends in the development of the industry, provisions of current legislation, regulatory documents, and established terminology in the field of metrology and information and measurement technologies. The proposed changes, as well as the possibility of supplementing with new (additional) competencies and learning results, should be considered and taken into account during the revision of the standard of higher education for the training of bachelors in the specialty "Information and measurement technologies".

7. Conclusions

Based on the results of the research, the composition and requirements of professional competencies and learning results for the bachelor's degree in the specialty "Information and measurement technologies" were analyzed. Changes to the description of competencies and learning results proposed by experts, taking into account the current state of the field, should be considered and used when revising the standard of higher education for the preparation of bachelor's in this specialty.

The method of group expert evaluation was applied to determine the importance of professional compe-

tencies and learning results using a well-founded algorithm. Based on the assessment, the priority of professional competencies and learning results was established. Undoubtedly, universities should pay attention to all established competencies and learning results. However, more attention should be paid to those identified by ex- perts as the most important and those that can significantly affect the quality of education in the specialty.

This may indicate that the least important professional competencies and learning results are purely for- mal. Therefore, to better balance their system, they need special attention during the next revision of the standard of higher education for the training of bachelors in the specialty "Information and measurement technologies". Professional competencies and learning results proposed by stakeholder representatives also require attention.

8. Gratitude

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9. Mutual claims of authors

The authors have no claims against each other.

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