METROLOGY, QUALITY, STANDARDIZATION AND CERTIFICATION

EXPERT ASSESSMENT OF COMPETENCES AND LEARNING RESULTS FOR MASTER'S ACCORDING TO HIGHER EDUCATION STANDARD IN INFORMATION AND MEASUREMENT TECHNOLOGIES

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Abstract. The purpose of this work is to analyze the learning processes at the second (master's) level of higher education for the training of specialists in industrial engineering. To achieve the goal, an analysis was carried out and the importance of applied competencies and learning outcomes in the standard of higher education for obtaining the master's degree in the specialty "Information and measurement technologies" was evaluated. The conducted research is based on expert assessments of scientists of the National Metrological Center of Ukraine and a higher technical education institution in one of the European countries. An algorithm for group expert assessment of the importance of competencies and learning outcomes has been proposed and substantiated, and their priority has been established. The most important competencies and learning outcomes that can significantly influence the quality of education in the specialty "Information and measurement technologies" have been determined. The identified competencies and learning outcomes with the least impact require attention, as this may indicate their formal nature. Taking into account the current trends in the development of the industry, provisions of current legislation, regulatory documents, established terminology in the field of metrology, and information and measurement technologies, experts proposed changes to the description of some competencies and learning outcomes. The results of the conducted research should be taken into account during the next revision of the standard of higher education for the preparation of masters in the specialty "Information and measurement technologies". At the same time, special attention should be paid to those competencies and learning outcomes that, according to experts, have the least impact. Research findings can also be useful for universities in identifying procedures and areas for improvement that will allow for better alignment of curricula, competency acquisition, and learning outcomes.

Key words: Expert assessment, competence, learning results, master's degree, information and measurement technologies.

1. Introduction

Quality assurance within the framework of the European Higher Education Area (EHEA) brings the system of Ukrainian universities to a high level of verification, monitoring, and accreditation [1], which promotes mutual recognition and transparency of the offered levels of higher education. The use of the European Credit Transfer and Accumulation System (ECTS) allows students to transfer and accumulate credits in different universities and countries, which facilitates international mobility [2]. In 2005, Ukraine began its accession to the EHEA. During this time, legislative and regulatory documents were adopted 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 brought into line with the International Standard Classification of Education (ISCED) [3]. National fields of knowledge and specialties are maximally equated to the international classification [4]. Currently, the code and name of the specialty 175 "Information and measurement technologies" is assigned to the field of knowledge 17 "Electronics, automation, and electronic communications". The main unit of the ISCED classification is Educational Programs (EP), and the classification of EP itself is carried out according to fields of knowledge, orientation, and purpose of EP. EP is 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. Undoubtedly, the level and effectiveness of EP depends on the goals defined in the curriculum and all other auxiliary strategic or fundamental processes (mobility, training, admission, human resources, material resources, etc.) to the assessment of the competencies acquired by the student. This allows for measuring the level of satisfaction of graduates and society.

In Ukraine, great attention is paid to the quality of higher education. All EPs of universities undergo accreditation for compliance with higher education standards, which is carried out by the National Agency for Quality Assurance of Higher Education (NAQHE). 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 to pursue a master's degree.

Higher education standards are important to ensure the quality of education and the possibility of comparison between different education systems. They help teachers, students, parents, and education authorities understand what to expect from a particular level of education and how to assess student performance. In Ukraine, the standard of higher education for obtaining a master's degree in specialty 152 "Metrology and information-measuring technology" [5], which applies to the specialty 175 "Information-measuring technologies", has been adopted and is valid. The standard provides for the graduate's mastery of integral, general, and special (professional) competencies and knowledge in the specialty. Accordingly, trained professionals should be able to work in all sectors of the economy directly related to measurement science, such as testing and calibration laboratories, research centers, and services.

Taking into account the continuation of the process of adaptation of Ukraine to the EHEA and harmonization with ISCED, some provisions of the higher education standard for obtaining the degree of higher education "master" in specialty 152 are irrelevant, need to be updated and brought to modern conditions. Such research will contribute to the improvement of the existing standard of higher education, as well as allow universities to better coordinate curricula, acquisition of competencies, and final learning outcomes, which determines the relevance and necessity of conducting special research in this direction. Also, the research results may be of interest to employers, as they will allow them to search for and hire the best students in the desired field of study. After all, the search can be carried out based on competencies needed by companies, which is a requirement for the employment of graduates.

2. Disadvantages

Basic scientific publications on improving approaches to the development of professional and communicative competencies [6–8] offer special tools for evaluating competencies [9]. The authors investigated the issue of perception and evaluation of the listener's competence [10, 11], 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], expert methods of evaluating OP quality criteria in the field of measuring technology [15, 16], the importance of applied competencies and learning outcomes in the standard of higher education for obtaining the degree of higher education "bachelor" [17]. At the same time, there are no scientific publications on the issues of professional and communicative competencies for a specific specialty and subject area, which remains an urgent task.

3. Goal

The purpose of the study is to develop a method of group expert assessment of the importance of professional competencies and learning outcomes for obtaining a master's degree in the specialty 175 "Information and measurement technologies". To achieve the goal, the following tasks must be solved: analyze the composition and requirements of professional competences and learning outcomes at the second (master's) level of higher education, propose and justify an algorithm for group expert assessment of the importance of professional competences and learning outcomes; establish the priority of professional competences and learning outcomes based on the conducted assessment.

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

According to the provisions of the Law of Ukraine "On Higher Education", the formulation of integral competence for the master's level of education consists of "the ability to solve tasks of a research and/or innovative nature in a certain field of professional activity". The main goal of obtaining the second (master's) level of higher education in the specialty "Information and measurement technologies" is to ensure the training of human resources with a high level of knowledge and technological competencies, able to work in various sectors of metrology, such as national metrology center, calibration, and testing laboratories, research and production institutions of related fields of activity. These professionals must be able to operate in all sectors of the economy directly related to the science of measurement.

The standard of higher education for obtaining a master's degree in the specialty 152 "Metrology and information-measuring technology" provides for the acquirer to acquire such integral competence as "the ability to solve complex specialized tasks and problems in the field of metrology and information-measuring technology, which involves carrying out research and/or implementation of innovations and is characterized by the uncertainty of conditions and requirements" [5]. A prerequisite for obtaining a master's degree is a bachelor's degree. To obtain the master's degree, at least 50 % of the OP volume must be aimed at ensuring general and special (professional) competencies in the specialty.

Special (professional) competencies that are relevant to a specific subject area and important for successful professional activity in the specialty "Information and measurement technologies" at the master's level of education deserve special attention. Also important are the results of training, which determine the normative content of training within this specialty and must be correlated with the defined list of general and special (professional, subject) competencies.

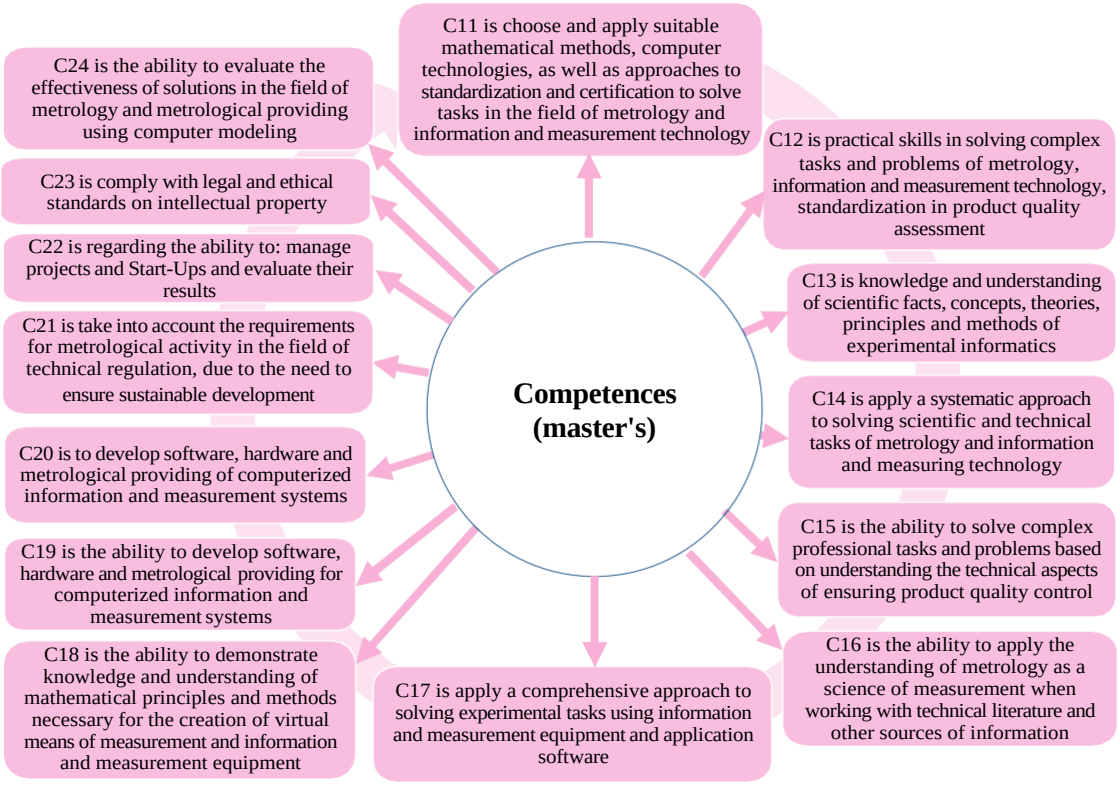


Fig. 1. Professional competencies of masters for specialty “Information and measurement technologies”

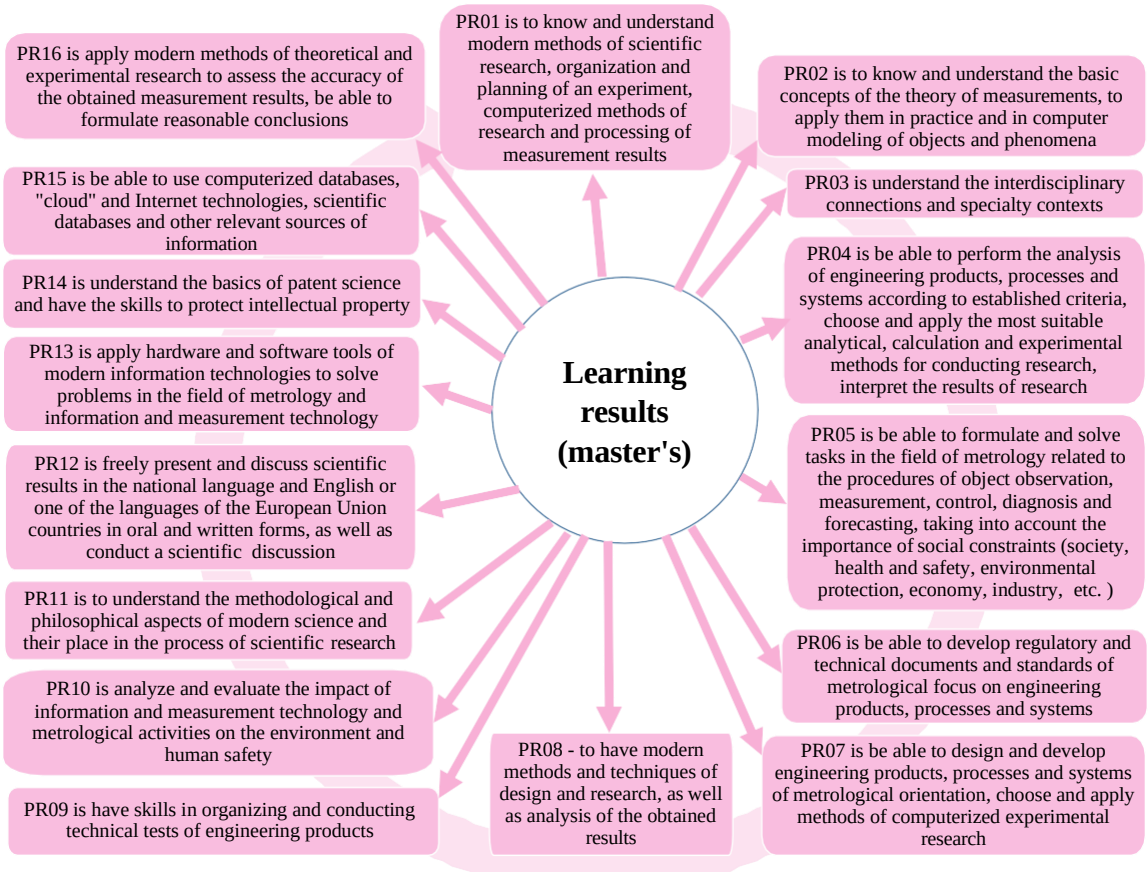


Fig. 2. Learning results of masters for specialty “Information and measurement technologies”

The higher education standard establishes a total of 14 professional competencies (Fig. 1), as well as 16 learning outcomes (Fig. 2) for a master's degree in the specialty "Information and measurement technologies" [5].

Algorithms of group expert assessment, applied in [17, 18], can be used to assess professional competencies and learning outcomes in the field of information and measurement technologies. The competence of each expert involved in the survey plays a significant role in increasing the accuracy and reliability of such an assessment. The selection of experts was carried out taking into account their competence, which is based on such objective data as a scientific degree in a specialty, and work experience in the specified field, in particular in managerial positions. We will assume that the competence of all involved experts is high, therefore taking into account their competence will not lead to significant shifts in the obtained estimates.

The necessary calculations were made using such basic indicators as the average score for each of the N professional competencies and learning outcomes, 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 outcomes as a simple average value (in points), as well as the ranking of the obtained values for each professional competence/learning outcome in the order of decreasing points received. The weighting criterion for professional competencies and learning outcomes is exceeding the obtained average score for all professional competencies or learning outcomes. The application of such a criterion made it possible to form a list of the most important professional competencies and learning outcomes. For clarity of the obtained results, their graphic presentation in the form of corresponding histograms was used.

5. Group expert assessment of professional competencies and learning results for a master's degree

To conduct a group expert assessment of professional competencies and learning outcomes at the second (master's) level of higher education, 18 experts were involved: 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 support" and other technical specialties related to information and measurement technologies took part in the evaluation. A survey of scientific staff was carried out utilizing a questionnaire to assess both professional competencies and training 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 [17, 18].

Fig. 3 and 4 present assessments of professional competencies and learning outcomes for the second (master's) level of higher education (red dashed line – medians of the given values of assessment of professional competencies and learning outcomes, respectively).

The sequence of importance of professional competencies is as follows: C17, C11, C14, C12, C13, and the sequence of least important professional competencies is as follows: C22, C20, C21, C23, C15.

The order of importance of learning outcomes is: PR16, PR02, PR01, PR04, PR13, PR15, PR08, and the order of least important learning outcomes is: PR11, PR10, PR14, PR12, PR06.

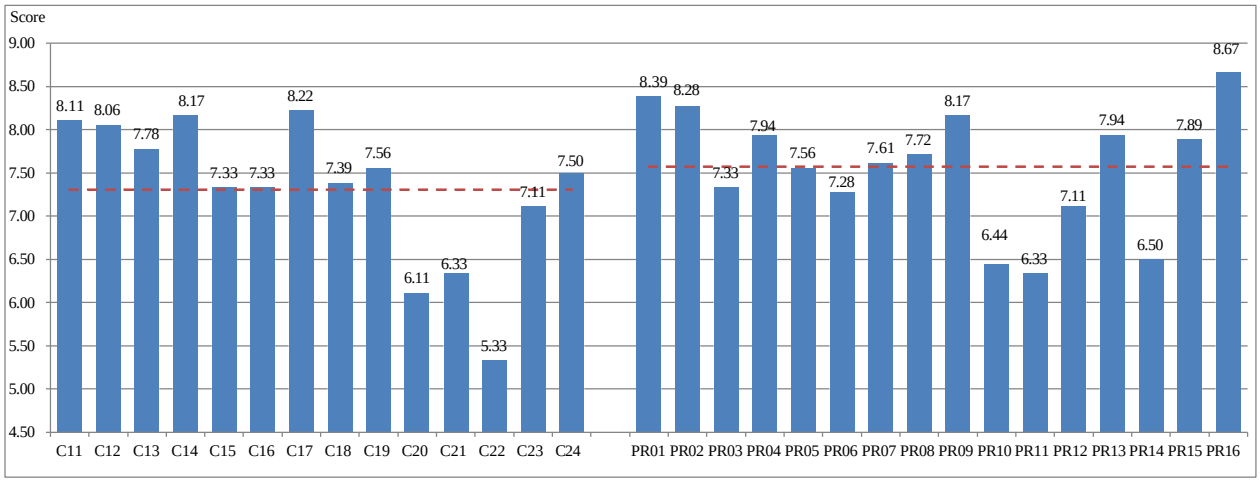
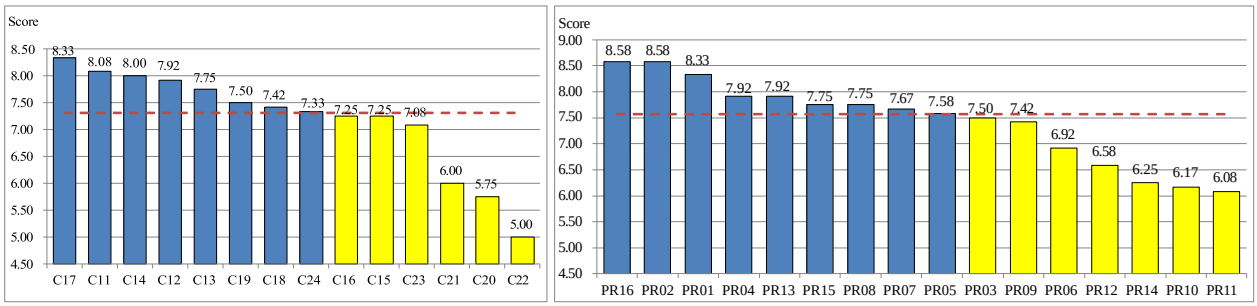


Fig. 3. Expert assessments of professional competencies and learning results for a master's degree in scores



a *b*

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

6. Discussion of the results of the assessment of professional competencies and learning results for the master's degree

In total, 5 (out of 14 – 35 %) professional competencies and 7 (out of 16 – 43 %) learning outcomes were identified.

The most important professional competencies (scores above the average level – 7.26) are the following (from 8.33 to 7.75 scores) regarding the ability to: apply a comprehensive approach to solving experimental tasks using information and measurement equipment and application software (C17, 8.33 scores); 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 (C11, 8,08); apply a systematic approach to solving scientific and technical tasks of metrology and information and measuring technology (C14, 8.00); practical skills in solving complex tasks and problems of metrology, information and measurement technology, standardization in product quality assessment (C12, 7.92).

According to experts, the least impact on the quality of education are the professional competencies (scores below the average level – 7.26) (from 7.25 to 5.00 scores) regarding the ability to: manage projects and Start-Ups and evaluate their results (C22, 5.00 scores); to develop software, hardware and metrological support of computerized information and measurement systems (C20, 5.75); take into account the requirements for metrological activity in the field of technical regulation, due to the need to ensure sustainable development (C21, 6.00); comply with legal and ethical standards on intellectual property (C23, 7.08).

The identification of deficiencies in some professional competencies in most cases indicates that such competencies are formal. Therefore, the specified competencies (C22, C20, C21, C23) require special attention during the next revision of the set of competencies for greater balancing of their system.

The most important learning outcomes (scores above the average level – 7.5) are as follows (from 8.58 to 7.75 scores): apply modern methods of theoretical and experimental research to assess the accuracy of the obtained measurement results, be able to formulate reasonable conclusions (PR16, 8.58 scores); know and understand the basic concepts of measurement theory, apply in practice and in computer modeling of objects and phenomena (PR02, 8.58); know and understand modern methods of scientific research, organization and planning of an experiment, computerized methods of research and processing of measurement results (PR01, 8,33); be able to perform analysis of engineering products, processes and systems according to established criteria, choose and apply the most suitable analytical, calculation and experimental methods for conducting research, interpret research results (PR04, 7.92); apply hardware and software tools of modern information technologies to solve problems in the field of metrology and information-measuring technology (PR13, 7.92), be able to use computerized databases, "cloud" and Internet technologies, scientific databases and other relevant sources information (PR15, 7.75), to have modern methods and techniques of design and research, as well as analysis of the obtained results (PR08, 7.75).

According to experts, the following learning outcomes (scores below the average level – 7.5) have the least influence on the quality of education (from 7.5 to 6.08 scores): understanding the methodological and philosophical aspects of modern science and their place in the process of scientific research (PR11, 6.08); analyze and evaluate the impact of information and measurement technology and metrological activities on the environment and human safety (PR10, 6,17); understand the basics of patent science and have the skills to protect intellectual property (PR14, 6,25); freely present and discuss scientific results in the national language and English or one of the languages of the European Union countries in oral and written forms, as well as lead a scientific discussion (PR12, 6.58); be able to develop regulatory and technical documents and

standards of metrological focus on engineering products, processes and systems (PR06, 6.92).

The identification of deficiencies in many learning outcomes in most cases indicates that they are formal. Therefore, the specified learning outcomes (PR11, PR10, PR14, PR12, PR06) require special attention during the next review of their set for greater balancing of the learning outcomes system.

During the evaluation of professional competencies and training 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 4 professional competencies (C11, C12, C16, C19) and 1 learning result (PR05).

In addition, the experts considered it expedient to expand the list of available competencies for the master's degree and proposed 3 new professional competencies, shown in Fig. 7.

For specialists in the field of information and measurement technologies, it is important to have the ability and skill to standardize the metrological characteristics of measuring instruments (MI) and automated information and measurement systems (AIMS), to formulate metrological and other technical requirements for MI and AIMS, as well as develop methods for their testing. For a metrology specialist, it is important to understand the interaction of the main components of the national and world metrological systems.

During the formation of proposals for changes to the description of competencies and learning outcomes, 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, should be considered and taken into account during the revision of the standard of higher education for master's training in the specialty "Information and measurement technologies".

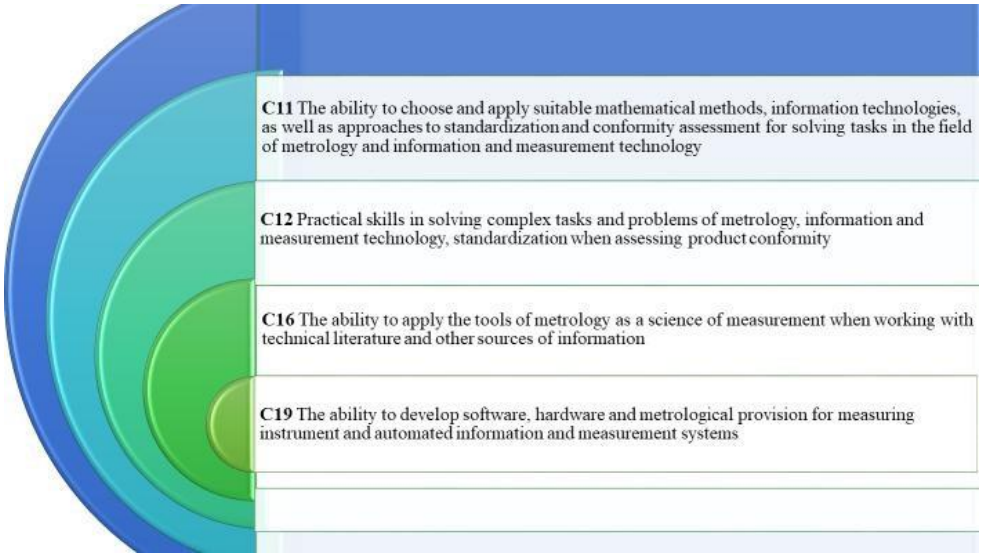


Fig. 5 Changing the description of professional competencies for a master's

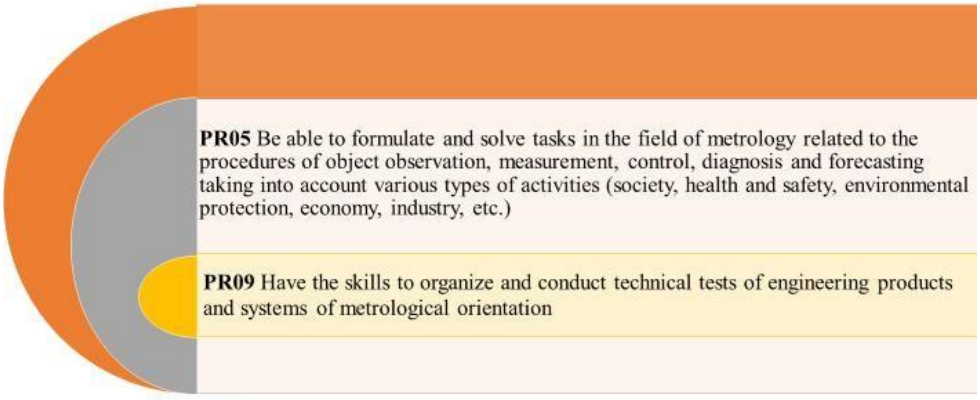


Fig. 6 Changing the description of learning results for the master's

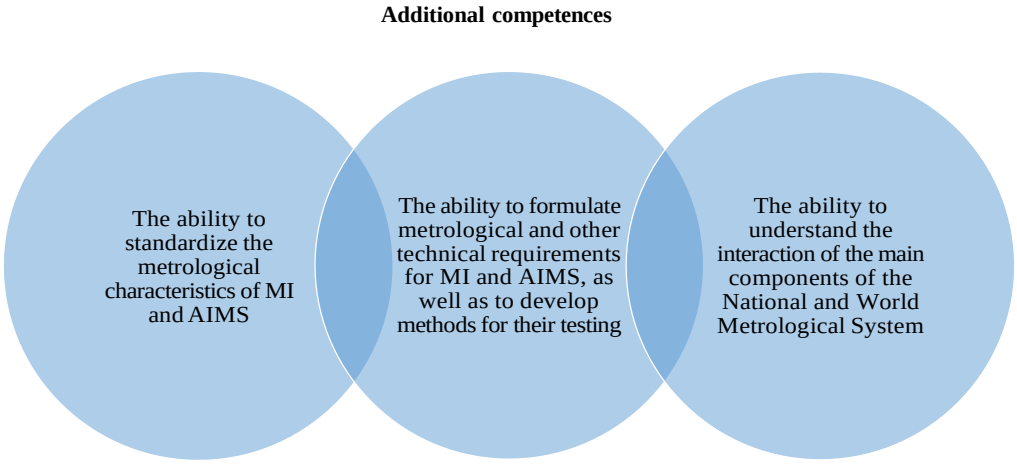


Fig 7 Addition of professional competencies for a master's

7. Conclusions

Based on the results of the research, the composition and requirements of professional competencies and learning outcomes at the second (master's) level of higher education in the specialty "Information and measurement technologies" were analyzed. Changes to the description of competencies and learning outcomes proposed by the experts, taking into account the current state of the industry, should be considered and used when revising the standard of higher education for the preparation of masters in this specialty.

The method of group expert evaluation was applied to determine the importance of professional competencies and learning outcomes using a well-founded algorithm. Based on the assessment, the priority of professional competencies and learning outcomes was established. Universities should pay attention to all established competencies and learning outcomes. At the same time, more attention should be paid to those identified by experts as the most important and those that can significantly affect the quality of education in the specialty.

The establishment of less weighty professional competencies and learning outcomes based on expert evaluations may indicate their formal nature. During the next revision of the standard of higher education for master's training in the specialty "Information and measurement technologies", it is necessary to pay special attention to those competencies and learning outcomes that have the least impact. The professional competencies proposed by the stakeholder representatives also need attention. The results of the study can be used by universities to identify procedures and areas for improvement, which will allow better alignment of curricula, acquisition of competencies, and final learning outcomes.

7. Gratitude

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7. Mutual claims of authors

The authors state that there are no financial or other potential conflicts regarding this work.

Reference

[1] The Standards and guidelines for quality assurance in the European Higher Education Area (ESG). [Online]. Available: https://www.enqa.eu/wp-content/uploads/2015/11/ESG_2015.pdf.

[2] ECTS Users' Guide. Luxemburg: Publications Office of the European Union, 2015, 108 p. [Online]. Available: https://op.europa.eu/en/publication-detail/-/publication/da7467e6-8450-11e5-b8b7-01aa75ed71a1.

[3] International Standard Classification of Education 2011. UNESCO Institute for Statistics, 2012, 88 p. [Online]. Available: https://uis.unesco.org/sites/default/files/ documents /international-standard-classification-of-education-isced-2011-en.pdf.

[4] Resolution of the Cabinet of Ministers of Ukraine dated April 29, 2015 No. 266 "On approval of the list of fields of knowledge and specialties for which higher education candidates are trained" as amended. [Online]. Available: https:// zakon.rada.gov.ua/laws/show/266-2015-%D0%BF #Text. (in Ukrainian).

[5] Order of the Ministry of Education and Science of Ukraine dated May 24, 2019 No. 731 "On approval of the standard of higher education in specialty 152 "Metrology and information and measurement technology" for the second (master's) level of higher education". [Online]. Available: https://mon.gov.ua/storage/app/media/vishcha-osvita/zatverdzeni%20standarty/2019/05/28/152-metrologiya-ta-informatsiyno-vimiryuvalna-tekhnika-magistr.pdf. (in Ukrainian).

[6] E. V. Koren, "Formation of professional competence of students of technical specialties," *Modern scientific*

researches, vol. 2, No 4, pp. 51-55, 2018. DOI: 10.30889/2523-4692.2018-04-02-028.

[7] Maya V. Bernavskaya, "Methodology of a system of professional competence," *Pacific Science Review*, vol. 16, No 2, pp. 81-84, 2014. DOI: 10.1016/j.pscr.2014.08.017.

[8] G. M. Rocha, R. P. Landim, "Inmetro's Metrology Executive Master's Degree Course," *Procedia – Social and Behavioral Sciences*, vol. 46, pp. 4928-4932, 2012. DOI: 10.1016/j.sbspro.2012.06.361.

[9] N. Lukyanova, Y. Daneykin, N. Daneikina, "Com- municative Competence Management Approaches in Higher Education," *Procedia – Social and Behavioral Sciences*, vol. 214, pp. 565-570, 2015. DOI: 10.1016/j.sbspro.2015.11.761

[10] John H. Bond, "Evaluation of Trainee Competence," *Gastrointestinal Endoscopy Clinics of North America*, vol. 5, No 2, pp. 337-346, 1995. DOI: 10.1016/S1052-5157(18)30444-6.

[11] Taina Kaivola, Tiina Salomäki and Juha Taina, "In Quest for Better Understanding of Student Learning Experiences," *Procedia – Social and Behavioral Sciences*, vol. 46, pp. 8-12, 2012. DOI: 10.1016/j.sbspro.2012.05.057.

[12] J. Morrison, W P Fisher Jr., "Measuring for mana- gement in science, technology, engineering, and mathematics learning ecosystems," *Journal of Physics: Conference Series*, 1379, 012042, 2019. DOI 10.1088/1742-6596/1379/1/012042.

[13] Emily Pey-Tee Oon, U Hoi-Ka, W P Fisher Jr., "Metrologically coherent assessment for learning: what, why and how," *Journal of Physics: Conference Series*, 1379, 012040, 2019. DOI 10.1088/1742-6596/1379/1/012040.

[14] M. A. Lope Domingo, J. A. Albajez, J. Santolaria, "The Accreditation of Industrial Engineering in Spain: Teaching and Learning the Skills of Manufacturing Engineering," *Procedia Engineering*, vol. 63, pp. 786-795, 2013. DOI: 10.1016/j.proeng.2013.08.174.

[15] O. Velychko, T. Gordiyenko and A. Salceanu, "Comparative Analysis of Evaluation of the Quality Criteria of Educational Program in Field of Measuring Technology," *2022 International Conference and Exposition on Electrical and Power Engineering (EPE)*, 2022, pp. 93-96, DOI: 10.1109/ EPE56121.2022.9959080.

[16] O. Velychko, T. Gordiyenko, and A. Salceanu, "Group Expert Evaluation of the Quality Criteria of Educational Program in Field of Measuring Technology," *2022 International Conference and Exposition on Electrical and Power Engineering (EPE)*, 2022, pp. 89-92. DOI: 10.1109/ EPE56121.2022. 9959082.

[17] T. Gordiyenko, I. Pototskyi, O. Velychko, I. Kuzmenko, A. Salceanu, "Expert assessment of competencies and learning results for bachelor according to higher education standard in information and measurement technologies," *Measuring equipment and metrology*. vol. 84, No. 1, pp. 32–36, 2023. DOI: 10.23939/istcmtm2023.04.030.

[18] T. Gordiyenko, O. Velychko, and A. Salceanu, "The Group Expert Evaluation in Electrical Engineering Education", in *Proceedings of the 2018 Intern. Conf. and Exposition on Electrical and Power Engineering (EPE 2018)*, Iasi, Romania, 2018, 6 p. DOI: 10.1109/ICEPE.2018.8559787.