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UNIVERSAL MATRIX MODEL OF FORMATION OF COMPETENCE WITH ACCOUNT OF THE FUNCTIONS OF ACTIVITY AND MEASUREMENT OF LEARNING RESULTS BASED ON DUBLIN DESCRIPTORS

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A conclusion on the need of the reciprocal movement of employers and educators in the process of formulating specialist competencies was drawn on the base of the analysis of the priorities of the European Commission. The justification for the principles of the formulation of competencies based on the functions of the activities that are determined by the employer is proposed. The basic oxonmetric proposals for the formulation of the functions of the activity have been developed and substantiated. The design, material, technological, instrumental managerial, business functions were identified. Proposed functions are compared with the curriculum for training specialists in several areas. The principles of measuring of learning outcomes based on Dublin descriptors are defined. It was proposed to strengthen the share of the “autonomy and responsibility” descriptor, the justifications for its formation and measurements are given. For this descriptor in the formation of all the components of competence, formulated with the functions of the activity, it is recommended to provide a real practical result. The forms of training, the most rational for the formation of learning outcomes in accordance with the descriptors of "knowledge", "skills", "communication", "autonomy and responsibility" are substantiated. A matrix model for the formation of competencies based on learning outcomes has been developed. A qualimetric approach to the measurement of learning outcomes is substantiated, on the basis of which the result of training is formed in an explicit form. A criterion for the formation of competences in the form of the surface of learning outcomes is proposed. The real level of competence of a specialist is compared with the requirements of the employer. The possibility of a non-stationary level of learning outcomes was revealed.Comparison of a given and real competence of a specialist should be made by groups of experts in the conditions of the counter policy of employers and educational institutions. The proposed approaches are implemented in the preparation of curricula for a number of specialties.

Keywords: competence, functions of activity, learning outcomes, Dublin descriptors, learning process, autonomy and responsibility, conditions of employers.

Рябчиков М.Л., Курана К. «Універсальна матрична модель формування компетентностей з урахуванням функцій діяльності та вимірювання результатів навчання на основі дублінських дескрипторів»

На основі аналізу пріоритетів Європейської комісії зроблено висновки про необхідність зустрічного руху роботодавців і працівників освіти при формулюванні компетентностей фахівця. Запропоновано обґрунтування принципів формулювання компетентностей на основі функцій діяльності, які визначає роботодавець. Розроблено та обґрунтовано основні оксонметричні пропозиції для формулювання функцій діяльності. Виявлено проектувальну, матеріальну, технологічну, інструментальну, менеджерську, бізнес функції. Запропоновані функції зіставлені з навчальними планами підготовки фахівців за кількома напрямками. Визначено принципи вимірювання результатів навчання, сформованих на основі дублінських дескрипторів. Залежно від рівня дескриптора до таких методів навчання можна віднести іспити і тести, відхилення отриманих результатів від ідеальних, співвідношенням самостійності при виконанні завдань, експертним оцінюванням реальних результатів. Запропоновано посилити питому вагу дескриптора «автономність і відповідальність», наведені обґрунтування його формування та вимірювання. Для даного дескриптора при формуванні всіх складових компетентності, сформульованих з урахуванням функцій діяльності, рекомендується передбачати реальний практичний результат. Обґрунтовано форми підготовки, найбільш раціональні для формування результатів навчання відповідно до дескрипторів «знання», «вміння», «комунікації», «автономність і відповідальність». Розроблено матричну модель формування компетентностей з урахуванням результатів навчання. Обґрунтовано кваліметричний підхід до вимірювання результатів навчання, на основі якого формується підсумок навчання в явному вигляді. Запропоновано критерій формування компетентностей у вигляді поверхні результатів навчання. При цьому реальний рівень компетентностей фахівця зіставляється з вимогами роботодавця. Виявлена можливість нестаціонарного рівня результатів навчання. Зіставлення заданої і реальної компетентностей фахівця має відбуватися групами експертів в умовах зустрічної політики роботодавців та закладів освіти. Запропоновані підходи реалізовані при формуванні навчальних планів ряду спеціальностей.

Ключові слова: компетентності, функції діяльності, результати навчання, дублінські дескриптори, процес навчання, автономність і відповідальність, умови роботодавців.

Рябчиков Н.Л., Курана К. «Универсальная матричная модель формирования компетентностей с учетом функций деятельности и измерения результатов обучения на основе дублинских дескрипторов»

На основе анализа приоритетов Европейской комиссии сделан вывод о необходимости встречного движения работодателей и работников образования при формулировке компетентностей специалиста. Предложено обоснование принципов формулировки компетентностей на основе функций деятельности, которые определяет работодатель. Разработаны и обоснованы основные оксонметрические предложения для формулирования функций деятельности. Выявлены проектировочная, материальная, технологическая, инструментальная менеджерская, бизнес функции. Предложенные функции сопоставлены с учебными планами подготовки специалистов по нескольким направлениям. Определены принципы измерения результатов обучения, сформированных на основе дублинских дескрипторов. В зависимости от уровня дескриптора к таким методам обучения можно отнести экзамены и тесты, отклонения полученных результатов от идеальных, соотношением самостоятельности при выполнении заданий, экспертным оцениванием реальных результатов. Предложено усилить удельный вес дескриптора «автономность и ответственность», приведены обоснования его формирования и измерения. Для данного дескриптора при формировании всех составляющих компетентности, сформулированных с учетом функций деятельности, рекомендуется предусматривать реальный практический результат. Обоснованы формы обучения, наиболее рациональные для формирования результатов обучения в соответствии с дескрипторами «знания», «умения», «коммуникации», «автономность и ответственность». Разработана матричная модель формирования компетентностей с учетом результатов обучения. Обоснован квалиметрический подход к измерению результатов обучения, на основе которого формируется итог обучения в явном виде. Предложен критерий формирования компетентностей в виде поверхности результатов обучения. При этом реальный уровень компетентностей специалиста сопоставляется с требованиями работодателя. Выявлена возможность нестационарного уровня результатов обучения. Сопоставление заданной и реальной компетентностей специалиста должно проводиться группами экспертов в условиях встречной политики работодателей и заведений образования. Предложенные подходы реализованы при формировании учебных планов ряда специальностей.

Ключевые слова: компетентности, функции деятельности, результаты обучения, дублинские дескрипторы, процесс обучения, автономность и ответственность, условия работодателей.

Problem statement in general

Among the priorities of the European Commission one of the main is to increase investment in employment. An integral part of this process is the training of specialists. The European Union, within its common market, seeks to create uniform conditions for its inhabitants. One of the steps in this direction is the Updating the International Standard Classification of Occupations [1], which involves the unification of fields of activity and qualifications for performing various jobs. In particular, they include: "Managers, Professionals, Technicians and associate professionals, Clerical support workers, Service and sales workers, Skilled agricultural, Forestry and fishery workers, Craft and related trades workers, Plant and machine occupants, and assemblers, Elementary occupations" .

Each profession must take into account a certain set of skills, which in modern pedagogical science is defined as competences.

In the documents of the European Commission, the process of the formulation of competencies is of a bilateral character. The education sector has begun creating standards based on a competence-based approach with the involvement of the Tuning project, Dublin descriptors etc.

Solving the problems of creating jobs, employment requires an active counter process from employers, business representatives. They should confirm or clarify the appropriateness and the need to form competences in educational institutions.

In this paper, an attempt of organizing this process in order to form real, business-relevant competencies has been made.

The state of the issue, the allocation of unresolved parts of the problem.

A number of works are devoted to the problems of the formation of competences. In this case, both the competencies themselves and the process of their formation are described.

The article [2] introduces a dynamic morph model to measure the dynamics of the formation of competencies. Morphing is considered as a tool for smooth transformation of key indicators of students. For this purpose the materials of journals and questionnaires are analyzed. The advantage of this approach consists in the continuous monitoring of the formation of competencies based on the morphological analysis of learning outcomes. In contrast to the existing discrete methods, the morphing model allows us to trace the learning outcomes in the process of their constant measurement and transformation, which, in the opinion of the authors of the article, significantly increases the level compared to the existing monitoring methods. The problem, in our opinion, is a clear selection of the key support stages for determining the results of training, as well as the justification of an adequate mathematical model of morphing between these stages.

In article [3], an attempt was made to justify a model for determining professional identity using the example of vocational education in Spain. The structure of specific competences for each professional profile was determined; the functions of activity for individual profiles were described. In this case, the method of expert evaluation was used. In our opinion, the study did not sufficiently use the generalization method for the inductive formation of the most general functions of an activity to establish a specific professional identity.

In work [4], attention was drawn to the main megatrends facing education researchers. The main requirements of the macro level to education are described. These include structural changes in the labor markets, training as an important aspect of the employer. The requirements for effective training are grounded. References are made to certain professional functions. Unfortunately, this study did not analyze the actual requirements for learning outcomes.

The 28th EAEEIE2018 conference [5] presented the experience of the Portuguese education system for the accreditation of a master's degree. It was emphasized that the main goal is to ensure a high level of quality, specifically focused on the professional environment. The structure and organization of a master's degree is justified by a set of core professional competencies. It is envisaged that this structure corresponds and is justified by the structure of the Dublin descriptors, and the learning outcomes correspond to the cooperation of education and industry. It would be useful to summarize these results for other educational levels and areas of training.

In [6], an attempt was made to construct an extrapolation model in which cognitive achievements based on the measurement of the first years of schooling can serve as the strongest predictors for predicting learning outcomes. An attempt was made to highlight the prognostic goals of the gradual measurement of learning outcomes. In our opinion more deep research is needed in this direction to substantiate extrapolation during studying various levels of learning outcomes in the formation of competencies.

Research [7] describes the development of criteria for measuring learning outcomes using a scale of student engagement. Key aspects of student engagement include (1) academic involvement, (2) cognitive involvement, (3) social involvement with peers, (4) social involvement with teachers and (5) emotional involvement. Despite the rationale of a multifaceted design with academic, cognitive, social and emotional aspects, this model should be considered as auxiliary-motivational. In our opinion, it does not provide the main task of the formation of competences, the results of which are substantiated by Dublin descriptors [8–9].

In [10], issues of evaluating learning outcomes in the field of non-formal engineering education were discussed. The need for a multifactorial direct measurement with a triangulation analysis is emphasized. We believe that these recommendations can further justify a multi-dimensional measurement of learning outcomes based on the dynamics of their formation.

Learning outcomes in most modern studies [11–12] are considered as the main driving force behind the development of education, which involves the development of new forms of measurement. It is emphasized in [13] that in any case, this direction should support reflection and communication around teaching methods. In addition, it justifies the need to develop standardized and reasonable means of measuring higher learning outcomes.

The purpose of the study [14] was to develop the competences of teachers to meet the scientific standards of the next generation. It is studied how teachers perceive engineering and pedagogical developments within the framework of the epistemological structure of the required components of the subject area. The formed structure is rather generalized. The main value of the proposed approach is to focus on the future, justifying the three-year phase for the formation of future competencies.

Article [15] identifies the conditions that provide employee-oriented training and innovation that have contributed to improved production in small and medium-sized enterprises in Sweden. The results provide directions for training specialists who are adapted to the context of modern production needs.

In [16], an attempt was made to formulate a real plan for a specific specialty based on the competence-based approach, taking into account the real functions of a specialist.

The purpose of this article is to formulate general approaches to the formation of competencies based on the functions of the activity and the measurement of learning outcomes based on Dublin descriptors, taking into account the bilateral movement of business and education requirements.

To form the necessary competencies of a graduate of an educational institution, it is necessary to proceed, first of all, from the demands of consumers. In our case for educational institutions they are employers. The possibility of iterative design of educational content, taking into account the influence of employers for the light industry, is shown, for example, in [17]. At the same time, the conditions of employers act as a kind of competency gauge, which graduates receive and serve as a source of feedback for the correction of educational content (Fig. 1).

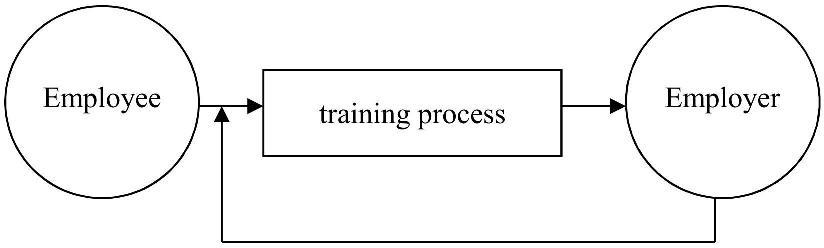

Fig.1 The correction by the employer of the training process according to [17]

Despite the fairly high validity of this approach, we can note the difficulties of its application. Discussion of the problems of providing light industry specialists with specialists at the Light Industry Cluster of the Kharkiv region of Ukraine showed a number of problems that arise in the communication of employers and educational institutions. Each individual employer can set specific tasks for a specialist. Employers, as practitioners in some cases find it difficult to formulate the needs of their production in the form of competencies. This problem can be solved by summarizing the needs of employers in a separate cluster and introducing the wording of competencies by specialists in the field of education. The second problem, which was discussed on the light industry cluster, is related to requests for reducing the time needed for training specialists. This request, in addition to the obvious request for the rapid acquisition of specialists, is primarily due to the rapid development of technology, the constant introduction of new processes and equipment. According to the employers of the Kharkov light industry cluster, the turnover of production processes occurs about once every three years. This is the maximum period of training a specialist, acceptable for a modern employer. By the way, this time period corresponds to the term of preparation of bachelor in many universities in Europe.

Taking into account the latter fact, the time to provide a tough feedback according to Figure 1 may simply not remain. Probably, the scheme for managing the process of training specialists in modern conditions should be adjusted to the requirements of the competence approach.

Another task that is put by employers to educational institutions is a significant increase in practical training, real graduate skills that can be achieved during practical training in the conditions of dual training, inter-production and intercultural communication, which requires, among other things, practice in international conditions with taking into account the global advanced technology. Such practices require additional linguistic and intercultural competencies [18].

These conditions put forward as a starting point for the formation of the learning process definition of the functions of activity characteristic of each individual industry. During studying such functions, a bilateral-integrated analysis of the production tasks of existing curricula for various specialties is necessary.

In our opinion, the procedure for the formation of functions of activity should be begun with the formulation of the main issues with which a separate branch of activity meets.

We offer the basic six most common questions that require an answer in most industries.

1. What to do?
2. With the help of what to do?
3. How to do (methods)?
4. How to do (order, algorithm)?
5. Who to do with?
6. What the reason to do?

The first question in this formulation is quite general and can be represented as a philosophical view of the meaning of life. In our understanding, this question should be of a specific nature, and it presupposes an answer about a specific object, which the specialist will deal with. When answering a question, an expert should create an image of what will be created. This process first must be mental, later - on paper or electronic media. The result of this process should be information that is suitable for implementation in a material form. In most cases, this process is known as design or pattern making - the preparation of documents necessary to create an object that does not yet exist. In this case, calculations, itemization of the object and its optimization can be applied.

Analysis of the curricula of various specialties (table 1.) shows that this component is in most of them. At the same time, it is possible to single out preparatory components that form the theoretical foundations that allow this function to be performed and the professional ones, which allow the design process for a particular profession to be carried out. As can be seen from table 1 the theoretical foundations of this function are formed in the study of mathematics, engineering and computer graphics, special components on the subjects with the names “design”, “pattern making”, ”project”. As an example, Table 1 shows the specialty “Technology of light industry”; the design function is provided by the subject “Designing of Clothes” and the specialty “Mechanical Engineering” —the design function is provided by the subject “Designing of Machines”.

For the “Design” branch of activity, drawing, painting, art history can be classified as basic subjects, providing design function, artistic design as a general concept, or special artistic design depending on specialization can be referred to as special subjects.

Table 1

Activity functions

№	Tasks	Functions	Light industry		Mechanical Engineering		Design	
			Підготовчі	Фахові	Підготовчі	Фахові	Підготовчі	Фахові
1	**What to do?**	**Design (pattern making)**	**Mathematics, engineering and computer graphics**	**Pattern making**	**Mathematics, engineering and computer graphics**	**Machine design**	**Drawing, painting, art history**	**Artistic design**
2	**With the help of what to do?**	**Materials**	**Chemistry**	**Materials science of sewing products**	**Chemistry**	**Materials science**	**Color studies**	**Artistic material science**
3	**How to do (method) ?**	**Instrume ntal**	**Physics, Applied Mechanics**	**Equipment for sewing production**	**Physics, Applied Mechanics**	**Metal-cutting machine tools and equipment**	**Compositio n basics**	**Fundament als of image theory**
4	**How to do (order, algorithm) ?**	**Technolo gical**	**Computer Science**	**The technology of sewing products**	**Applied Mechanics, Computer Science**	**Technology of mechanical engineering**	**History and theory of design**	**Special technologie s in design, computer technology in design**
5	**Who to do with?**	**manageri al**	**Fundamental s of economics and production organization**	**Development of sewing enterprises**	**Fundamental s of economics and production organization**	**Development of machine building enterprises**		**Manageme nt in design**
6	**What the reason to do?**	**Business**	**Psychology**	**Marketing and merchandisin g in the industry**	**Psychology**	**Marketing and merchandisin g in the industry**	**Psychology**	**Marketing and brandying in design**

The second question of the proposed system “Using what to do?” Can be reformulated as “From what to do?” It assumes the ability of a specialist to select the necessary source materials so that the object conceived can be realized in reality. Usually in the existing curricula, special subjects in this regard are disciplines with the title "Materials Science".

In the machine building industries, these can be metal and non-metallic materials, in light industry - textile materials, in design - materials used in the performance of artwork. The initial subjects that provide specialty in the first two cases should be chemistry, or more advanced courses, such as physics and chemistry of polymers. For artistic specialties, such as design, color science can be added to them, which in this case largely determines material properties.

After answering the questions “what” and “from what” the natural question arises is whether it can be done at all. In our scheme, the question is “how to do it?”

In turn, the problem of "how to do" can be divided into two. The first involves devices, appliances, tools that will be needed to implement the proposed project. In the existing curricula for various specialties, the courses “Equipment for sewing production”, “Metal-cutting machines” and others can answer for this question. Providing these courses involves the study of physics, theoretical and applied mechanics.

The second part of this question involves the development of an algorithm, the order of implementation of the developed idea, the ability to be provided with technology courses (sewing technology, engineering technology, special technologies in design) and, depending on the specialty, involve the study of computer science, physics, chemistry, history and design theory.

The question “With whom to do?” is determined by the peculiarities of social production, in which the specialist acts as a leader, organizer. Manager's functions are reflected in special courses for training specialists (table 1).

All the above questions may not be realized without the last question - “What the reason to do?”, which determines the possibility of implementing an idea, project, material embodiment in market conditions. Education of relevant abilities is implemented in the courses "Marketing and merchandising in the industry". At the same time, besides the above, it is likely to study courses related to consumer psychology.

The described functions, in our opinion, describe quite fully and universally the requirements for specialists, which are mainly put forward by the employer.

The functions of the activity agreed upon with the employer are the basis for the formulation of the competencies that a graduate of an educational institution should possess.

In accordance with the proposed scheme, these are competencies in the field of design, materials science, equipment, technology, management, and marketing.

After establishing the list of necessary competencies, the next problem arises, requiring coordination between employers and educators on measuring the level of established competences. According to the opinion of most specialists in the field of education, the main means of measuring competencies should be learning outcomes [11–12].

We propose to consider learning outcomes in the context of the accumulation of competencies and the measurement of their level. In our opinion, the Dublin descriptors system can adequately reflect the levels of learning outcomes.

We accept the formulation of descriptors in the composition:

Knowledge;

Skills;

Communications;

Autonomy and responsibility.

In this case, the first two descriptors are left almost without comment, the communication descriptor will be understood as the ability to find and update information within individual competencies.

The descriptor autonomy and responsibility in most cases is understood as the ability to further improve the specialist. We propose to add to this the direct meaning of the word responsibility. This implies a significant increase in the practical orientation of the educational process with the mandatory final realization of learning outcomes.

In this case, the descriptor system implements the learning outcomes in the form of a sequential incremental system within each competence (Table 2).

For example, for component of competence "design", the "knowledge" descriptor should define the basic principles, approaches, calculations. The "skill" descriptor defines the ability to visualize calculation ideas. Probably, it should include the possession of modern computational graphical tools CAD / CAM / CAE, the ability to visualize models, the implementation of drawings and drawings, layout. The "communication" descriptor implies the ability to search for information, summarize it, and readiness to introduce new knowledge. For the competence in question, this item should include the ability to search for promising CAD / CAM / CAE tools, comparing them with existing ones. The highest level of competence in our model is achieved in the conditions of using the "autonomy and responsibility" descriptor. If one perceives the given descriptor as close as possible to its meaning, then its strongest implementation can be a demonstration of a real model that is supposed to function. Within the boundaries of competence, "design" we are still talking only about the reality of the project, which can and should be modified to reflect the other components of competence.

Table 2

Competences and Learning outcomes

Descriptors / Складові	Knowledge	Ability	Communication	Autonomy and Responsibility
Design (pattern making)	Basic principles, approaches, calculations.	Graphic, CAD / CAM / CAE use, model visualization, layout	Comparison of modern and advanced methods with traditional CAD / CAM / CAE	Real model operates
Materials	Main properties, composition, means of obtaining, interaction	Definition of the main characteristics of materials	Possibility of use of perspective, in particular nanomaterials	The proposed materials are available, meet the requirements of functionality and environmental friendliness
Instrumental	Principles of operation of the equipment, main characteristics, directions of use	Exploitation of the main technological equipment	Promising equipment, in particular automatic and semiautomatic with digital control	The offered facilities are available, meet the requirements of functionality and environmental friendliness
Technological	Processing modes, methods of creating the form, methods of connection	Development and control of the technological process in the production	Research and implementation of advanced, promising technological processes	The developed sequence provides greater efficiency compared to the base one
Managerial	Labor psychology, basics of labor protection, labor legislation	Planning, distribution, analysis of time expenditures, communication	New types of organization, in particular adaptive management	Relation of the team during internship or probation period
Business	Bases of psychology, legal bases of business	Communication, emotional recognition, negotiation, presentations	Surveys, marketing search, introduction of innovations	Trial samples made as a result of training, realized on the market
Organizational forms	Lectures			
	Practical and laboratory classes			
		Training practices		
			Course project	
				Graduate project
Control and Measurement	Estimates on examinations and tests	Deviations from the given (normalized) results	Percentage of information obtained independently	Expert evaluation

In the described conditions, all the proposed descriptors take the form of explicit learning outcomes that can be measured and evaluated.

Competence associated with the choice of materials at the level of "knowledge" should take into account the basic properties, composition, methods of production, interaction of materials. Skills for this component of competence include defining the basic characteristics of materials. The “communication” descriptor determines the ability to search for materials that are not directly available, the possibility of using promising materials, in particular materials with nano properties.

Considering our interpretation of the “autonomy and responsibility” descriptor at this level, it is necessary to be able to prove that these materials meet the structural, technological requirements, as well as the requirements of functionality, efficiency and environmental friendliness.

The component of competence associated with the selection and operation of equipment, tools to ensure the implementation of a given project at the level of knowledge should take into account the principles of operation of equipment, basic characteristics, and directions of use. The “skill” descriptor within this competence provides for the ability to operate the main process equipment. The “communication” descriptor provides for the ability to find promising equipment, in particular, automatic and semi-automatic with digital control. The “autonomy and responsibility” descriptor should take into account that the proposed solutions are available;

meet the requirements of functionality and environmental friendliness.

The technological component of competence provides knowledge in the field of processing modes, methods for creating forms, methods of connection. Within this competence, the specialist should be able to develop and control the technological process. In terms of communication, it is necessary to study and implement advanced and promising technological processes. Responsibility should be expressed in the fact that the proposed technological sequence provides greater efficiency compared with the base.

Organizational competence provides for the work of a specialist as a manager who must know the basic provisions of labor legislation, the basics of labor protection, and labor psychology. Within this competence it is necessary to be able to communicate, plan, distribute, and analyze time and material costs. Using various types of communication, the specialist should become familiar with new types of organization, in particular, with adaptive management. Responsibility is determined by the attitude of the team during the internship or practice.

Business competence determines the feasibility of a product developed and manufactured. It is based on knowledge of psychology, the legal foundations of business. Within this competence, a specialist should be able to communicate, recognize emotions, negotiate, and conduct presentations. A “communication” descriptor within a given competence implies conducting surveys, marketing search, and introducing innovations. The highest form of autonomy and responsibility within a given competence can be the actual implementation on the market of test samples made in the learning process.

As a result, the general model of the formation of competencies takes the form of a matrix (Fig. 2). The initial data in this model are the functions of activity for a profession. They can be selected from the above considerations or formulated by specialists. There may be several such functions; we denote their total number n. Basic competencies are formed on the base of the functions of the activity. The number of competencies should correspond to the number of functions of the activity.

Competency descriptors must be formulated. They determine the completeness of their development. Although Dublin descriptors are currently used to describe competences, their number or interpretation may differ in different cases. Descriptors must match learning outcomes.

As a result, separate elements of the competence matrix are formed at the intersection of individual components of competence and learning outcomes. These items must be measurable and comparable. The sum of elements for individual lines indicates the level of relevant competence, the sum of elements in columns indicates the level of an individual descriptor (knowledge, skills, communication, autonomy, responsibility. The sum of all elements of the matrix indicates the overall level of competence of a specialist.