Competency-based Approach to the Assessment of Professional Training for a Medical Student to Work with Medical Equipment

Usen Baizak
Ahmet Yesevi University, Turkistan, Kazakhstan
ubayzak@mail.ru

Kanapiya Kudabayev
South Kazakhstan State Pharmaceutical Academy, Shymkent, Kazakhstan

Mariya Dzhazdykbayeva
Ahmet Yesevi University, Turkistan, Kazakhstan

Gulmira Assilbekova
Ahmet Yesevi University, Turkistan, Kazakhstan

Bahyt Baizakova
Ahmet Yesevi University, Turkistan, Kazakhstan

Aigul Mintassova
Ahmet Yesevi University, Turkistan, Kazakhstan

Abstract—The article solves the problem of describing the professional training for a medical graduate in terms of competency-based approach and identification of ways to develop these qualities to work with medical equipment. A model for the competence formedness level assessment has been elaborated, which indicates all its input and output parameters.

On the basis of the developed methods and algorithms for calculating the competence formedness level for the training course 'Anesthesiology, Resuscitation, and Intensive Care' a calculation has been made of all the required importance coefficients of the courses, their modules, and other learning activities involved in the formation of competences.

Keywords—competency-based approach, assessment of competencestowork with medical equipment

1   Introduction

Each student enters a medical school with a unique propensity, certain knowledge, experiences, expectations, and perhaps with a sense of vocation. The importance of

the student's compliance with the medical school in terms of having the necessary knowledge base, including natural and liberal sciences, which actually makes an educated person, is generally acknowledged. At present, there are different approaches to the curriculum design in a medical school overseas, such as a curriculum based on organ systems that focuses on the syllabus organization; a curriculum on the basis of the competency-based approach aimed at learning outcomes; a program based on teamwork, where more attention is paid to teaching methods. However, all the existent programs are focused on certain parts of the complex system, but do not take into account how the other components of the educational process are subject to change and interact with each other [Bordage, Harris, 2011]; that is, it has become necessary to find an optimum approach to the creation of modern curriculum design in a medical school, and the essence of the competency-based approach requires more attention.

Over the last 20 years, the attitude to the competency-based approach in medical education has been rather contradictory. It is generally accepted that the competency-based movement emerged to introduce behavioral goals in the education of the 1960s and 1970s [Jolly, 2012]. Gradually, however, an interest developed in the prospects of the competency-based approach because of the obvious useful principles that remain unaltered:

1) the focus on learning outcomes; 2) a better compliance and preparation for the actual practice; 3) the potential to eradicate the specialist training time-binding; 4) an increased recognition of skills; 5) the improvement of credit transferability between universities [Jolly, 2012].

In other countries, the evolution of the competency-based approach ideas in medical education, which originated in the early twentieth century, led to the fact that responsibility, learning outcomes, the individualization of the educational process, and avoiding the time-dependent curriculum design became the main aspects of the competency-based approach. Recently, the desired learning outcomes have been defined by the key competences or roles, which a medical graduate must have or fulfill. In the US, the Accreditation Council for Higher Medical Education identifies the following competences: patient care, medical knowledge, practice-oriented training, interpersonal communication skills, professionalism, and medical practice based on human systems [Bordage, Harris, 2011]. The Council has also developed a concept of clinical milestones on the basis of 6 generalcompetences. These are the categories of clinical skills, in which students should demonstrate a growing skill and determine the speed, at which they progress in the course of training. A similar approach is presented in the form of confidential professional activities that are specific behavioral situations where a competent specialist must demonstrate an acceptable level of skill and interaction. These subcompetences, i.e. the core competences, the generic competences, the confidential professional activities, etc., represent the beginning of the classification schemes that bind the abstract competences and the observable behavior through a series of intermediate taxonomic categories. In Canada, the roles of a medical university graduate are defined by the Royal College of Physicians and Surgeons: a medical expert, a communicator, a team worker, a manager, a health advocate, a scholar, and a professional. These roles comprise over 28 specific core competences, which

are then fleshed out as 126 generic competences [Bordage, Harris, 2011]. Thus, the six competences a physician must possess have been developed in the US (ABMS/ACGME); seven ones – in Canada (CanMeds), seven ones – in the Institute of International Medical Education (IIME), and 12 are represented in the Dundee outcome model (DOM).

The most obvious congruence is observed only in the first two competences that can be classified as professionalism and communication skills [Albanese et al., 2008]. These differences may have arisen due to the fact that, although several lists of competences are presented, there is no precise competence definition content. Moreover, so far there have been disputes about the separation of the concepts of 'competence' and 'competency'. The difference between a competence and competencyis presented in one of the articles [Fernandez et al., 2012], where competences are considered as the means selected for special tasks, whereas competency is regarded as a more extensive concept, including the integration of variety of skills and abilities.

In the literature, the following definitions of competency can be found, that is, 'what it means to be a competent physician': 1) able to provide medical care and/or other professional services in accordance with the standards of practice established by the members of the profession and meeting the expectations of society [Whitcomb, 2002]; 2) a complex composition of behavioral situations, based on the knowledge, skills, attitudes, and competency as a personal aptitude [Carraccio, 2002]; 3) a set of skills, knowledge, and attitudes required for the general practice of public health [Albanese, 2008]; 4) significant observable knowledge, skills, and attitudes [Bhatti, Cummings, 2007]; 5) the knowledge, skills, attitudes, and personal qualities necessary for medical practice [Calhoun, 2002].

2 Terms of Reference

The new paradigm of education should be oriented to the needs formation in constant replenishment and updating of knowledge, improving skills and expertise, their consolidation and transformation into competences. In particular, the paradigm of knowledge in education should be reconsidered from the perspective of the competency-based approach.

A long-standing practice of drawing up qualifying professional characteristics of a specialist has existed in the national education system in relation to higher education, which enshrined requirements for expertise and skills of graduates in different specialties where, in addition to the knowledge paradigm, the terms 'readiness', 'ability', 'responsibility', 'understanding', and 'worldview' are present, extending the narrow confines of such a paradigm. At the same time, the very principles of the specialist model development have been subjected to critical analysis and improved. Thus, N.F. Talyzina points out that 'the description of the education purpose (the specialist model) means a representation of either a system of typical tasks, or a system of skills (activities) pertinent to them'.Itis also emphasized that the structure of the specialist model should envisage: 'a) tasks (activities) determined by the peculiarities of the century; b) the tasks determined by the peculiarities of the social and political for-

mation; c) the tasks imposed by the requirements of the profession' [Bhatti, Cummings, 2007]. These general requirements for the education goals specification are still valid at the present time and contribute to the modernization of education.

The need to describe personality traits of high school graduates in terms of the competency-based approach is long overdue, and Bologna Process requires a common understanding of the content of qualifications and degrees in all the participating countries' curricula and designates general and specific competences of graduates as a joint effort priority area[Baizak, 2015].

The medical graduate's professional activity description in terms of the competency-based approach and the identification of ways to develop these qualities to work with medical equipment is considered to be one of such tactical tasks.

3 Methods

The model of the competence formedness level assessment.

Currently, universities and colleges are facing quite an acute problem of training future specialists and identifying their professional orientation. As a result of the educational process transition to the new standards, a new approach both to the learning process and to the assessment of students' knowledge and progress is to be developed. The main distinguishing feature of this approach would be that there is a transition from the formation of traditional expertise and skills to the formation of competences, expressing the professional orientation of students and future graduates. This would allow human resources departments in enterprises to select budding specialist more carefully [Baidenko, 2005].

Let us consider an approach to the assessment of students' progress moving away from the standard models, in which students learn the subjects and receive grades, and going to a model, in which the student's professional level constitutes a set of competences in order to determine their future professional orientation.

Formally, the model of a student and a graduate being trained and having received an education can be represented as follows [Bermus, 2005]:

$$M = \{PC, CC, A, W, N, S\}, \tag{1}$$

where M is the conventional symbol for the model of a student or a group of students;

PC is set of professional competences that a graduate possesses upon graduation;

CC is a set of comprehensivecompetences a graduate possesses upon graduation;

A is a set of indicators and methods of assessing the level of competence formedness, according to the subjects studied;

W stands for weighting coefficients of competences (characteristics) and their formative subjects;

N stands for norms;

S means scores and gradesin the studied subjects and their modules, and other types of training activity.

The interconnection of the specialist components is shown in Fig. 1.

This diagram shows how the components forming the competences of students throughout their training period are interrelated. The quality standards are a very important component; they determine what level of quality the professional characteristics developed in a graduate must have.

This component is determined by employers interested in the industry specialists. Human resources departments should have relevant professionals working with universities and colleges.
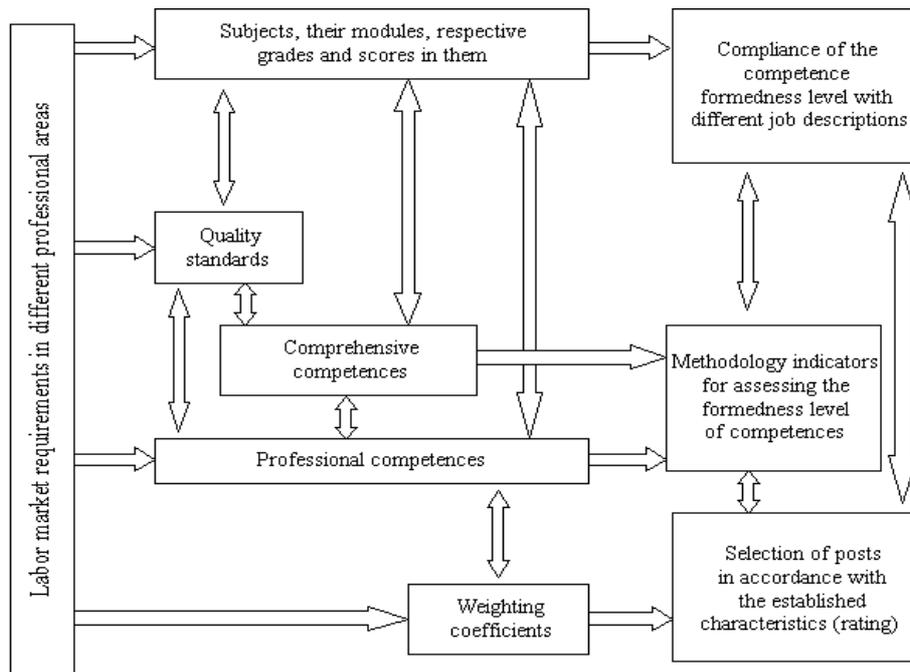

Fig. 1. The interrelation of the student model components

Many indications that characterize the level of formedness of each competence separately are as follows:

$$C = (Y_i\,(MY),\ T,\ S,\ U,\ G,\ E), \tag{2}$$

where C is the competence, the outcome of the i-*th* subject upon the completion of its course;

S is the entire set of subjects studied by a trainee throughout the learning period and participating in the formation of a competence (throughout a course, a semester, all the training, etc.);

T stands for the set of subjects involved in the formation of a competence;

U is the definition evaluation nominal scale [Umin, Umax], where the left limit is minimum allowable, the right limit is maximum allowable;

E is the measurement error taking into account the number of subjects involved in the formation of a single competence;

G is the final grade inclusive of all the subjects; can be given only upon the completion of training.

Then, the mathematical model of the approach to assessing the formedness level of each competence, developing in the student in the process of learning, is described as follows and depends on the following parameters [Yefremova, 2010]:

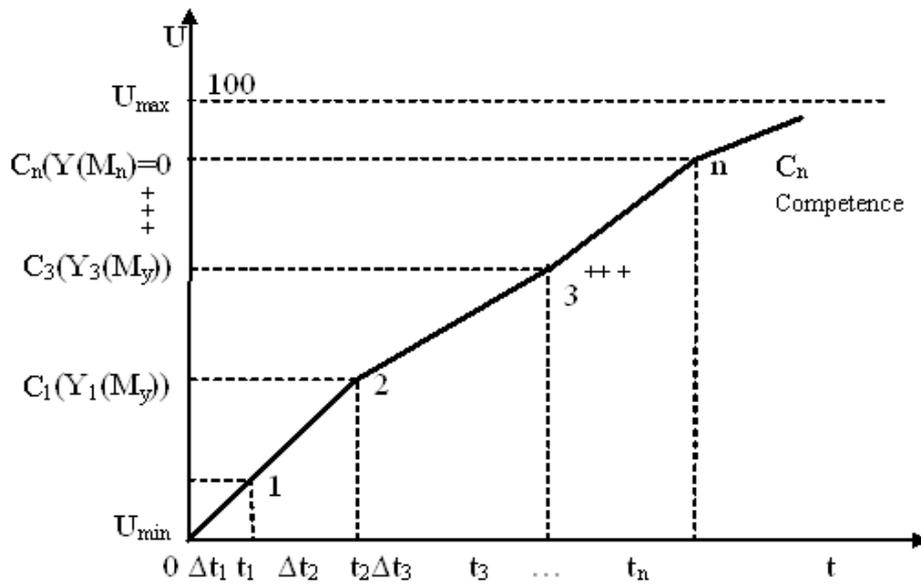$$\begin{cases} G = G(Y,U) \\ C = C(Y,U,S,T,G,E) \\ C \geq U_{min} \end{cases} \tag{3}$$

Fig. 2. The components dependency graph

The curricula prescribe two types of competences (general cultural ones - GC, professional ones - PC), which are formed in each student enrolled in a certain course; they can be represented as a matrix, as shown below:

$$M_G = \begin{pmatrix} CC_{11}CC_{21}CC_{31} \dots CC_{n1} \\ CC_{12}CC_{22}CC_{32} \dots CC_{n2} \\ CC_{13}CC_{23}CC_{33} \dots CC_{n3} \\ \dots \quad \dots \quad \dots \quad \dots \quad \dots \\ CC_{1m}CC_{2m}CC_{3m} \dots CC_{nm} \end{pmatrix} \tag{4}$$

$$M_P = \begin{pmatrix} PC_{11}PC_{21}PC_{31} \dots \quad PC_{n1} \\ PC_{12}PC_{22}PC_{32} \dots \quad PC_{n2} \\ PC_{13}PC_{23}PC_{33} \dots \quad PC_{n3} \\ \dots \quad \dots \quad \dots \quad \dots \quad \dots \\ PC_{1m}PC_{2m}PC_{3m} \dots \quad PC_{nm} \end{pmatrix} \tag{5}$$

Where *CC* stands for comprehensive competences;

PC means professional competences;

n is the number of a competence;

m is the number of a student.

Thus, the dependence of all the components of competences on the subjects looks as follows:

$$C_i(t) = \begin{pmatrix} C(S_n(t), \ M_m(t)) \\ C_2(S_n(t), \ M_m(t)) \\ \dots \dots \dots \dots \dots \dots \dots \dots \\ C_i(S_n(t), \ M_m(t)) \end{pmatrix} \tag{6}$$

where $C_i(t)$ are the competences formed in a student, their values changing over time, in the course of studying the subjects;

$S_n(t)$ are the subjects studied throughout the training period;

$M_m(t)$ are the modules studied in the cycle of each subject, during a semester or the whole course.

Thus, it is obtained that the values by the competence formedness level depend on grades in the subjects and their modules that change over time, in the course of studying the subjects involved in the formation of a particular competence; the final grade in it can be received only upon the completion of training, that is, a student who has completed 2 years cannot score 100 points, as these points are only generated upon the completion of the whole course.

Thus, the model for assessing the competence formedness level has been described, where its input and output parameters are indicated.

4 Results

The calculation of the competence formedness level in medical students in terms of using medical equipment

To test the methodology for the final calculation of the competence formedness level for the training course 'Anesthesiology, Resuscitation, and Intensive Care', the grades in the subject modules and other learning activities were taken for the entire training period in several groups.

Analyzing the grades, the following conclusions can be drawn: for the students who have excellent final grades in the subjects and, at the same time, excellent values in all the modules within a subject as well, their formedness level of almost all the competences will be the same. However, in most cases in the objective assessment, not every student is equally good or equally bad at performing all types of training activities; it all depends on the subjects studied and on the level of their comprehension and acquisition. Someone may be a good practitioner, someone a theoretician or an analyst, while someone is doing well in science. In such cases, an automated system for assessing the formedness level of competences will determine the professional orientation of a student (a future graduate).

Let us consider various examples of the competence formedness level calculations.

For four students, the values in the modules of different subjects and other learning activities involved in forming competences of different cycles are taken, and an example calculation according to their level of formedness on the basis of the developed methods and algorithms is presented.

For student 1, the formedness levels of the following competences are calculated *according* to the formulas:

The subject coefficients of belonging are calculated taking into account the opinions of all the experts and their credibility coefficients, as follows:

$$\mu_i = \sum_{g=1}^{m} \mu_{i_g} \cdot k_{a_g}, \text{ where} \tag{7}$$

m is the number of experts participating in the expert assessment.

The values of the coefficients are taken by the columns of the tables - the experts, taking into account all the values. Thus, it is found that the final absolute competence formedness value level can only be obtained upon completion of studying all the subjects from all the cycles involved in the formation of competences.

The calculation of the relative index by the formedness level of competences with account of one subject C_n is made by the formula:

$$C_n = C_s \cdot k_i \tag{8}$$

Accordingly, in order to calculate the relative value of the formedness level of competence for a semester (year) C_{Se} it is needed to add up all the values in the subjects, which participated in the formation of a competence, for the period multiplied by a weighting factor:

$$C_{Se} = \sum_{i=1}^{n} C_i, \text{ where} \tag{9}$$

n is the number of subjects involved in the competence formation for a certain training semester.

PC – 1, PC – 2; PC – 3, PC – 4; PC – 5,PC – 6, PC – 7; PC – 8, PC – 9 ;PC – 10 :

$$\begin{aligned} C_{PC_1} = 0{,}24(0 \cdot 65 + 0{,}321 \cdot 89 + 0{,}188 \cdot 83 + 0 \cdot 65 + 0{,}321 \cdot 91 + 0{,}17 \cdot 93) \\ + 0{,}22 \cdot 90 + 0{,}24 \cdot 82 + 0{,}14 \cdot 91 + 0{,}19 \\ \cdot (0{,}542 \cdot 78 + 0{,}458 \cdot 91 + 0 \cdot 70) = 90 \end{aligned}$$

For the rest of the competences of student 1, the following values are obtained:

$$C_{PC_2} = 86; \; C_{PC_3} = 81; \; C_{PC_4} = 84; \; C_{PC_5} = 83; \; C_{PC_6} = 76; \; C_{PC_7} = 74;$$

$$C_{PC_8} = 82; \; C_{PC_9} = 82; \; C_{PC_{10}} = 81$$

From these values, a conclusion can be drawn that this student has the highest score (excellent) in the formedness level of competences PC-1, PC-2. The competences PC-3, PC-4 PC-5, PC-8, PC-9, PC-10 have a lower score and fall in the 'good' interval, whereas the PC-6, PC-7 have also fallen in the 'good' interval, but the score is even lower. It should be noted that the average score on the student's academic performance is '4'. In total, the student has very few excellent grades in the subjects,

but there are competences that have been formed with the 'excellent' outcome. Thus, the professional orientation of the student can be inferred by assessing the formedness level of competences, which a simple system of assessment per subjects would not be able to provide.

Then, the formedness levels of the same competences are calculated for student 2 and the following values are obtained:

$$C_{PC_1} = 77; \ C_{PC_2} = 77; \ C_{PC_3} = 73; \ C_{PC_4} = 75; \ C_{PC_5} = 71; \ C_{PC_6} = 70; \ C_{PC_7} = 73;$$

$$C_{PC_8} = 74; \ \ C_{PC_9} = 75; \ C_{PC_{10}} = 71$$

Out of the examined competences of the student, the formedness level of almost all of them falls into the 'good' interval, except the PC-6, whose value falls into the 'satisfactory' interval (however, it requires an error calculation and making a decision on the level of its formedness), the average score in the subjects was closer to the value of 'satisfactory'; they have many more of these grades than 'good' ones, and very few 'excellent' grades. Just as in the previous case, it is found that the final values solely in the subjects are not evidence of the formedness level of certain competences.

The formedness levels of the same competences are calculated for student 3, and the following values are obtained:

$$C_{PC_1} = 76; \ C_{PC_2} = 74; \ C_{PC_3} = 68; \ C_{PC_4} = 73; \ C_{PC_5} = 75; \ C_{PC_6} = 72; \ C_{PC_7} = 75;$$

$$C_{PC_8} = 74; \ C_{PC_9} = 72; \ C_{PC_{10}} = 69$$

Out of the considered competences of different sections, it can be seen that for a number of competences the graduate's formedness level falls within the 'satisfactory' interval; in most of the calculated values, the competences formedness level stands at 'good' value. The graduate's average score in the subjects is closer to 'good'. It is thereby found that with an average 'good' score, a number of graduate's competences have formed only with the 'satisfactory' value.

The formedness levels of the same competences of student 4 have the following values:

$$C_{PC_1} = 56; \ C_{PC_2} = 60; \ C_{PC_3} = 62; \ C_{PC_4} = 68; \ C_{PC_5} = 55; \ C_{PC_6} = 52; \ C_{PC_7} = 50;$$

$$C_{PC_8} = 72; \ C_{PC_9} = 76; \ C_{PC_{10}} = 72$$

In this case, it is found that part of the competences from the section have not formed (a grade that falls within the 'unsatisfactory' range has been received, while the other part of the competences have formed at the 'good' level. Thus, it can be seen that the student's total average score in the subjects amounts to 3; at the same

time, part of their competences has formed with a good score and gives an indication of their professional orientation.

Fig. 3 and 4 represent diagrams showing the competences formedness level of 4 different students who have different scores in the subjects and a different grade point average in general.
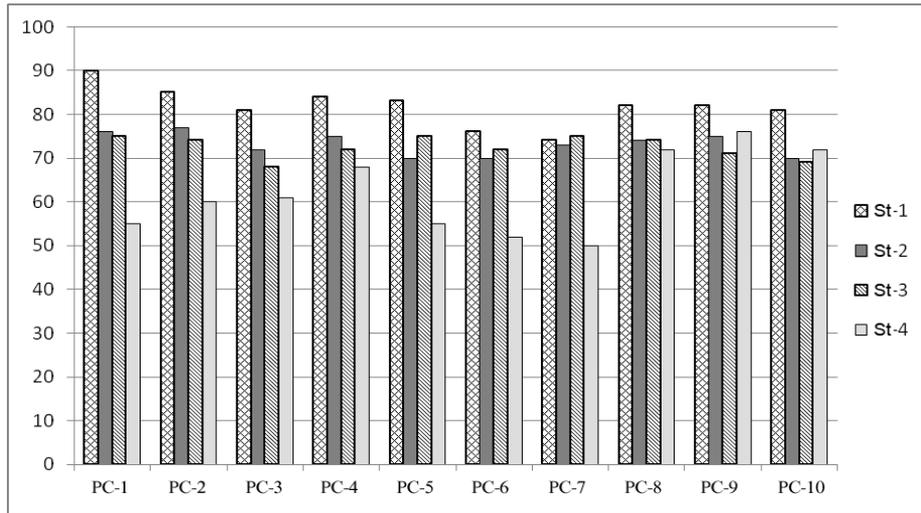

Fig. 3. Diagram of values by the formedness level of competences for four different students in the range of assessment [0; 100]
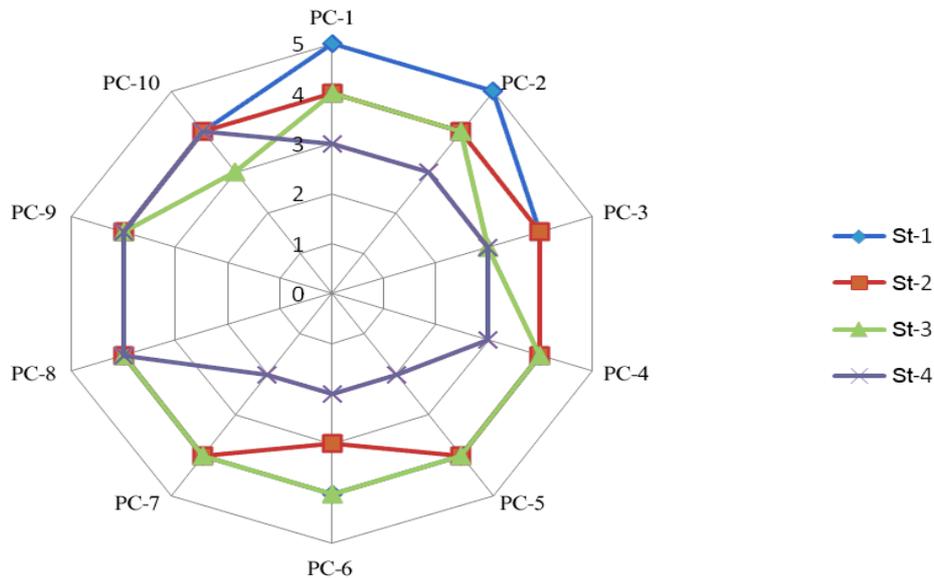

Fig. 4. Diagram of values by the formedness level of competences for four different students in the range of assessment [2; 5]

As can be seen from the diagrams, the students have values different from each other by the formedness level of competences, whereby the student 2, whose average score in the subjects is 'satisfactory', has more competences of a higher formedness level than that the student 3, whose average score is closer to 'good'; i.e., the student 3 at an average has a better academic performance in the subjects than that the student 2. It can be concluded that making an assessment of the formedness level of the student's competences is an important part of the educational process, which allows determination of the graduate's professional orientation.

5   Conclusions

1. The problem of describing the professional activities of a medical graduate has been solved in terms of the competency-based approach and the identification of ways to develop these qualities for dealing with medical equipment.
2. A model for the assessment of the competences formedness level has been elaborated, where its input and output parameters are indicated.
3. On the basis of the developed methods and algorithms for calculating the formedness level of competences for the training course 'Anesthesiology, Resuscitation, and Intensive Care', a calculation of all the required importance coefficients of the subjects, their modules and other learning activities involved in the formation of competenceshas been made. From the calculated values a conclusion can be drawn that different modules of the same subjects have different importance coefficient values for certain competences, as well as one and the same subject in different ways influences the level of a particular competenceformedness, which proves the need for making an expert assessment. After that, for a number of competences of several students a calculation of the formedness level of competences has been made showing that even in a small group of students under consideration (some of them performed equally on the average), different competences are formed at a different level. Consequently, conducting this assessment is necessary for determination of the future graduates' professional orientation.

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7 Authors

Usen Baizak is with Ahmet Yesevi University, Turkistan, Kazakhstan (ubayzak@mail.ru).

Kanapiya Kudabayev is with South Kazakhstan State Pharmaceutical Academy, Shymkent, Kazakhstan.

Mariya Dzhazdykbayeva is with Ahmet Yesevi University, Turkistan, Kazakhstan.

Gulmira Assilbekova is with Ahmet Yesevi University, Turkistan, Kazakhstan.

Bahyt Baizakova is with Ahmet Yesevi University, Turkistan, Kazakhstan.

Aigul Mintassova is with Ahmet Yesevi University, Turkistan, Kazakhstan.