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Оценка сбалансированности процесса формирования компетенций: анализ учебных планов российских вузов

Введение. Учебные планы являются основным инструментом организации учебного процесса в российских вузах. От их обоснованности и сбалансированности напрямую зависит качество обучения и возможный уровень сформированности компетенций выпускника. Переход на компетентностную модель образования потребовал изменения принципов составления учебных планов. Однако до настоящего времени качество учебных планов оценивается по формальным критериям, слабо связанным с компетентностным подходом. Также не сформулированы ответы на простые вопросы: сколько дисциплин могут и должны формировать одну компетенцию, сколько компетенций может формироваться в рамках одной дисциплины и в течение одного семестра, как влияет наличие разрывов в процессе формирования компетенций на итоговый уровень их сформированности.

Цель работы – предложить количественные характеристики для оценки сбалансированности и согласованности процесса формирования компетенций на основе статистического анализа актуальных учебных планов российских вузов.

Материалы и методы. В качестве материала для исследования были выбраны учебные планы по направлению подготовки «Прикладная информатика» федеральных государственных бюджетных и автономных образовательных организаций (всего 45 институтов и университетов). Были применены методы математико- статистического анализа: частотный анализ, методы сравнения средних, анализ СКО.

Результаты исследования. В среднем каждую компетенцию формирует от 2 до 8 дисциплин. Наибольшее количество дисциплин в большинстве учебных планов формирует по 1, 2 или 3 компетенции. Дисциплин, формирующих более 4 компетенций, в учебных планах большинства вузов сравнительно немного. Показано, что отсутствие преемственности и развития, наличие разрывов в процессе формирования компетенции могут снизить достигнутый уровень компетенции до 30% от возможного за счет забывания.

Обсуждение результатов. Наличие отклонений от усредненных показателей может в некоторых случаях свидетельствовать о недостаточной сбалансированности учебных планов. В перспективе возможно встраивание предложенной методики в интеллектуальную систему оценки характеристик образовательного процесса в рамках СМК вуза.

Ключевые слова: образовательный стандарт, компетенция, учебный план, качество образования, забываемость

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Assessment of the balance of the competence formation process: analysis of the curricula of Russian universities

Introduction. Curricula are the main tool for organizing the educational process in Russian universities. The quality of education and the possible level of formation of the graduate's competencies directly depend on their validity and balance. Going on a competence model of education demanded change in the principles of drawing up of curricula. However, until now, the quality of curricula is assessed according to formal criteria that are weakly related to the competence-based approach. Also, answers to simple questions have not been formulated: how many disciplines can and should form one competence, how many competencies can be formed within one discipline and within one semester, how the presence of gaps in the process of forming competencies affects the final level of their formation.

The aim of the work is to propose quantitative characteristics for assessing the balance and consistency of the process of forming competencies based on a statistical analysis of the current curricula of Russian universities.

Materials and methods. As a material for the study, curricula were chosen in the specialty "Applied Informatics" of federal state budgetary and autonomous educational organizations (45 institutes and universities in total). Methods of mathematical and statistical analysis were applied: frequency analysis, methods for comparing means, analysis of standard deviations.

Research results. On average, each competency forms from 2 to 8 disciplines. The largest number of disciplines in most curricula forms 1, 2 or 3 competencies. There are relatively few disciplines that form more than 4 competencies in the curricula of most universities. It is shown that the lack of continuity and development, the presence of gaps in the process of forming competence can reduce the achieved level of competence to 30% of the possible due to forgetting.

The discussion of the results. The presence of deviations from the average indicators may in some cases indicate an insufficient balance of curricula. In the future, it is possible to embed the proposed methodology into an intelligent system for assessing the characteristics of the educational process within the framework of the university's QMS.

Keywords: educational standard, competence, curriculum, quality of education, forgetfulness

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Introduction

Nowadays Worldwide there are two approaches to the organization of higher education. Adherents of "academic freedoms" give students the right to choose their own learning trajectory, thus preparing them for a fierce competition in the highly skilled labor market. In this case the restrictions are: the closed list of disciplines offered for study to choose from and the sufficient basic knowledge and skills of students [15]. The second approach assumes that universities are entrusted to develop the final curriculum [19]. This ensures a pedagogically adjusted learning sequence. Academic freedom in this case is limited to the choice of university and several optional disciplines. Despite the different approaches to the organization of higher education in various countries, they have one goal: to train highly qualified, competent specialists who are able to apply their knowledge to solve practical tasks. The problem of organizing the educational process has been raised for a long time [6], but in spite of the diversity of existing approaches, the task of improving the quality of vocational education remains relevant [10].

The quality of the curriculum has a significant impact on the quality of the educational process. The curriculum defines the whole forming process of knowledge, skills and competences systems of students. Curriculum distributes over time and coordinates the processes of teaching many disciplines, from the first lessons to the graduation thesis defense.

Errors in curriculum design can significantly reduce the quality of graduate training [12]. Therefore, the optimization of the curriculum is a key problem in the organization of the educational process [16]. Establishment and optimization of the curriculum [17] requires an adequate model of the educational process [18]. The task of educational process modeling [3] and optimization was the subject of a significant some researches. The main goal of the curriculum optimization is to distribute disciplines by semesters [2], and credit units by disciplines [1] in order to achieve maximum quality of graduate training, i.e. maximum level of competences formation necessary for successful professional activity [21].

However, in this statement, the task of optimization is characterized by a high degree of uncertainty, due to the lack of generally recognized methods of measuring the level of graduates competence, as well as the absence of direct and clearly defined connections between the knowledge, ability and skills acquired during the study of a particular discipline and the level of formation of competences. Thus, the curriculum optimization problem belongs to a class of difficult-to-formalize tasks with fuzzy- restriction, incomplete and fuzzy raw data, and no conventional models describing the impact of input characteristics and curriculum structure on the final result.

The developed curricula must comply with various regulatory documents and standards. As a rule, these are formal restrictions, for example, the total, semester and weekly academic load, the permissible number of examinations and tests per session, the ratio of lecture to practical classes, the availability of optional disciplines in the curriculum, etc. These restrictions are necessary, however, they are not directly related to the quality of education, as they do not affect the meaningful, competent component of the curriculum.

The aim of the paper is to develop a methodology for assessing the balance of the process of forming competencies, based on the statistical characteristics of the curricula of leading Russian universities. The significance of such research is enhanced by providing

universities with considerable academic freedom to develop the content of education and additional opportunities to form curriculum aimed at better taking into account the interests of the professional community and developing the competences that are required for successful work.

Materials and methods

While building an optimal curriculum, it is necessary to solve problems of distribution of disciplines and competences by semesters, to provide for step-by-step development of each competence, to agree on sequences of their formation and spent time resources.

At the same time, the process of phased competence formation requires to study disciplines in a logical sequence corresponding to the maximum level of competence formation at the end of this process. Starting from the educational process planning stage, the competences serve as a link between the disciplines of the curriculum and they provide more focused construction of the educational trajectory. Competency model oriented educational programs assumes that at the stage of its development, substantive and interdisciplinary skills, requiring an integrated application of knowledge and focused at development of a certain competence, will be identified. Therefore, in a properly planned educational program, interdisciplinary relationships are already embedded in the competence model due to the established clear logical link between the necessary competences and disciplines of the curriculum designed to provide them.

The question is how many competences can be formed at the same time in the student within one semester? How many competences can (or should) one discipline form? How many disciplines need to be studied in order to form one competence and how many credit units to spend on its formation.

Neither normative documents nor modern pedagogical science give a clear answer to these questions. On the other hand, these parameters allow simple formal verification, are easily analyzed and can contain information about the quality of the educational process.

If we assume that the curriculum tends to be compiled, by the most experienced tutors who's aim is to achieve the best possible educational result, the study of the country leading universities curriculum characteristics may be important information.

The possible analogy can be researches of the German doctor Carl Wunderlich who in the middle of the 19th century on the basis of data on the body temperature of 25 thousand people established that the normal temperature of the healthy person is 36.6 °C. Although there is no strict scientific justification for the value obtained, almost no one questions it. To date, measuring temperature and detecting deviation from this value is the simplest, most reliable and most effective indicator of a wide range of diseases.

Similarly, there are no valid scientific recommendations on the values of formal criteria characterizing the educational process. However, analysis of mean values and variance of these parameters according to the sample of leading Russian universities can reveal the range of their optimal value.

As a model example, we will analyze the curriculum drawn up in accordance with the requirements of the federal state educational standard for the specialty "Applied informatics" in universities of Russia implementing this educational program. Bachelors in this specialty are trained for 4 years (8 semesters). The curricula posted on the websites of universities in the section "Information on the educational organization" were used. The sample analyzed

includes federal state budgetary and autonomous higher education institutions (total data for 45 universities). Data on the distribution of disciplines by semester and competencies formed by each discipline were extracted from each curriculum. The mean values and standard deviations of the number of competencies mastered simultaneously, the number of competencies formed in one discipline, the number of disciplines forming one competence were calculated. The Chi-Square Test was used to test the normal distributions.

Research results

Eighth (the last one) semester data was excluded from the given analysis, as it usually consists of various types of practices and state final certification, which, includes almost all competences in accordance with formal requirements, rather than pedagogical needs. Figure 1 shows the frequency distribution of the quantity of competences generated in one semester.

It turned out that the distribution law of competences quantity formed in one semester in various universities is close to normal. This distribution, the graph of which is shown in the same figure, is characterized by the following values: the weighted mean value of the quantity of competences generated in the semester was 12.08, the standard deviation was 3.7. As is known, at normal distribution 95% of all values should fall within the range of $\pm 2\text{sigm}$. By analysis of this curve it is easy to identify universities, which have this value significantly different from the average one. It is necessary to pay additional to such universities, determine the reasons for such deviations and, accordingly, find out what they are related to. For example, is difficult to find a reasonable explanation to the sharp increase in the quantity of competences formed in the 3-th semester (20-23 competences) in the curriculum of three of the analyzed universities.

Figure 2 shows the average quantity of disciplines that form each universal (UC) or general professional (GPC) competence.

Figure 1 Frequency distribution of the quantity of competences generated in one semester

The list of these competencies is specified in the federal state educational standard and includes 8 universal and 9 general professional competencies (<http://fgosvo.ru>). The dashed line shows the average values from the sample of universities, the fill indicates the area of standard deviations from the average values. Each competence has its own specificity, which must determine the quantity of disciplines that form it. For example, the competence of the UC-8 "Able to create and maintain safe living conditions, including in emergency situations" or the UC-7 "Able to maintain the proper level of physical fitness to ensure full social and professional activity" in most universities is formed by one or two disciplines, with minimum values of standard deviations.

Figure 2 Average quantity of disciplines forming each competence

On the other hand, the contents of such competences as GPC -2 "Able to use modern information technologies and software, including domestic production in solving the problems of professional activity", or UC-1 "Able to search, critical analysis and synthesis of information, apply system approach to solving the tasks" assumes formation by much bigger amount of disciplines. Therefore it is necessary to analyze average value for each competence.

On average, each competence forms 2 to 8 disciplines. However, there are competencies formed by only one discipline. In two universities there are competences, the formation of which occurs in the study of 14 and 17 disciplines. Such deviations hardly suggest that the curriculum is balanced in terms of competence formation.

Figure 3 shows the frequency distribution of disciplines forming a certain quantity of competences, which characterizes the quantity of competences formed by one discipline. The dashed line shows the average values of the quantity of disciplines in the university curriculum that form the specified quantity of competences. Solid lines show standard deviations from averages. The dash-dotted and dashed lines indicate dependencies for those universities whose indicators differ significantly from average values.

Figure 3 Quantity of competencies formed by one discipline

The analysis of statistics showed that in most universities, from 10 to 23 disciplines form one competence, from 10 to 26 disciplines form two competences and from 2 to 13 disciplines form three competences. Disciplines forming more than 4 competences are relatively few in the curriculum of most universities. Usually, these are complex disciplines, integrating several general professional and professional competences at once. At the same time, in the curriculum of some universities there are disciplines forming more than 7 competences. The formation of 8, 9, or 10 competences within one discipline requires an assessment of their degree of formation and is quite difficult. The existence of such disciplines in the curriculum may indicate a lack of balance.

In some universities, the maximum of the graph is shifted to the area of more competences (University-2, University-3 on the chart Figure 3), compared to the average values. It can be assumed that the curriculum in these universities is overloaded with complex disciplines compared to most other universities. Another extreme case is seen in the example of the curriculum of University-1, in which almost all disciplines form either one or two competences, with minimal variation of this indicator. In this case, the university managed to establish in the curriculum a mutually unambiguous correspondence between disciplines and competences. In our view, this shows not a good balance of the curriculum and a high professionalism of the teachers who made up the curriculum and work programs of the disciplines, but a strong administrative pressure on the teachers in the formation of the educational program [2].

Another equally important characteristic that depends on the quality of the curriculum is the level of competence formation. It is largely determined by the degree of consistency of the curriculum disciplines, the consistency of interdisciplinary relationships in the stage-by-stage formation of each competence [9]. As we know, learning processes are always accompanied by the process of forgetting. Some researchers [11] it is shown that the period

for which knowledge decreases to the residual level (20-30%) can be 10-20 weeks, i.e. the duration of this forgetting period is approximately equal to one semester at the university. In the work [8], we proposed a model for assessing the achieved level of competence formation, which takes into account the presence of gaps in the process of gradual formation of competence. It is noted that the presence of even one gap at the last stages of the competence formation process can lead to a significant decrease in the achieved level of competence formation, relative to the maximum possible.

Based on the curricula posted on the websites of universities, and the proposed model [7], the achieved levels of formation of universal and general professional competencies are calculated, with the influence of forgetting processes. Figures 4 and 5 show the results obtained, normalized to the maximum possible levels for each competency. The achieved levels of competence formation for several universities are shown in comparison with similar levels corresponding to the curriculum from the sample educational program (SEP), proposed by the Ministry of Science and Higher Education.

Figure 4 The level of formation of universal competencies

From the curves shown in Figure 4, it can be seen that the structure of the SEP curriculum, from the point of view of the continuity of the process of forming universal competencies, is more balanced in comparison with the working curricula of most universities. At the same time, the curricula of different universities differ significantly in the degree of consistency and continuity in the formation of competencies. For example, the ideal trajectory for the formation of universal competencies is proposed in the curriculum of University 1, since it has the highest possible level of formation of all universal competencies. And the most unbalanced curriculum is at University 3, which forms the competencies of UC-2, UC-3, UC-7, UC-8 at the level of 40-50% of the maximum possible level.

A similar analysis was carried out for general professional competencies (Figure 5).

Figure 5 The level of formation of general professional competencies

The structure of the curriculum proposed in the SEP project in terms of the formation of general professional competencies can be considered well balanced. At the same time, in the working curriculum of University 4, during the formation of almost all defense industry gaps are observed, which leads to a significant decrease in the achieved level of their formation (35-75%).

Even successful students in the implementation of such a curriculum will not be able to reach the maximum possible level of competence formation in the development of which there are gaps.

The discussion of the results

In contrast to approaches to the analysis of curricula based on formal indicators and subjective opinion about the interrelation of disciplines, statistical criteria have been defined that allow objectively (quantitatively) diagnosing strong deviations in the structure of the curriculum from the mean values. In addition, in contrast to the well-known works in which the influence of forgetting processes on the effectiveness of studying individual disciplines is investigated, a model has been built to assess the impact of forgetting on the effectiveness of the formation of competencies.

We agree with the opinion of authors [14], that the quality of learning outcomes is influenced by various factors, primarily existing curricula, educational programs and standards, in particular the structure of the curriculum. To optimize the structure of the curriculum, many researches build graph or network models [4] applicable by well-known and tested graph theory algorithms [1], fuzzy logic methods [5], or neural network approaches [22]. However, the input data for these models are, mostly, the subjective opinions of experts evaluated, for example, on the Likert scale [20], which reduces their adequacy. In addition, the target functions used in these models, such as finding the optimal path on directed graphs, or the minimum cost of implementing the educational process, are not always directly related to the main goal of education.

The paper analyzes the ratio of disciplines and competencies by semester, as well as an analysis of the structure of the curriculum, taking into account forgetfulness, and the following results are obtained:

- It turned out that the distribution law of competences quantity formed in one semester in various universities is close to normal.
- On average, each competence forms 2 to 8 disciplines. However, there are competencies formed by only one discipline. Deviation from the mean indicates an imbalance in the curriculum in terms of the formation of competencies.
- The largest number of disciplines in most of the curriculums forms one, two or three competences, which seems quite justified. Disciplines forming more than 4 competences are relatively few and usually, these are complex disciplines, integrating several general professional and professional competences at once. The formation of 8, 9, or 10 competences within one discipline requires an assessment of their degree of formation and is quite difficult. The existence of such disciplines in the curriculum may indicate a lack of balance.
- The analysis revealed average values of the proposed parameters: number of competences formed in one semester – from 9 to 15, the number of competences formed of one discipline – from 1 to 3, the number of courses forming one competence depends on the type of reference and for most competences amounts from 4 to 8.
- An analysis of the degree of balance of the curriculum and the maximum possible level of competence formation of a specialist, taking into account forgetting, showed that with a visible identical set of disciplines studied, the final result differs

significantly: in some universities 100%, and in others 40-60% (in terms of universal competencies) and 35-75% (in terms of professional competencies).

Thus, the proposed, easily identifiable characteristics of the curriculum (the number of competencies formed in one semester, the number of competencies formed by one discipline, the number of disciplines that form one competence, the presence of gaps in the process of forming competence) allow to quickly analyze the curriculum.

The scientific novelty of the research is due to the fact that the quantitative indicators of the curriculum proposed in this work, characterizing the process of forming competencies, are objective and closely related to the achieved quality of education.

Forgetting processes have been relatively well studied in the study of individual disciplines, but there are practically no works that investigate the effect of forgetting on the effectiveness of the formation of competencies.

Conclusion

The presence of deviations in the mean values of the proposed indicators in some cases may indicate an imbalance in the curriculum. A deeper analysis of the causes of their occurrence will improve the quality of the curriculum and the entire educational program.

When developing curricula, universities should pay attention to achieving consistency and continuity of the process of gradual formation of competencies.

The proposed methodology is applicable to any specialty of bachelor's training in Russian universities and can be used in quality management systems of the educational process, with state and public accreditation.

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