The Innovative Methods of Competency Assessment

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***Abstract* — The problem of competency assessment of students of Russian universities is relevant. The reason for this is the integrative nature of competency, which makes it difficult to assess it in a rapidly changing socio-economic environment. From the standpoint of an open education system focused on the interaction of professional and educational structures, the outcome of higher education is characterized by the professional competency of graduates. Since the professional competency development is carried out through the education content, an integral part of its formation is subject competency fostering. Subject competencies are built in studying academic disciplines or groups of disciplines. On the example of mathematical competency of economic university students, the authors present a model that reflects its structure, content and development dynamics considering the continuity of undergraduate and graduate programmes. The levels of mathematical competency development have been identified. They are subject, interdisciplinary, and professional levels. On the basis of the proposed levels which correspond to the mathematical training stages, the criteria and indicators of competency development have been worked out. They enable to monitor the intellectual and personal development of bachelors and masters, taking into account the requirements of the modern labor market. The results of pedagogical measurements on the example of creative and action-oriented component of mathematical competency at the professional stage of training have been shown.**

Keywords — innovative methods, competency, mathematical competency, competency assessment, multilevel economic education, open education system.

I. INTRODUCTION

Results from the analysis of statutory documents, theoretical studies and teaching practice show that the closed system of education doesn't have any potential for solving modern pedagogical problems. The reason for this is a consistent gap between the requirements of the labor market and the provision of educational services. The federal law "On Education in the Russian Federation" emphasizes the necessity of the networking format of educational program implementation that is a tool for cooperation of educational organizations with enterprises and cultural institutions. This, in turn, allows us to solve the problems related to adapting university graduates in an open environment in the context of globalization, informatization and variability of a social development system. This strategy ensures the development of an open education system focusing on the needs of the real economy, which necessitates the exetension of university academic freedoms in the structure and content of education, as well as the participation of employers in training at all stages of the learning process. The aim is to prepare a competent, mobile and creative worker who is able to solve problems in a changing socio-economic environment in accordance with the academic program track and level of higher education [1].

Modern competency-based education plays an important part in the context of formation of an open education system. This education form provides acquiring knowledge along with building competencies which enable students to get knowledge on their own and be ready for life-long learning. Taking in consideration the above, we will characterize the vocabulary of the research problem.

These days, the training content in Russian universities is determined by their degree programmes, which are based on the relevant state educational standards. The current Federal State Educational Standards of the third generation for higher education (FSES HE 3+) are "framework".

They focus not on resources, but on the learning outcomes i.e. the competencies of graduates. In the conditions of result-oriented higher education, the main notions of educational standards ("competence" and "competency") are being widely discussed due to their various interpretations. This problem is studied in research papers of Russian [2-4] and foreign scientists [5-7]. The analysis of the information sources shows that there are different points of view on the nature of these concepts. In this study we distinguish the terms "competence" and "competency". We share the opinion of scientists (Yu.I.

Aleyevskaya, N.L. Ashirbagina, N.A. Meshcheryakova) and consider that competence is an ability reflecting norms of behavior. By competency we mean a set of interconnected knowledge, abilities, skills, and experience including the personal attitude to the object of activity [8].

According to the researchers, competencies built by university education allow students to adapt to changes in their future professional life. These competencies can be divided into three groups: instrumental competencies (analysis, synthesis, planning, and information management); interpersonal competencies (teamwork ability, interpersonal relationships, and ethical obligations); systemic competencies (adaptation to new situations, creativity, and leadership) [9]. This approach to higher education has a broad view on vocational training, combining cognitive, operational and personal components, the synthesis of which forms the ability to act in various professional situations [10].

In recent years, there has been a growing interest of researchers in developing competencies in the subject area "Mathematics". The development of theory-based and tried out models of competencies is the subject of discussions on the improvement of mathematical training. As for the assessment of learning outcomes, scientists identify the following key aspects for future development:

- working out more advanced ways to enhance the quality of learning outcome assessment in mathematical education [11];
- improving the relation between fundamental research and practical aspects [12];
- providing equity and addressing heterogeneity of assessment [13].

Taking into account the nature of these problems, we should note that competency-based learning outcomes include elements that are difficult to characterize. In this regard, there are difficulties in assessing them by qualimetric methods. This work seems to be relevant as it focuses on improving the assessment methods of mathematical competency of economic university students, considering the requirements of the modern labor market.

II. Materials and Methods

This study presents the authors' approach to the development of assessment methods of mathematical competency of economic university students. The hypothesis of the study is the assumption that the organization of mathematical training under the conditions of an open education system will provide effective development of mathematical competency as a component of professional competency of graduates. The objectives of the study are:

- setting requirements to mathematical training under the conditions of an open education system;
- building a mathematical competency model as a result of mathematical training that reflects the structure of the subject area competency, content and its development dynamics considering the continuity of undergraduate and graduate programs;
- developing criteria and indicators of mathematical competency taking into account the modern labor market requirements;
- conducting pedagogical measurement to assess the level of mathematical competency components.

III. Research Questions

According to open education system principles focused on the interaction of professional and educational structures, the final object of higher education is professional competency of graduates. The professional competency development is carried out through the content of education. In this regard, an integral part of its development is building subject area competencies. In this study, we deal with the problem of mathematical competency assessment of economic university students considering the continuity of undergraduate and graduate programmes.

A. Requirements for mathematical training of students in an open education system

As noted earlier, in line with the Bologna Process that integrates Russia into the Common Education Space, the current FSES HE 3+ are "framework". They focus not on resources, but on the learning outcomes (competencies of graduates). The analysis of modern theoretical studies and teaching practice showed that the requirements for the learning outcomes, formulated in the form of a list of competencies, are a core factor of university training. However, despite the progressiveness of an updated version of the FSES HE, it is possible to single out some problems. They are:

- bad coordination of graduates' competences from the standpoint of continuity of higher education levels;
- constant increase of labor market requirements to graduates in a changeable socio-economic environment;
- lack of a clear focus on the use of educational management opportunities based on learning outcomes monitoring in the transition to an open vocational education system.

It is possible that these shortcomings will be eliminated in the FSES 4. These days, the leading Russian universities can introduce changes in the structure and content of educational programs at all levels of higher education, as under the federal law "On Education in the Russian Federation" they are given the right to independently develop and implement educational standards

In this study, we deal with the peculiarities of mathematical training development for bachelors and masters of Economics. The experimental base of the research is the Financial University under the Government of the Russian Federation (Financial University) that is included in the list of universities, which have the right to develop and implement educational standards at all levels of higher education. The key scientific findings were obtained in the course of research project execution "Sustainable development of Russia in the context of global changes" in the Omsk branch of Financial University.

In order to detail the requirements for outcomes of mathematical training of bachelors and masters of Economics in an open education system, the analysis of the educational standard of higher education of Financial University in subject area 'Economics' was carried out. The content of the educational standard includes general competencies as a set of general scientific competencies (GSC), interpersonal competencies (IPC), systemic competencies (SC), reflecting the ability of an individual to positive intellectual and psychological self-development, readiness for life in the context of social interaction, as well as professional competencies (PC) relevant to the types of professional activity undergraduate and graduate programs are oriented to.

To determine the "weight assignment" of the importance of competencies developed by the disciplines of the subject area "Mathematics", we studied the requirements of regional employers of Omsk and Omsk region represented by professional structures, including government agencies, businesses and non-profit-making organizations (Ministry of Finance of Omsk region, Federal Tax Service Directorate of Omsk region, Omsk regional public organization "Free economic society of Russia"). Respondents were asked to rank competencies. Heads of economic departments, chief accountants, economists of 18 government agencies, 26 businesses and 2 non-profit-making organizations were involved in the study. The calculation of the "weight assignment" of the importance of competencies was made as a result of finding the ratio of the amount of points assigned to a particular competency by all respondents to the total amount of points awarded. The results showed that the integral weight of 13 competencies developed by the disciplines of the subject area "Mathematics" is 100%. The analysis of the content of competencies with the highest "weight assignment" of importance from the point of view of the mathematical component of professional training (instrumental competencies IC-2 - 10%, IC-5 - 9%), demonstrates the special significance of the mathematical model formulation skills for description and prediction of professional objects and processes, as well as the skills of using modern software. This, in turn, contributes to the development of the competency-based sphere in general mathematical training at the undergraduate level and lays a solid foundation for its increment in the course of a specific master's programme.

The selected cluster of competencies allowed us to justify the relevance of the inclusion of disciplines of subject area "Mathematics" in an optional part of educational programmes in subject area "Economics" in the Omsk branch of Financial University. Such disciplines as Elements of linear algebra and balance models in Economics, Elements of discrete mathematics relate to the optional part of basic professional education programmes of higher education. "Mathematical fundamentals of financial decisions" and "Econometric research in Economics" are included in the optional part of Master's Programmes. The study of these disciplines is aimed at the development of competencies with high "weight assignment", for example, IC-2, IC-5.

The experience of designing a competency cluster as indicators of subject education gives us the possibility to structure the competency components as an outcome of mathematical training in an open education system.

B. Mathematical competency as an outcome of mathematical training

Considering competency as a generic concept that determines the productivity of activities in a particular area, we define the content of its specific manifestation that is mathematical competency as an outcome of mathematical training, taking into account modern requirements.

In a contemporary changeable environment, all the requirements for training of economists are impossible without mastering a complex mathematical apparatus, data mining that enables them to solve vocational tasks in situations of uncertainty and multivariance. In this regard, by "mathematical competency" we mean an integrative personality characteristic, which is manifested in the readiness to apply mathematical knowledge and skills, an ability to use them in new situations to solve vocational tasks, assess the results and mastery experience.

In contrast to the previous studies on the problem of mathematical competency development, where scientists distinguish in competency structure motivational, cognitive, action-oriented and reflexive components, we emphasize creative application of mathematical training outcomes to solve vocational tasks in new conditions. In that respect, the action-oriented component is supplemented by the creative component, which characterizes an ability to solve tasks in situations of uncertainty and multivariance. It is shown in Table 1.

TABLE I. MATHEMATICAL COMPETENCY MODE

Components	Content
Motivational	**Bachelor's degree programme** -formedness of academic and professional motivation due to the value-based attitude to mathematics; -understanding the importance of the mathematical model method.
	Master's degree programme - readiness for personal fulfillment in the context of academic and professional motives; - awareness of the importance of the modeling method for investigation and prediction of real processes in a rapidly changing world.
Cognitive	**Bachelor's degree programme** - availability of fundamental and applied mathematical knowledge; - knowledge of methods of analysis, synthesis, generalization, and mathematical modeling; - knowledge of how to use modern software.
	Master's degree programme - knowledge of possibilities of mathematical model method for research and forecasting of real economic processes; - knowledge of how to study on one's own new techniques, research methods, and modern software.
Creative and action-oriented	**Bachelor's degree programme** - skills and experience of mathematical activity at the stages of mathematical modeling to solve profession- oriented tasks; - knowledge of modern software to use it for mathematical modeling.
	Master's degree programme - ability to articulate a problem, set objectives,

	identify modeling stages and implement them on the basis of knowledge integration; - ability for self-increment the experience of creative mathematical activity, considering its limitations and consequences.
Reflexive	**Bachelor's degree programme** - ability to analyze the significance of motives of academic and professional goals; - ability to analyze the results of activities, including own activities.
	Master's degree programme - readiness for self-correction in the context of the importance of motives and results of achieving academic and professional goals.

The proposed mathematical competency model together with the characteristics of its structural components (motivational, cognitive, creative and action-oriented, reflexive components) reflects the dynamics of the components development from the standpoint of the continuity of undergraduate and graduate educational programmes. For example, at the bachelor's degree level the development of creative and action-oriented component is characterized by the expertise in mathematical modeling in the course of solving profession-oriented tasks, as well as knowledge of modern software for mathematical modeling. At the master's degree level it is an ability to articulate a problem, set objectives, identify modeling stages and implement them on the basis of knowledge integration from related fields, as well as the ability for self-increment the experience of creative mathematical activity.

The experience of structuring the mathematical competency components enables us to develop relevant assessment methods.

C. Mathematical competency assessment

The mathematical competency assessment as a subject of control is particularly difficult because of its integrative nature. The complexity of diagnostic procedures is caused by the multilevel nature of mathematical training and the contribution of various disciplines to competency development. Using the results from the analysis of theoretical studies and teaching practice on the problems of mathematical competency assessment, the authors identified the following levels of its development:

- subject level (within the disciplines of mathematics);
- interdisciplinary level (within the disciplines of mathematics, IT and general professional disciplines);
- professional level (within professional disciplines, productive practice, bachelor thesis, master's thesis).

The proposed levels of mathematical competency development correspond to the mathematical training stages. All three stages of mathematical training are implemented in the framework of the bachelor's degree programme; in the master's degree programme there are two stages. They are interdisciplinary and professional stages. On the basis of the proposed mathematical competency levels which correspond to the mathematical training stages, the criteria and indicators of competency development were identified. They provide monitoring of intellectual and personal development of bachelors and masters.

In the course of experimental work, a diagnostic system was created. Its testing and assessment materials enable us to evaluate the dynamics of the development level of the mathematical competency components within the input, current and final control at each stage of mathematical training.

In regards to interaction of professional and educational structures, we should note the importance of mathematical competency assessment at the professional stage of mathematical training. For example, the level of the creative and action-oriented component was assessed by the analysis of graduation theses in the application of economic and mathematical methods (probabilistic and statistical methods, optimization methods). The data obtained are given in Table 2.

TABLE II. ASSESSMENT OF THE CREATIVE AND ACTION-ORIENTED COMPONENT

Competency codes	**Weight assignment of competencies**	**Economic and mathematical methods**	**Weight assignment of the method, Mi**
GSC-1 PC-4 PC-6	0,06 0,08 0,07	Probabilistic and statistical methods	0,17
GSC-2 IPC -3 PC -5	0,08 0,08 0,08	Methods of financial decision making and profitability evaluation	0,12
GSC -2 PC -4 PC -5	0,08 0,08 0,08	Theory of risk analysis	0,12
SC -1 IC -5 PC -3	0,08 0,09 0,07	Optimization methods	0,12
SC -1 IC -2 IC -5	0,08 0,1 0,09	Network planning	0,118
SC -2 IPC -3 IC -2 PC -2	0,06 0,08 0,1 0,08	Simulation methods	0,183
SC -2 IC -2 IC -4 PC -3	0,06 0,1 0,07 0,07	Elements of system analysis, building and research information systems	0,168
Σ			1 (100%)

We demonstrate how to calculate the average weighted assessment of the creative and action-oriented component, taking into account the weight assignment of the importance of competencies developed by this method. On the example of probabilistic and statistical methods we show the calculation of the weight assignment M1 as the sum of the ratio of the weight assignments of competencies to the number of methods using this competency. The weight assignment value of this method is 0,17:

$$M_1 = \frac{0,06}{1} + \frac{0,08}{2} + \frac{0,7}{1} = 0,17.$$

The average weighted assessment of the creative and action-oriented component was defined as the sum of productions of the weight assignment of the *i*-th method to

the average (on a 5-point scale) graduation thesis assessment of bachelors and masters who used this method. The positive impact of the developed methodical system of mathematical training of bachelors and masters of Economics on the mathematical competency level is confirmed by the pedagogical experiment results. The experiment was conducted from 2001 to°2017 in the Omsk branch of Financial University. 700 students of the enlarged group of the subject area "Economics and management" participated in the experiment. Validity verification of the pedagogical experiment results is performed using Pearson's chi-squared test and G-sign test.

IV. Results and Discussion

The competency-based format of modern education focuses on the effectiveness of subject training of students considering the vocational task solution. Taking this into account, the study proposes a scientific approach to learning outcome assessment in accordance with the stages of mathematical training (subject, interdisciplinary, and professional levels). The criteria and indicators of formedness of mathematical competency components have been developed. They provide monitoring of intellectual and personal development of students according to the profile and level of higher education in a changing social and economic environment.

The results confirm the hypothesis of the study, showing the effective development of mathematical competency in an open education system.

V. Conclusion

Summing up, we underline that the development of subject training in the higher education system should be based on an effective partnership of professional and educational structures. The advantage of this cooperation is common standards of education, on the one hand, and knowledge focused on the modern labor market needs, on the other hand. The development of such partnership provides the state with a competitive market of educational services; it allows business to influence the quality of graduate training, enables educational institutions to implement popular educational programmes.

The experience of designing a competency cluster as indicators of subject training presented by the authors gives an opportunity to structure the mathematical competency components and to develop methods for their assessment in an open education system.

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