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Competency-Based Approach in Training Mathematicians: Challenges of Time

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Abstract

The paper considers possible approaches to and recommendations for forming a competitive professional mathematician in Kuzbass region. The necessity of an advanced market of scientific, technical and software developments increases, and so does that of a steady connection between the developers and potential employers. Accordingly, professional mathematicians and competent programmers capable of creating new specialized packages of applied programs are highly sought. The problem of responsibility of higher education institutions for quality training of professionals required by the region is becoming urgent. At higher education institutions, forming of professional mathematicians' readiness for professional activity implies participation of students and their teachers in mathematical research and projects in applied profile areas, in performance of works to orders of organizations. Competency-based approach to teaching of mathematics students on the basis of creating a vocationally oriented information environment by organizing the cooperation of the university with large companies running their businesses in the region. Quality training of professional mathematicians is backed up by creation of chairs at the employer's enterprises jointly with the university chair in order to perform scientific developments for the coal industry of Kuzbass.

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1. Introduction

At present the most important task of higher education of Russia is quality training of professionals matching the change in the labor market. The need of professionals capable of resolving the economic problems the country is

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facing is increasing.

There has been set the task to increase the employer's role in preparation of professional personnel. In the system of benchmarks and targets, such target was pointed out as introduction of state education standards developed for forming of educational programs in line with the world trends and labor needs.

It is mentioned in the Concept of the long-term social and economic development of the Russian Federation for the period of up to 2020 that the growing role of human assets is one of the major factors of economic development (Konceptcija Federal'noj celevoj programmy razvitija obrazovanija na 2016-2020gg., 2014).

K.E. Abbakumov, A.M. Kotochigov, N.N. Kuzmin, O.Yu. Markova, D.V. Puzankov, A.A. Shekhonin et al. note the requirement of innovation methodological restructuring of evaluating the quality of knowledge adopted, skills acquired, abilities and competencies (Otchet po proektu «Sovershenstvovanie struktury GOS VPO na osnove kompetentnostnoj modeli vypusknika i razrabotka informacionnoj tehnologii ih proektirovanija», 2005).

A similar opinion is supported by many Western researchers: the results of education and competencies are very important for working out new approaches to evaluating and ensuring quality. With the competency-based approach, the results of education and competencies are central to the activity of reforming the education (Bolonskij process: seredina puti, 2005, p. 111].

Professor Jürgen Kohler says competencies mean particularities consisting in knowledge, understanding and actions. They should be treated in a multi-dimension way, both in the dimension of generic abilities going beyond the framework of specialities (generic competencies) and from the standpoint of specific character of a speciality (professional competencies) (Kohler, 2000).

As for the competency model, it is essentially characterized in the work by a group of authors who prepared the basis of materials of a scientific and research project "Development of models of a bachelor of a speciality and a master of a speciality. Implementation of the models according to groups of specialities unlike the qualification model typical of the current state education standards, the competency model of a professional oriented to the professional activity sphere is less rigidly attached to the certain object and subject of labor. This ensures mobility of graduates in changeable conditions of the labor market (Kuzminov, Puzankov, Fedorov, Shadrikov, 2004).

Today's professional school has a problem to it without overcoming which its innovation development will be considerably hindered. The problem is the contradiction between the growing need of professionals and the lack of effective mechanisms and models of employment of graduates, the poorly developed market of scientific and technical developments, and the lack of a steady connection between the developers and the potential investors.

Mathematics is known to occupy a special place in science, culture and public life being one of the vital constituents of the world scientific and technical advance. Studying mathematics plays a system forming part at all levels of education by developing the cognitive abilities of man, also ones to logical thinking, and influencing the teaching of other disciplines.

Fulfillment of the task set to create innovation economy, implementation of long-term goals and objectives of social-economic development of the Russian Federation are impossible without a high level of mathematical education (Konceptcija razvitija matematicheskogo obrazovanija v Rossijskoj Federacii, 2013).

With regard to this, the problem of responsibility of education structures for the quality of professional training of applied mathematics professionals is becoming urgent.

The practical activity of a competent and competitive professional mathematician implies a high level of his readiness for resolving the practical problems of the economy.

2. Goals, methodology and objectives of the research

The paper aims to promote activating the process of forming a competitive professional in today's labor market, to suggest possible variants of forming the competence for training professional mathematicians in conditions of studying at a classical university.

The methodological basis of the research are theoretical provisions about the role of one's vigorous activity in one's personal self-development, as well as that of personal and subjective factors in self-fulfillment and self-development; the provisions of psychology and pedagogics about the leading role of activity in the professional training; theoretic provisions of consistency, scientific rigor, connection of theory and practice, availability of learning, acmeology and synergetics, dialectic unity of the professional and educational problems.

The main objective of the research was giving a theoretic ground to the model of forming the professional readiness of a professional mathematician in conditions of studying at a classical university and implementing it in

the educational process.

The novelty of the research is orienting to the competency-based approach in developing the educational programs while bearing in mind the employers' requirements for the competencies of higher education institution graduates, as well as to the practical education content constituent that ensures a successful and high quality adaptation of graduates to the professional activity of a professional mathematician.

3. Results and discussion

In the recent years, the competency-based approach has been paid much attention to at higher education institutions. The approach implies forming in students of their own experience in resolving problems in various spheres and kinds of activity, it promotes forming of independence, an ability to make responsible decisions, a creative approach to any business, an ability to go through with a job, to study and renew one's knowledge continuously, as well as flexibility of thinking, and abstract, systemic and algorithmic thinking as such.

Ensuring of forming in graduates of such competencies they will need in their professional activity is an important task of the modern education.

The area of professional activity of graduates of the mathematical faculty at a classical university encompasses, in particular, scientific and research activity in areas using mathematical methods and computer technologies, resolving various problems using mathematical modeling of processes and objects and software. In particular, a graduate shall possess competencies helping him to successfully deal with the professional tasks in scientific and research activity, in the area of application of mathematical and algorithmic modeling methods when analyzing the applied problems, and to use mathematical methods in scientific research.

When studying in the area of applied mathematics, students have to master main numerical methods and algorithms of resolving mathematical problems, to have an idea about the applied programs packages available, to know how to use the numerical methods in resolving applied problems using the modern computer technologies, to develop numerical methods and algorithms and to implement the algorithms in a high-level programming language; to master numerical methods development methods and technologies, and to have skills of systemic thinking within the context of the profession being obtained. An important aspect is development of needs and motives of academic activity, for the student to be committed to master the required knowledge and abilities before he actually faces the practical questions in order to be prepared to resolve them correctly.

Based on the structure of academic activity of resolving applied problems, the following competencies have been singled out: significant skills of independent computer operation, programming, using the information processing methods and numerical methods of resolving basic problems; skills of independent algorithm construction and analysis; mastery of algorithmic modeling method during analysis of setting of mathematical problems; an ability to spot the applied aspect in solution of a scientific problem, to present and interpret the result correctly.

One of the most important tasks of modern education is to necessarily promote the development of a need in students to not merely use ready knowledge but to create it and extract it from the information received, to learn to systematize and analyze the information, to be capable of continuous self-education, to know how to use in practice the knowledge and skills they received during learning, and to be able to approach the solution of complicated problems in a creative way.

In order to form the required competencies in students during learning, such organization of the academic process is necessary as to ensure a smooth transition from academic and cognitive activity to research one, to acquiring the skills of practical work. While studying a certain applied problem, a student comes to a clearer understanding of the reality, to obtaining new knowledge while also developing his observation power, attention, and analytical skills. The practical application of knowledge accumulated before allows forming the required competencies and an ability to use computer technologies for numerical solution of a certain mathematical model.

Continuous renewal and development of software means requires elaboration of new skills of processing the information.

Experience shows that students' practical using ready packages of mathematical applied programs for solving problems (e.g. MATLAB) frequently results in failure to understand what exactly happens during solution of a certain problem and, therefore, in difficulties analyzing the results obtained. In order to solve a certain class of applied problems, it becomes necessary to create special packages which would take into account the specific character of the problems. In connection to this, professional mathematicians and skilled programmers are highly

sought who can create new specialized packages of applied programs.

The development of higher education system in Kemerovo region required by the region labor market is based on the efficient combination of scientific and vocational training of personnel.

The employers' requirements for competencies of the graduates and the structure of classes are changing. The demand for professionals having high-quality engineering and technical education is growing among the employers. The necessary development of innovation clusters "higher education organizations – enterprises – authorities" is possible in several economic spheres of Kemerovo region by integrating efforts of educational organizations, scientific organizations training professionals and conducting scientific developments for one and the same spheres of the economy or for adjacent ones, and of enterprises that need professionals having the relevant higher education (Postanovlenie Ob utverzhdenii plana meroprijatij «Razvitie sistemy vysshego obrazovanija v Kemerovskoj oblasti na 2015-2020 gody», 2014).

A developed market of scientific, technical and software developments, and a steady connection between the developers and potential employers is essential. Students who study mathematics and information technologies and their teachers must participate in mathematical research and projects in applied profile areas and perform works to orders of organizations.

Orienting to competency-based approach in development of educational programs of various levels allows taking into account the requirements of employers for competencies of higher education institution graduates.

Currently, expanded participation of business representatives in forming and implementing the educational programs of higher education is an important trend. Activity of creating chairs at the enterprises jointly with educational organizations of higher education that teach students in priority development areas of science has to be developed. This creates a certain incentive for interaction of higher education organizations with large companies running their businesses in the region.

Learner-centered model of education taking into account the external challenges and trends will allow raising the competitiveness of higher education institution graduates considerably.

In order to integrate the scientific potentials of ICT SB RAS, Kemerovo state university and the Institute of coal and coal chemistry SB RAS in the area of information technologies, computational methods and comprehensive training of highly qualified professionals for further development and implementing of modern methods for solution of applied problems for mining industry of Kuzbass, a joint laboratory "Information and computational technologies" has been created at the chair of computational mathematics of KemSU.

Jointly with the laboratory, the staff and students develop both theoretical bases of numerical methods for solving the problems of movement of fluids, gas and methods of practical problems: movement of contaminated fluids in pipelines and flooded coal workings, river beds, progress of tsunami and waves in water areas of ports, ultra-filtration of mixtures of various liquid fractions, underground coal gasification, problems of stable burning of multi-component and multi-phase reacting systems a special case of which are problems of emergence and propagation of forest and underground fires, underground coal gasification.

Methodical and organizational aspect of forming the required competencies in students is selection of relevant methods, means and organization forms of teaching.

Knowing how to use the computer for solving applied problems is based on deep understanding of meaning of the main technological chain (object – information model – algorithm – program – result – object) links and relations between them. Meanwhile, the key to knowing how to use the computer correctly and efficiently is understanding the information modeling method.

Any professional activity has its particularities. Each of them has tasks and objects that objectively determine a set of requirements for a person doing this kind of activity.

The generic model of a professional includes general cultural, psychological and pedagogical, fundamental and special constituents. The most significant components of the model can be singled out as follows:

- Forming of foundations of scientific world outlook.

The foundations of scientific world outlook are formed by means of students' getting foundations of scientific knowledge in the relevant subject areas. Disciplines and courses containing fundamental knowledge underlie the formation of general and professional culture.

- Forming of systemic thinking in students on the basis of mastery of algorithmic work method.

It is doubtless that the influence of studying informatics and the use of computers in the process of upbringing and education plays a great part; it fosters development of theoretical and creative thinking of students, formation of algorithmic work method skills using which a student clearly sees the sequence of actions determining

how the initial data is processed into the result sought.

With regard to this, computer sciences influence essentially the development of so-called systemic thinking, which is very important. Every professional problem is in its essence a complex one, i.e. it is a system and requires systemic analysis and construction of a coherent model of its solution. Moreover, in the modern world, one has to handle a huge flow of information and it is crucial to know how to extract this information from numerous sources, also using the Internet, to systematize, realize correctly and to use in the most efficient way. Any professional must possess systematization skills.

- Acquisition of abilities and skills in using the information and computer technologies, numerical solution of applied problems. Hypertext technologies, computer graphics, telecommunication access methods, multimedia, numerical methods, information modeling methods have become widely used recently.

An integral system of knowledge cannot be achieved on its own and spontaneously – it has to be formed persistently during the general professional training. This is promoted by creation of a vocationally oriented information environment that will allow ensuring successful vocational and personal self-fulfillment of graduates.

Let us single out the operational-processual component using which the final result can be achieved, namely, the formed readiness of students for the professional activity of a mathematical faculty graduate. Let us represent the structure of the operational-processual component consisting of three phases as a drawing (see Figure 1).

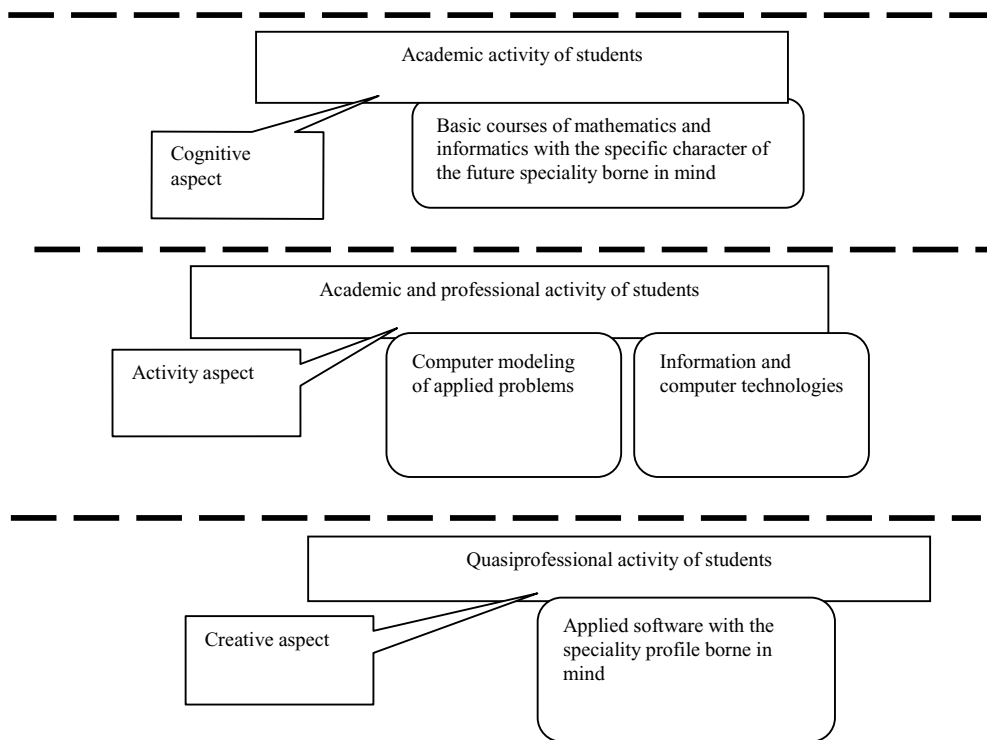


Figure. 1. Structure of the operational-processual component of forming the students' readiness to the professional activity of a graduate of the mathematical faculty of higher education institutions

The first phase includes studying the main mathematical and information courses, such as "Programming languages and translation methods", "Office programming", "Physics", "Numerical methods", "Mechanics of fluids", "Introduction into GIS-technologies", "Methods of solving the hydrodynamics problems", "Software tools of visual programming", "Solving the multidimensional problems of mathematical physics" etc. Their objective is acquisition of basic knowledge in higher mathematics and information technologies: architecture and functioning principles of modern computing machines, study of software of modern computer systems, acquisition of skills in

algorithmization, programming and modeling of various study problems, as well as skills of working with information and in the Internet.

The second phase contains academic and professional activity. The students study the relevant special courses, for example, "MS Access database management system", "Iteration methods of solving the SLAE", "Computational hydrodynamics", "Introduction into Java technology", "Hydrodynamic calculations visualization packages", "Fractional steps method", "Management of intellectual property", "Solving the multidimensional problems of mathematical physics", "Processing of remote probing data" and others.

The students use computer technologies as a means for solving their vocationally oriented problems, they acquire skills of working with modern software and applied programs packages required in their future professional activity. The students are also being prepared to academic Olympics in mathematics and programming.

Commencing from the second year of studies, teachers of the chair hold a scientific workshop for students on a regular basis in order to prepare them for working on real projects.

The students participate in scientific activity within tasks for state works and Federal target programs. Topics of course papers correspond to the scientific direction of the chair of computational mathematics, for example: "On one mathematical model of underground gasification", "Flow of an ideal stratified liquid in a rectangular water body", "Numerical solution of the problem of dummy ground capacity".

While working on their course projects and doing the research work, the students use computer modeling of various applied problems. Meanwhile, skills of systematization of information and independent work are acquired. Independent work enhances the cognitive activity of students and fosters the formation of systemic thinking.

Education forms are as follows: lectures, practical and laboratory classes at IT rooms, organization of students' independent work, working on course and diploma projects. Such methods as heuristic and problem ones are widely used; with the problem method, the theoretical material is presented based on setting a problem and resolving it during studying, a dialogue, an argument, and the discussion and resolving of problem situations continues at practical classes and workshops.

Thanks to modern multimedia means, it is possible to conduct special courses in the form of workshops using the technology of organization of cooperation in learning. Each student prepares his speech at the workshop in a topic previously suggested to him. He studies the topic in detail, prepares a report, presentation, necessary demonstration programs etc. Thus, the student during his preparation for the workshop acquires the skills of self-education, self-evaluation of his own activity. The main form of organization of the students' activity becomes a dialogue. The teacher organizes the discussion of the problem, possible alternative approaches to resolving it, encouraging all students of the group to take an active part in the discussion. This furthers the development of skills to single out the important point in the material under study, to give arguments and to support one's viewpoint, to present the material in a consistent and logical way, and to use the opportunities of multimedia presentations. The quality of the class thus given is evaluated by the study group with the teacher keeping his leading role, which has upbringing significance.

Such a method allows students to comprehend their activity, develops an ability to rebuild one's actions, motives and needs. With regard to this, it is important to create an atmosphere of trust and friendliness among the students and teachers.

As we have pointed out, such form of special course classes makes communication active, furthers turning the interaction of the teacher and students into a dialogue, creates conditions for mutual education and training of speech skills. On top of that, students master communicative qualities during this, which allows them to communicate with each other efficiently and ensures psychological compatibility in their joint cognitive activity.

At the second phase, it is the role of the teacher that also changes: he now is an advisor and leader during the education process. In its turn, this leads to a higher responsibility of students. Forming of a creative atmosphere where learning is permeated with a spirit of competition leads to changed role of students, too. The conditions created require clearer inner attitudes and responsibility on their part. The cooperation of a teacher and a student in conditions of vocationally oriented information environment promotes development of personality and satisfaction of its needs of self-fulfillment.

The third phase sees the students' activity become quasiprofessional, i.e. the closest to the professional one. This level implies differentiated training. When working on a diploma project, a special attention is paid to organizing the independent scientific and research work of students using the opportunities of modern computer technologies.

From the third year of studies, the students are engaged into works on commercial contract topics, e.g.

"Development of calculation technique for the process of scour at the drilling platform substructure under the effect of waves and flow for various geological conditions, taking into account the bottom configuration and substructure type of the gravity-based platform" and project works, e.g. "Modeling of flows with variable density and viscosity in solving the applied problems", performed within implementation of the project part of the state assignment in the scientific activity sphere of the RF Ministry of education and science. Such important topics can be mentioned as "Scour at oil rig substructures", "Three-dimensional flow of a liquid", "Waves on the surface of a heavy liquid", being worked on by students and teachers of the chair jointly with the State Marine Design Institute of Saint-Petersburg and JSC "Prirazlomnaya Oil Rig".

Many research projects performed by students have a great scientific and practical use in Kuzbass region, for example, ones made jointly with the Coal institute SB RAS, ICT SB RAS, topics being "Sewage waters treatment", "Non-stationary model of proliferation of foreign matters in closed water bodies", "Solution of the model of propagation of dust from a fugitive source", "Software complex for visualizing the results of hydrodynamic calculations". Works "Modeling of flow in blood vessels with movement of valves borne in mind", "Movement of blood in large blood vessels and a prosthetic heart valve" were performed jointly with the cardiological center. In cooperation with the city dairy plant, works on the topic range "Concentrating of milk" and others were performed.

Software complexes and special programs packages developed at the chair with active participation of students have received certificates of state registration (Bondareva & Zaharov, 2014)

Many works of students performed independently or jointly with their scientific advisors have been published in various titles (Bondareva & Zaharova, 2014; Bondareva et al., 2014; Gejdarov et al., 2014).

Beginning with their fourth year, students publish their papers and present them at conferences of various levels, including the international one (Vjunnik & Kirichenko, 2014; Gubina, 2014; Malashin, 2014; Rezvin, 2014; Poluhina, 2014; Gurskih, 2014; Dolgov, 2014; Bajdenko, 2005; Strategija social'no-jekonomicheskogo razvitija strany do 2020 goda, 2008) and many others.

Continuity of training is ensured by forming the vocationally oriented environment where the basic and specialized software is used as a means of comprehensive education throughout studying the disciplines of information and special cycles. The creation of vocationally oriented information environment by integrating the information and special disciplines and organizing the cooperation with large companies and SB RAS provides new opportunities both for teachers and students and serves as a natural incentive for the use of information and computer technologies, methods of numerical modeling of applied problems of economy, because students face the necessity to use them actively as methods, forms and means of upbringing and education process.

At the chair, the weekly scientific workshop "Mathematical models. Methods of solution" promotes active involvement of students into scientific and research work. Members of the chair and students specializing at the chair of computational mathematics take an active part in the workshop.

Thus, depending on the students' preparation level, forms of their activity change too. In the upbringing and education process, when competencies of students required in the future professional activity are formed at the first phase and the main mathematical and information courses are studied, the computer and its software are the subject of the academic activity during which the main knowledge and skills are obtained and required competencies are formed. As for the second and third phases, the subject turns into the means of solving the professional problems in the academic and professional and in quasiprofessional activity of students. It is this transition of subject into means that conditions the development of professional thinking of professional mathematicians.

The competencies formed ensure competitiveness of a graduate which generates confidence, promotes the professional success, helps overcome the feeling of uncertainty in the prospects of life. Hence it is very important to form in students a motivation to compulsory evaluation of their competitiveness.

Thus, in order to achieve quality training of a professional mathematician prepared for successful professional activity, the priority trends in organization of the educational process have to be singled out. One of such trends can be creation of a system of accompanying a student, learner-centered teaching, independent works and rating system of assessment of knowledge and abilities of students that are successfully implemented at the mathematical faculty of KemSU.

The implementation of learner-centered approach to teaching is aimed at organizing the exploration and research activity of students but not at transmission of ready knowledge. In this case, the teacher poses a problem task to students, analyzes it and brings the students to understanding the cognition object, to revealing and realizing the lack of knowledge and skills adopted earlier. The teacher demonstrates not the work method but the search of this method. When solving the academic and professional problem thus posed, a student acquires skills of self-

education and self-evaluation of his own activity in the course of research. As for the teacher in this case, he would become an assistant, a consultant, a participant of the joint search for the solution of the problem. The main students' exploration activity organization form becomes a dialogue in which the content of the problem is determined and ways of its solution are analyzed. Such a method allows students to comprehend their activity and to develop abilities to rebuild their actions, motives and needs. With regard to this, it is important for the students to be sure that the teacher is trying to help them but not to punish for quite possible omissions in performance of tasks.

The independent work of students houses tremendous cognitive and upbringing opportunities. It increases the creative activity of students, it fosters diligence, self-confidence, persistence in attaining one's goals, raises the sense of responsibility for the task committed etc.

The information system "Rating of students" functioning at KemSU promotes obtaining an exact and complete picture of knowledge and abilities of students broken down to all topic units. Rating assessment of knowledge places students before the necessity to perform academic work on a regular basis throughout the term. A kind of competition element that emerges so prompts students to get higher rating scores and fosters the sense of responsibility of students for each other during studying.

4. Conclusion

It has been determined that competency-based approach in training professional mathematicians promotes a fast and high quality adaptation of graduates to professional activity. It is conditioned by the requirement of the labor market and by potential employers of Kuzbass region.

The analysis of economic development problems of the modern society has revealed a contradiction between the existing classical university education and the regional economy needs of top qualification personnel.

We have come to the conclusion that forming of mathematical faculty graduates' readiness for the professional activity is influenced by the organization of educational process at higher education institutions by partnership with real economy companies, development of scientific research, innovation developments targeted at resolving the regional development problems. One of the important qualities ensuring the implementation of the professional activity functions of a professional mathematician is the presence of self-education skills, formed systemic thinking based on mastery of algorithmic work method, skills of solving the practical economy problems within the scientific direction of the chair.

The readiness of students of the mathematical faculty of a classical university for professional activity starts forming during learning at the higher education institution. Its foundation is an extensive knowledge of computers, strong programming skills that are formed in the junior years during studying the information and computer sciences. Meanwhile, the course programs are compiled with the specific character of the mathematical faculty borne in mind which implies adoption by students of the modern software designed for solving the vocationally oriented problems. At this phase, it is important to form the motivation for mastering the disciplines in students. Creation of vocationally oriented information environment by integration of information and special disciplines and by organizing the cooperation with the potential employers, the use of computer technologies in studying of special sciences, students' participation in research activity during performance of term, course and diploma paper, scientific research promote the formation of systemic thinking based on mastery of algorithmic work method and the development of skills of self-education in the area of professional interests.

We have determined and checked pedagogical conditions of forming the mathematical faculty students' readiness for the professional activity. We refer to them the following: creation of vocationally oriented information environment in the upbringing and education process; the use of phased continuous training of students with the specific character of the future professional activity borne in mind; organization of students' learning against the rating assessment of knowledge and abilities; the implementation of learner-centered approach to teaching and organization of independent academic, cognitive, scientific and research activity of the students.

The result of such organization of the educational process is forming highly qualified professionals who work successfully not only in our region but also in other regions of Russia, as well as in the USA, Australia and other countries.

Graduates of the faculty work at large state and commercial production organizations, at coal enterprises of Kuznetsk Basin, in firms, banking and insurance companies as information system administrators, programmers; they are owners and joint owners of businesses of the most varied scale, they proceed with theoretical and practical investigation in scientific and research institutes. Many attain a brilliant career path and occupy leading and

responsible positions.

Over three hundred teachers of mathematics and informatics who graduated from the mathematical faculty in various years have received high government and ministry awards.

Alumni of the faculty teach at higher and secondary education institutions. The best ones start studying for the research degree at the university and academic institutions and defend their candidate theses successfully.

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