ИТ-образование: методология, методическое обеспечение

IT education: methodology, methodological support

УДК 378
DOI: 10.25559/SITITO.14.201801.233-244

MATHEMATICAL PROGRAMS MODERNIZATION BASED ON RUSSIAN AND INTERNATIONAL STANDARDS

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Abstract

Russian education standards have come a long way from being extremely detailed and regulating the content of education programs at all levels to the current state when there is a great freedom for universities in defining its education programs. The downside of that freedom is too general formulations of these competences and absence of framework requirements for the scope and content of individual parts of educational programs for the various types of training. This raises the problem of preserving the unity of educational space in Russia and the traditionally high level of teaching mathematics in Russian universities. Russian scientific and educational community together with industry and business are currently looking for the ways to solve this problem.
In the paper, the experience of the modernization educational programs in the field of information and communication technologies is considered. The methodology of creation of valid assessment tools funds to check formation of competences is presented. The presented results are based on the methodology of international and Russian scientific and methodological projects.

Currently obtained results of approbation of the methodology showed that the chosen modernization methods are an effective tool for solving the designated math-related problems in engineering education in Russian universities and, consequently, students will start to correspond more adequately to the labor market needs.

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Том 14, № 1. 2018 ISSN 2411-1473 sitito.cs.msu.ru

Keywords

Competencies; estimation fund; Federal state educational standards.

МОДЕРНИЗАЦИЯ МАТЕМАТИЧЕСКИХ ПРОГРАММ НА ОСНОВЕ РОССИЙСКИХ И МЕЖДУНАРОДНЫХ СТАНДАРТОВ

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Аннотация

Российские образовательные стандарты прошли достаточно длинный путь от максимальной подробности и регламентации содержания образовательных программ, эволюционируя в сторону наибольшей свободы вузов при их проектировании. Недостатком этой свободы являются слишком общие формулировки этих компетенций и отсутствие даже рамочных требований к объему и содержанию отдельных частей образовательных программ для различных образовательных программ. Это порождает проблему сохранения единства образовательного пространства в России и традиционно высокого уровня преподавания математики в российских университетах. Российское научное и образовательное сообщество совместно с промышленностью и бизнесом в настоящее время ищут пути решения этой проблемы. В статье рассматривается опыт модернизации образовательных программ в области информационно-коммуникационных технологий. Представлена методология создания средств достоверной оценки инструментов для проверки формирования компетенций. Представленные результаты основаны на методологии международных и российских научно-методических проектов. В настоящее время полученные результаты апробации методологии показали, что выбранные методы модернизации являются эффективным инструментом решения заданных математических задач в инженерном образовании в российских университетах, и, следовательно, студенты станут более адекватно соответствовать потребностям рынка труда.

Ключевые слова

Компетенции; фонд оценочных средств; Федеральные государственные образовательные стандарты.

Introduction

Russian education standards of higher school have come a long way from being extremely detailed and regulating the content of education programs at all levels to the current state when there is a great freedom for universities in defining its education programs [1 - 2]. Russian educational standard is the system of mandatory requirements to an educational programme [3]. The accordance of the educational programme to the state standard is checked during the state accreditation [4].

Before 2011, state educational standards (SES) of the second generation acted in Russian higher education. They regulated the content of educational programmes, the set of mandatory disciplines and the amount of every discipline in hours and quality of education. In accordance with the standards there was the set of didactic units and an adequate electronic system of the independent verification of corresponding student’s knowledge and skills [5].

Since 2011, modern Federal state educational standards (FSES) were enacted in Russia [3]. The purpose of FSES is the implementation of European Bologna principles in Russian education. The main principle is the competences approach [6-11]. The essence of this approach is that the learning outcomes are described by the system of competences. A competence is the dynamical combination of knowledge, skills, abilities and personal qualities that a student should be able to demonstrate after his or her education. The competences should be transparent, i.e. understood for employers, teachers and students.

Moreover, FSES introduced credit units for measuring educational work corresponding to ECTS (European Credit Transfer and Accumulation System) [12] and a two-tier system of higher education.

New standards have the framework structure. With the introduction of FSES, Russian universities have obtained more independence and freedom in the development of educational programs, in the selection of its content [1, 2].

But in other hand some problems have appeared. The downside of that freedom is too general formulations of these competences and absence of framework requirements for the scope and content of individual parts of educational programs for the various types of training. This gives rise to the problem of preserving the unity of educational space in Russia and the traditionally high level of teaching mathematics in Russian universities.

The use of existing FSES is impossible without the development of competencies cards, without filling competencies with specific content that correlates with educational material of specific disciplines. It is necessary cardinal modernization of educational programms for implementation new standards.

Russian scientific and educational community together with industry and business are currently looking for the ways to solve this problem.

In the paper, the experience of the leading Russian universities is considered to develop educational programs in the field of information and communication technologies taking into account the methodology of the international and Russian scientific and methodical projects [13-18]. The methodology of creation of valid assessment tools funds to check formation of competences is presented.

Analysis of problems

The problems of FSES implementation in Russian universities were considered in series of works. For instance, papers [19-23] is devoted to the analysis of the current state of Russian higher education.

To understand the essence of the appeared problems, consider the following example of the state educational standard for bachelors in the area of studies "Applied Mathematics and Computer Science" acted before 2011. In accordance with the standard the educational programme must contain the following disciplines: “Calculus”, “Geometry and Algebra”, “Differential equations”, “Probability theory and mathematical statistics”, etc. [19]. Moreover, the standard determinated that, for instance, the main subjects of discipline “Calculus” in the area of studies "Applied Mathematics and Computer Science" were functions of one and several variables (continuity, differential and integral calculus, extremums), functional sequences and series, Fourier series and Fourier transform, a function of a complex variable, measure and the Lebesgue integral. The amount of the discipline must be equal to 816 hours. It is equivalent to 22 credit units of ECTS.

Now FSES does not contain requirements to a set of programm’s disciplines, its content and amount. Therefore, there is an opportunity for unscrupulous participants of the educational process unreasonably reduce content of disciplines and requirements for their mastering. Earlier, if a discipline was too difficult to learn for students, universities sought an opportunity to increase its contact hours. Now universities reduce the requirements to this discipline and its content.

The transition to a two-tier system of education has led to the reduction of hours devoted to mathematics. Such reduction reaches up to 50% for various engineering programs compared to the same requirements of SES [19]. Moreover, the recent trend is to the exclusion of basic mathematical disciplines of the educational process of students of humanitarian areas, in spite of an increasingly wide range of problems in which mathematics can be applied.

Despite the reduction in the total number of general cultural, general professional competencies of the future graduate and their unification, the formulations of FSES competences are vague and difficult to verify. These competences are transformed into abstract declarations with very broad and conflicting interpretations. For example, consider the competence “The ability to understand

and apply in research and applied activities modern mathematical apparatus and the basic laws of science" [3, 19]. What does it mean? How does it can be verified? What is the mandatory set of disciplines that form the competence? New standards do not have answers for the questions. It is necessary to develop the concretization of competence meaning.

It can be interesting to know the expert exam procedure of the educational programme quality during the state accreditation. Firstly, an expert considers the fund of the educational programme. If the expert finds that the fund is valid then he/she chooses 7 competences and verifies a degree of their formation among a student's group (50 students) during 20-30 minutes using the verifying procedures of the educational organization. It can be seen that it is necessary for an educational organization to have verifying tests in particular for the successful state accreditation. But it is very difficult for universities to develop own funds of assessment tools.

To ensure technical implementation of the higher education reform in Europe in accordance with the Bologna Process, an international project was launched in 2010 under the title "Tuning Educational Structures in Europe" – TUNING. Its integral part was the project TUNING RUSSIA. It was intended to promote modernization of the educational system in line with international trends, with the account of Russia's cultural and educational traditions, to help universities in solving difficult problems that arise in the course of globalization of education [13-16].

Other international project Meta-Math was aimed to help Russian universities to solve educational problems on the base of international experience. International project «Modern Educational Technologies for Math Curricula in Engineering Education of Russia» 543851-TEMPUS-1-2013-1-DE-TEMPUS-JPCR (MetaMath) [17, 18] was started 01.12.2013 and was developed during three years. The purpose of the project was to identify ways of solving the problems of modern mathematical training for higher engineering education of Russia. Project META-MAT aims to help Russian universities to solve the problems of higher education associated with the transition to new educational standards.

Analysis of the current state of the educational process, implemented in the framework of the Project META-MAT, involves the comparison of the Russian system of engineering education with the system of leading European universities.

Mathematical training for engineers in European universities is based on the standard SEFI – European society for engineering education. This document clearly reflect the European understanding about what is the mathematics that engineers need, and how it should be learned and taught [24].This document contains qualification frameworks for curricula of mathematical disciplines, levels and objectives of teaching, sections on teaching mathematics, evaluation forms, description of learning outcomes.

New information technologies and, in particular, e-learning systems are actively used in European universities [25-28]. This allows universities to take out some of the material for independent study and focus on really difficult topics of the discipline. E-learning systems also allow to automate and, as a result, simplify the knowledge assessment process [29-33].

Today, universities have the opportunity to create highly effective educational programs, design and implement optimal control and measurement materials that reveal the quality of education, the level of the formation of key and professional competencies. The actual direction of the pedagogical community is the problem of designing evaluation tools that allow an objective evaluation of educational results. The implementation of the requirements of the federal educational standards has set the universities the task not only to update the basic professional educational programs, but also to develop a system for evaluating educational results, updating evaluation tools that make it possible to implement the practice-oriented educational process. At the same time, all aspects of the organization of the educational process are touched upon, including the content, methods, means and learning technologies. So, for example, in the educational systems of different countries (USA, Germany, France) there is a lot of experience in using the project method in teaching [34]. This allows solving several problems of higher education at once and makes it much easier to check the level of competence formation. The new federal state standards put before the Russian education the actual task of developing a system for assessing the degree of formation in the students of competencies determined by state standards for the relevant areas of training. To effectively solve this task, in the conditions of limited time intervals, the possibilities of distance learning systems - LMS (Learning Management System) - are increasingly being used. At the present time, there is an increasing trend in the use of electronic testing materials both at the stages of the final generalization, control, correction and finalization of learning outcomes, and for the purposes of ongoing monitoring.

The experience of Russian universities in the development of e-courses, interactive test tasks, the formation of evaluation funds based on the international mathematical standard SEFI is useful.

Materials and methods

Methodological base of educational programms modernization is competencies approach. The implementation of this approach is ensured by Tuning project methodology. The methodology of this project, which summarizes the experience of specific steps in the development of core educational programs that meet the requirements of the Bologna process, has been successfully used to reform a number of programms, primarily in the field of information and communication technology.

In accordance with the TUNING definition, "by competence, we understand good performance in diverse, authentic contexts based on the integration and activation of knowledge, rules and standards, techniques, procedures, abilities and skills, attudes and values" [14, 16]. The Tuning methodology supposes the reviling content of competence during competences map development. The TUNING methodology for competence mapping involves the description of particular competences by means of a set of indicators that show specific qualitative aspects in the mastering of the given competence. Besides, several levels of competence achievement are identified. At each level, the quantitative degree of mastering each indicator is characterized by descriptors. In most cases, three indicators, two or three skill levels and five descriptors are used to build a competence map. Skill levels were determined based on the following principles: the first level corresponds to the level of technical literacy, or the lowest level of performance; the second level corresponds to the level of understanding the concepts and the ability to use them, this is the level of middle-tier managers; while the third level corresponds to the level of in-depth detailed mastery, which is the level of experts.

The methods of competence indicator definitions corresponded to "Methodical recommendations on development of main professional educational programms" of Russian Education and Science Ministry (22.01.2015 N DL-1/05vn). The first indicator was regarded to knowledge, the second indicator was regarded to skills and the third indicator was regarded to experience or abilities.

Methods of learning outcomes and skill levels formations for competencies of mathematical training were based on SEFI standard. If we compare Russian federal standards and SEFI standard we can note that Russian competences of mathematical training (for example, "The ability to understand and apply in research and applied activities modern mathematical apparatus and the basic laws of science") correspond to general SEFI-competences:

1. Thinking mathematically;
2. Reasoning mathematically;
3. Posing and solving mathematical problems;
4. Modelling mathematically;
5. Representing mathematical entities;
6. Handling mathematical symbols and formalism;
7. Communicating in, with, and about mathematics;
8. Making use of aids and tools.

But SEFI-standard contains the set of professional competences that reveal the content of mathematical training an engineer. For example, competences of differentiation are formulated in the following form: "As a result of learning this material you should be able to

- understand the concepts of continuity and smoothness;
- differentiate inverse functions;
- differentiate functions defined implicitly;
- differentiate functions defined parametrically;
- locate any points of inflection of a function;
- find greatest and least values of physical quantities".

The European experiences and research results have proven that significant improvements in learning outcomes in mathematics can be achieved by applying new Technology-Enhanced Learning (TEL) tools and pedagogic approaches. It has been proven that due to the application-oriented nature of math studies within STEM curricula the uptake of modern TEL methods has a maximum effect on overall quality of education.

Modern information and communication technology (ICT) provides a variety of tools that can be used to support students' comprehension and pedagogical reform. Teachers may run their courses using learning platforms like Moodle. In these environments they may distribute course material, support communication, collaboration, and peer learning and organise face-to-face meetings with video-conferencing tools. Students can get feedback on their mathematical skills' from their teacher, peers, and also by using carefully chosen computer generated exercises, which are automatically checked by computer algebra systems (MathBridge (http://www.math-bridge.org/)) [18, 25]. There exist mathematical programs like Matlab and Mathematica, which support mathematical modelling of real problems. Information and communication technology can amplify great teaching, but great technology cannot replace poor teaching. The use of technology does not itself guarantee better learning results, but it can even weaken the student performance. This obvious fact has been known for a long time. The design of a computer-based instructional system should be based on content specific research of learning and comprehension and pedagogical model of the learner and the learning process. In designing computer-based teaching and learning environments real didactic tasks should be considered. One should think thoroughly what to teach and how to teach.

Than modernization of educational programmes was also based on teaching project methods [21]. The essence of the project approach is that educational aims are achieved during student project completing [34].

Results

The maps of mathematical competences of FSES in area of ICT were developed using SEFI-competences. The fragment of the similar map for the competence "The ability to understand and apply in research and applied activities modern mathematical apparatus and the basic laws of science" of discipline "Calculus" is shown in the table 1.

Table 1. Fragment of competence card for discipline "Calculus"

Indicators	Descriptors				
To understand the concept: converging and diverging sequences; continuity of the function; differentiability; smoothness; derivative	lack of knowledge of the material	presence of major errors in the knowledge of basic material	knowledge of basic material with a number of minor errors	knowledge of basic material with a number of notable errors	knowledge of basic material without errors
To be able to: find limits of sequences; find derivatives of complex functions; differentiate inverse functions; differentiate functions defined implicitly; differentiate functions defined parametrically	no ability to solve standard problems	major errors in solving standard tasks	ability to solve standard problems with minor errors	ability to solve all standard problems with minor errors	ability to solve standard and non-standard tasks
To know a variety of methods and ways of calculating limits, methods of differential calculus	lack of skills	lack of a number of important skills	presence of the minimum required skills	presence of most of the basic skills, demonstrated in standard situations	presence of all the skills demonstrated in standard and non-standard situations

It can be seen that indicators of the competence map corresponds to SEFI professional competences.

Using Math Bridge, Moodle and other electronic systems [18, 28-32], useful tools for the competences formation were developed. In particular, electronic controlled eliminated courses were created. The electronic course in Moodle system was implemented for teaching "Calculus" in study programs AMCS and FCSIT (Applied Mathematics and Computer Sciences, Fundamental

Computer Sciences and Information Technologies, respectively). The main steps of the course modernization were: decreasing the number of lectures; increasing the number of consultations (from 15 hours to 30 hours); increasing the number of engineering examples in the course; using project learning (two projects per term at least). The topics of the projects are: ”Approximate calculation of functions: a creation of the calculator for logarithms, trigonometric and hyperbolic functions”, ”Technical and physical applications of derivatives”, ”Research of the normal distribution, the logistic function, the chain line”, ”The calculation of the center of gravity”, ”Applications of Euler integral”, and so on.

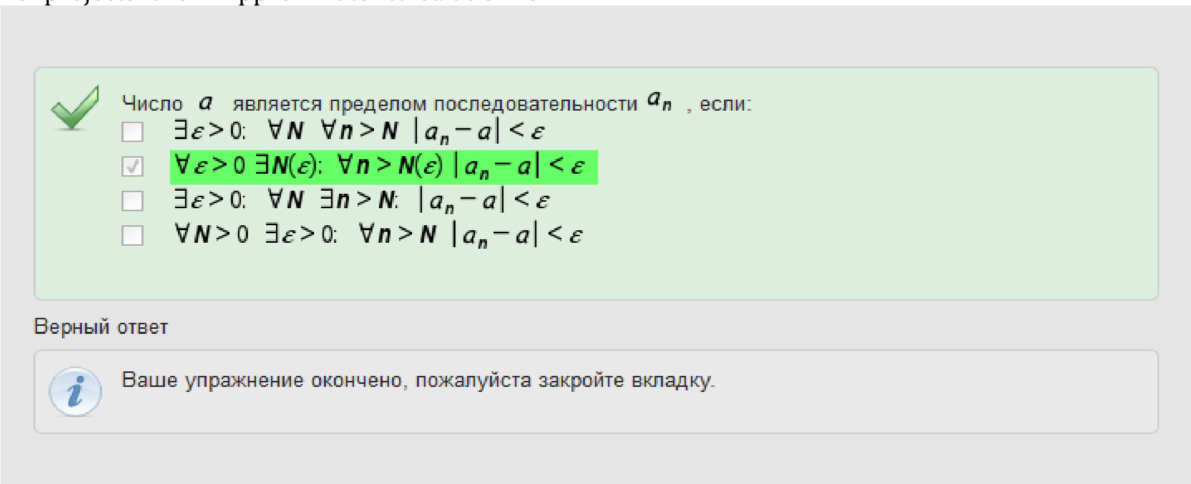
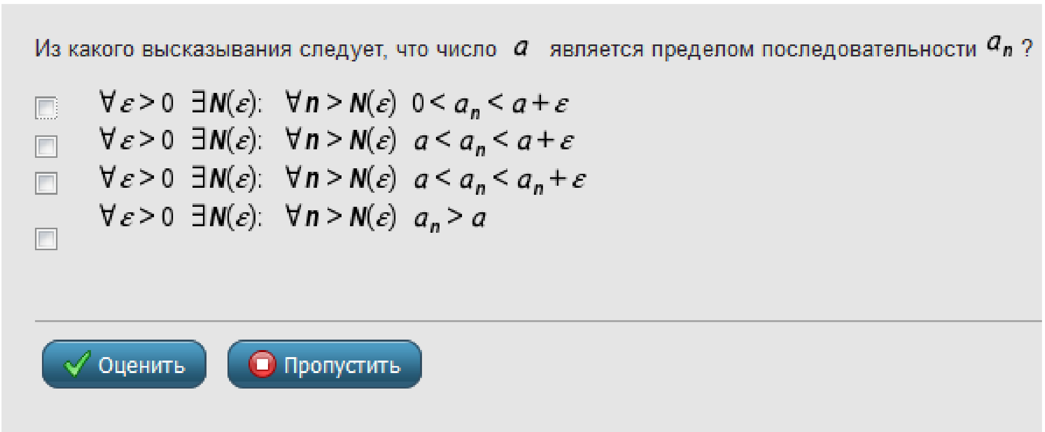


Figure 1. An example of electronic test for discipline “Calculus”



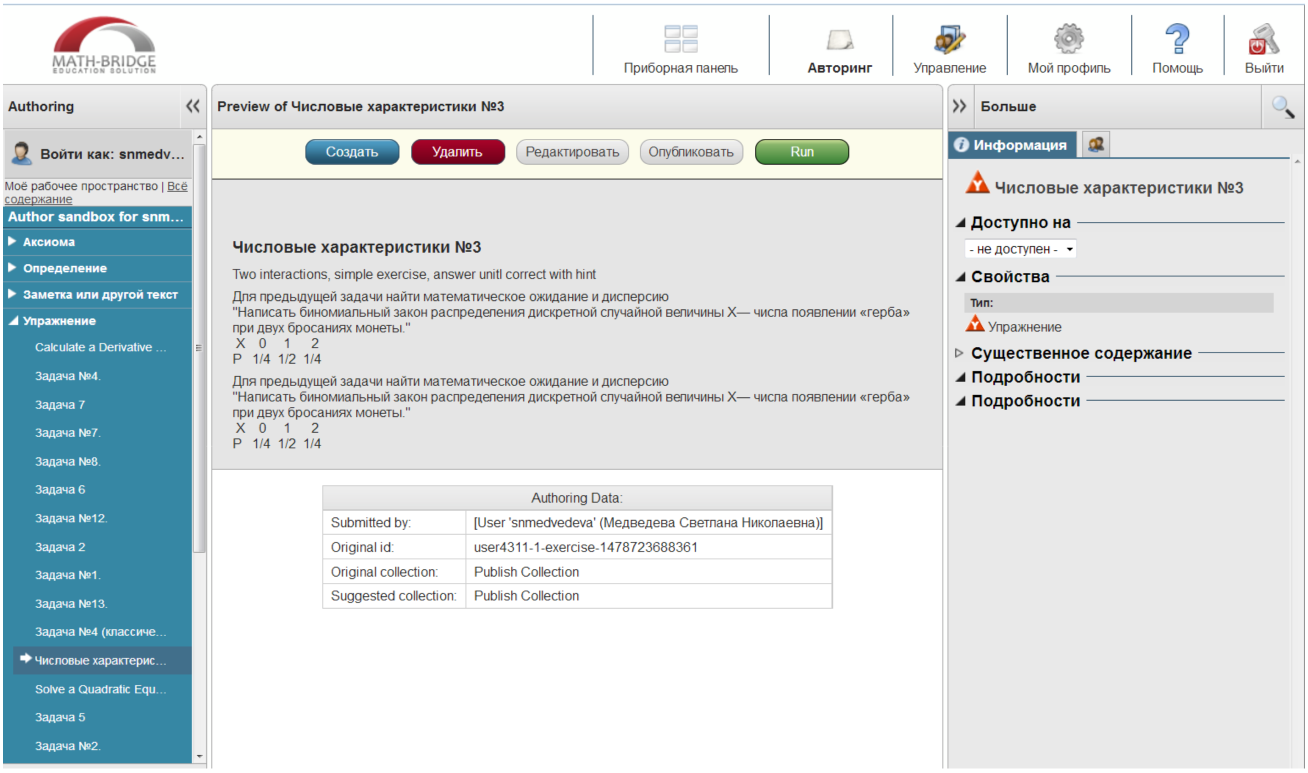


Figure 2. An example of electronic test for discipline «Probability Theory and Mathematical Statistics»

Then the fund of assessment tools for independent verification of competences formation was developed (including the creation of electronic tests using Math-Bridge). All tests are based on SEFI competences, they contain a large amount of simple tasks (during 60 minutes students must fulfill 20 tasks) that allow to control 160 SEFI competencies from the 0th to the 2nd level in areas ”Analysis and Calculus”.

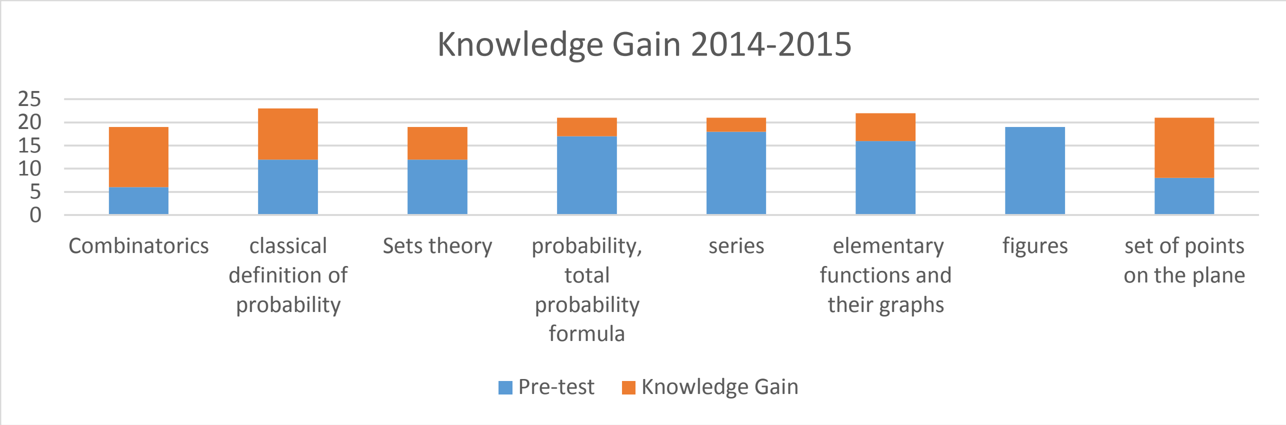
An example of electronic tests for discipline “Calculus” is shown in the Figure 1. The developed tests can be use during accreditation audit.

The modernization effects of discipline “Calculus” were checked in Lobachevsky state university of Nizhniy Novgorod. During the training, students were divided into 2 groups. One of them was trained with the traditional technology, the other - with the upgraded technology. Comparative test results showed a significant improvement in the development of competence the second group, which confirms the effectiveness of the upgraded learning technologies. This study allows to conclude that the chosen directions of modernization programs are a promising means of improving the quality of mathematical training.

In Tver State University the work was being carried out to introduce electronic means of teaching to support mathematical courses. In particular, work is underway to create distance learning materials for bachelors of 1-4 courses. According to the discipline "Theory of Probability and Mathematical Statistics", during the semester students had to pass two tests (pre- and post-test). Passing the test passed remotely and was considered as an integral element of the implementation of the curriculum. For those students who could not pass the test the first time, the possibility of a re-examination was provided. Within 1.5 hours each student had to answer 15 questions. Successfully passed the test, if the percentage of correct answers was above 70. In Figure 2 shows an example of a test in probability theory.

Table 2 provides information on the increase in knowledge for participants in the two tests.

Table 2. Results of pre- and post-test 2014-2015 (N=25)



The obtained experience and results show that Russian universities have good prospects for introducing electronic learning systems into the educational process, which will help assess the level of competence formation [18, 32]. Thus the results of the investigation are very useful for Russian universities in the conditions of Federal state educational standards.

Conclusions

The article analyzes the problems in the area of mathematical and engineering education in Russia. The experience of modernization of educational programs based on the methodology of series of international projects was shown. Currently obtained results of approbation of the methodology showed that the chosen modernization methods are an effective tool for solving the designated math-related problems in engineering education in Russian universities and, consequently, students will start to correspond more adequately to the labour market needs.

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Submitted 20.01.2018; Revised 20.02.2018; Published 30.03.2018.

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Поступила 20.01.2018; принята к публикации 20.02.2018; опубликована онлайн 30.03.2018.

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