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Improved Teaching of Mathematics as an Important Component of Interdisciplinary Engineering Education

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The paper considers the outcomes of the project "Modern Educational Technologies for Math Curricula in Engineering Education of Russia" (Tempus), implemented by the consortium of European and Russian higher education institutions. Having analyzed the national and international experience in teaching mathematics, the authors suggest a new method to enhance math teaching thus improving the quality of engineering education. The method implies using the intelligent system of e-learning.

Key words: mathematics in engineering education, engineering education, mathematical background, programme improvement, e-learning system, TEMPUS-METAMATH, mathematics and engineering education, content-related competencies.

The Russian system of engineering staff training has been widely recognized. During the Soviet period this education system was a basis for success in cosmic explorations, development of heavy industry and building, etc. In the 1990's the economic crisis and social transformations led to radical changes in the Russian higher education. Inadequate funding of universities, brain drain etc. resulted in deterioration of engineering training in Russia. At the beginning of the 21-st century the economic growth of Russia conditioned high demand for the new generation of engineers capable of improving economy. The old system of engineering training failed to meet new requirements to the full extent, therefore, the demand for modernization of this sphere was recognized at the state level. One can enumerate a number of government measures focused on improving higher education: adoption of the new law on education; universities' differentiation with various missions including changes in financing policy; implementation of federal programmes aimed at improvement of education; development of new state education standards, etc. Among those measures it should be noted № 2506-p "The concept of development of mathematical education in the Russian Federation" of 24.12.2013 developed and approved by the Government of the Russian Federation. In particular, it states that without high level of mathematical training it is impossible to accomplish the mission of innovative economy development, achieve long-term goals and objectives of social-economic development of the Russian Federation.

Mathematics is a fundamental base for the entire range of curricula in engineering training. At present, the issue of mathematical training quality is acute in higher engineering and natural-science education in Russia. The experience in teaching mathematics at the undergraduate level allows for conclusion that nowadays there are serious problems both from the teachers' point of view and that of students.

Contemporary students have significant difficulty with learning traditional mathematical disciplines, which is reflected in lowering students' academic achievement, high expulsion rate or transferring to other (economic, juridical, humanitarian) departments (up to 40%). Such a problem is typical not only for Russia. In the US nearly 40% of engineering students do not finish their studies or change their profiles, whereas in Europe the share of engineering students being expelled from the university ranges from 15% to 40%. In Russia, this problem is closely connected with poor school training in mathematics. Besides, the transition to the new education standards and two-layered education system have led to reduction of mathematics class hours. In different engineering profiles such a reduction may reach up to 50% as compared to previous requirements of the state education standard. For example, the state education standards of the second generation for training specialists in applied informatics provided about 800 hours for basic mathematical disciplines, of which up to 500 were class hours. The tentative basic education programmes of the third generation standards for the same profile of applied informatics provide the volume of initial mathematical training in 18 credit units (648 hours), of them not more than 59 % are given for class hours.

To address the challenge of mathematics education quality effectively in new conditions, it is necessary to review the methods of teaching mathematics.

To solve the enumerated problems of mathematics training in contemporary higher engineering education system is the primary goal of the international TEMPUS project "Contemporary educational techniques of teaching mathematics in engineering education of Russia" 543851-TEMPUS-1-2013-1-DE-TEMPUS-JPCR ("Modern Educational Technologies for Math Curricula in Engineering Education of Russia"), or MetaMath (2013-2016) for short [1] performed by consortium of Russian and European universities. The primary goal of the project is to develop methods of increasing students' motivation in learning mathematics, improve the quality of mathematics education, transform mathematics into clear and understandable subject for students. The consortium includes 2 universities of Germany (Saarland University, Saarbrьcken and Chemnitz University of Technology), Universite Claude Bernard Lyon I (France), Tampere University of Technology (Finland), 5 universities of Russia (Lobachevsky State University of Nizhni Novgorod – the coordinator of the Russian project participators, Tver State University, Kazan National Research Technical University, Saint Petersburg Electrotechnical University "LETI" , Ogarev Mordovia State University, and Association for Engineering Education of Russia.

The key objectives of the projects are:

- To perform a comparative analysis of the best European and national practices in teaching mathematical disciplines for science profiles.
- To improve mathematical courses of ten different curricula of science profiles. In the course of improvement, the curricula and practice of the Russian and European universities will be combined for the academic achievements to be recognized and to implement the best European techniques in teaching mathematics.
- To introduce electronic system of teaching mathematics support Math-Bridge [2] developed by European universities consortium into learning process. It will permit implementing different pedagogical strategies and teaching scenarios. Math-Bridge is an intellectual training system that allows teachers and students to interact with thousands of mathematical learning objects available in seven languages. Math-Bridge users may choose one of numerous prerequisite courses or dynamically generate mathematical courses adjusted for a specific student's needs, preferences, abilities, and current knowledge. Math-Bridge fosters extensive training

experience using different types of learning objects: definitions, theorem, evidences, examples, and interactive exercises.

- To develop new university competences in developing and providing access to updated online mathematics courses.

The following disciplines studied by all engineering students were chosen for analysis of mathematical courses: linear algebra, geometry, analysis, differential and integral equations, probability theory elements, bases of mathematical statistics.

To assess the quality of mathematical training within the project, the international standard of European Society for Engineering Education (SEFI) [3] is used. SEFI standard "A Framework for Mathematics Curricula in Engineering Education" (the latest edition of 2013) indicates the qualification scope of mathematical curricula, contains the levels and tasks of training, section on teaching mathematics, assessment forms, description of learning outcomes. The analysis of this document and comparison with the learning outcomes prescribed by curricula of the Russian universities in the Federal State Educational Standards and standards independently established by the Russian research universities has shown their conformity. Nearly all aspects of learning mathematics mentioned in SEFI are reflected in mathematical disciplines of the Russian universities.

The analysis of contemporary condition of the education performed on the course of the project included comparison of the Russian system of engineering education with that of European partners. The experience of all foreign universities-project partners was analysed. Of two major alternatives in teaching mathematics in the course of engineering training (to teach students "how to do this"; or to teach students "to understand how to do this"), the second option was chosen in the project taking into account the traditions of Russian higher school. In the course of the project, the following trends in improving mathematical curricula were developed based on the analysis of the current problems and experience of the European partners.

1. Introduction of remedial courses on elementary mathematics for the first-year students (to fill in the school gaps) due to changes of some parts in the relationship between class and self-study hours in favour of the latter in some parts. The curriculum includes "Introduction course of elementary mathematics" and independent work with libraries of mathematical objects in the Math-Bridge platform.

2. Transformation of curriculum structure. Instead of traditional lectures (which are, as a rule, not enough to give the necessary information) the curriculum comprises summarizing lectures and tutorial lectures. The purpose of summarizing lectures consists in problem statement on the selected topics and review of the methods for its solution as well as defining tasks for independent work on the stated problem with necessary recommendations on its performance. Tutorial lectures are aimed at assisting students to perform independent work and overcome learning difficulties both found by students themselves and revealed by the teachers when managing the independent work.

3. Enhancement of student independent work in learning subject. It is achieved by upgrading methodical support for student independent work, using project technique and e-learning systems, monitoring over independent work. In contrast to traditional approach, a part of learning material is not delivered at lectures, but given for self-study using recommended aids and electronically managed course. In this case students are instructed by the teachers at summarizing lectures, assisted at tutorial lectures and report on independently studied material during the test period. The focus in learning discipline on student independent work allows sufficient expanding of learning material, which is impossible in case of traditional lectures.

4. Application of project method. The primary objective of the project method is to give students opportunity to learn independently in the course of solving practical problems that require integration of knowledge from different subject area. The project tasks are of applied significance to demonstrate the importance of mathematics in solving real-life problems and, in this way, increase students' motivation to its study. The projects are performed under teacher's supervision. They also involve teacher's tutorials and final project defense.

For example, the course "Mathematical modeling" includes the following four compulsory projects: "Use of dynamic systems for mathematical model building", "Mathematical models of selection processes", "Mathematical models of chemical processes", "Mathematical models of biological systems/ Mathematical models of social-economic processes". Each project is performed by the group of 3-4 students that gives them the experience of team work.

5. Using e-Learning in academic process. For example, to support learning process in UNN synchronous electronic courses in all disciplines of the major were designed. They are on the website http://e-learning.unn.ru/) and include students' electronic test to check their performance and independent work.

6. Enhancement of teachers' monitoring of students' independent work skills. In this case the algorithm of independent work, forms and criteria of assessment, volume of work, deadlines, and tutorial assistance are clearly defined. It was also planned to carry out four electronic tests (within a term) and defend four compulsory projects. In case of student's effective performance during the term he/she does not have stress within the examination period.

The next stage of the project was assessment of improved curricula. For this purpose, the students studying the course were split into two groups: students learning traditional curriculum and those learning the improved one. Splitting into groups was made in such a way that the average Uniform State Exam results in the groups were nearly equal. i.e. students of both groups were similar in their initial levels. At the beginning of study there was pre-testing to determine the level of students' competencies prescribed by SEFI standards in the sphere of elementary mathematics and simple calculus (Zero and elementary levels). At the end of the term there was testing again (post-testing) with similar tasks. The goal of the testing was to reveal the changes in basic mathematical knowledge level at different forms of learning.

The example of testing outcomes on mathematical analysis is given in Tab. 1. More detailed results are given in [4]. SEFI competencies are presented in large groups. The test results are presented in percent of tasks correctly completed.

The test results show that the improved curriculum shows higher level of knowledge in absolute indicators in a number of competences. This is, for example, "Sequences and Series".

It is even more noticeable that improved curriculum shows better outcomes in the relative indicators – changes between pre-and post-testing results. This is, for example, "Differentiation".

The traditional curriculum shows decrease in the outcomes in a number of competencies (for instance, "Trigonometric functions"), whereas the improved curriculum does not show any decline. This effect can be explained by the fact that the improved curriculum allows upgrading school knowledge due to remedial course on elementary mathematics, intensive independent work and continuous relations of studied material with the applied issues.

Thus, the current study has shown that trends in improving curriculum are effective tools to increase quality of mathematical training. The results obtained may be a basis for solving urgent problems of engineering education.

Table 1. Relative level of SEFI competencies at the beginning and end of the course

№	SEFI competences (large groups)	SEFI level	1 group (traditional curriculum)		2 group (improved curriculum)	
			Pre-testing (%)	Post-testing (%)	Pre-testing (%)	Post-testing (%)
1	Real number arithmetic	0	87,36	83,81	88,41	92,16
2	Linear equations	0	96,55	94,29	82,61	94,12
3	Trigonometric functions and their applications	0	57,47	40,95	44,93	54,90
4	Trigonometric identity	0	82,76	80,00	65,22	94,12
5	Functions and reversed to them	0	51,15	51,43	61,59	82,35
6	Sequences and Series	1	43,97	76,43	40,22	86,76
7	Progressions	0	69,83	65,71	68,48	69,12
8	Logarithmic and exponential functions	0	52,59	63,57	70,65	75,00
9	Differentiation	1	75,86	82,86	65,22	94,12
10	Stationary points, maximums and minimums	0	70,11	58,10	60,14	76,47
11	Function study and graphing	1	48,28	94,29	45,65	97,06
The number of tested students			29	35	22	19

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Interdisciplinary-Based Additional Professional Education for Students of Technological University

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The article describes the project of National Research University. It has been revealed that additional professional education based on the interdisciplinary approach enhances interdisciplinary competence of students, thus, increasing their competitiveness. Such a training requires not only application of universal education technologies, but also search for numerous alternative solutions.

Key words: interdisciplinary research, additional professional education, students of National Research Technological University.

Reflecting the integrated character of the current science and knowledge acquisition, interdiciplinarity or interdisciplinary approach does not only imply a synthethis of knowledge, methods and approaches of various fields of science, but also suggests a certain degree of integration. It is regarded as an innovative methodology that definitely has indisputable value due to its synergetic character.

As a number of researchers stated, "division of contemporary science more likely rests on various scientific problems of disciplinary character than on the disciplines themselves [1, p.13]. Educators and phycologists suggest transfer of knowledge from one field of science to another one as one of the methods to develop way of thinking [1, p.12]. Most of the recent scientific advancements and discoveries have been made at the confluence of two or even more disciplines.

Interdisciplinary connections [2, p.27] are didactic equivalent of interscientific connections. According to the opinion of a number of scholars, the highest level of the interdisciplinary connections is integration stipulated by the objectives of the scientific knowledge and assumptions that reflect the unity of the real world [3,p.162].

The mission of Kazan National Research Technological University is to develop as a Russian Engineering-Training Center of Chemical Technologies which would provide training, scientific, design and manufacturing services and, thus, contributing to the complex development of the industry in the interests of the region, country and the whole world. The increase in the competitiveness of the University as a training and scientific center due to interdisciplinary professional teams is one of the priorities of the university.

In order to achieve the above-mentioned goal, the project "Additional Professional Education for Students as a Career Perspective (from student bench to the position of supervisor)" has been launched. The project itself is based on the interdisciplinary principles.

In the current context of ever-changing professional activity content when a modern engineer should be able to switch from one activity to another one and perform various professional functions, revision of engineering training system is of particular urgency. In this regard, the issue of additional training becomes especially important [4, c.103-106].

Additional professional training can be offered within various education programmes and completed in several stages in parallel with basic degree programmes. A student can choose additional professional programme according to his/her interests and needs, and

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