Engineering creativity education in Russian Universities

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INTRODUCTION: WORK EXPERIENCE IN THE PROJECT TUNING-RUSSIA

Authors have been participated in the project “Tuning – Russia” since 2010. The project was carried out in the framework of TEMPUS program of the inter-university cooperation and was aimed to set up educational programs of undergraduate and graduate level [1]. Project TUNING-RUSSIA («Setting educational programs in Russian universities") is part of the international project "Tuning Educational Structures» («Tuning Educational Structures», hereinafter - TUNING), which involved more than two hundred universities in Europe and Latin America, as well as several post-Soviet countries.

The methodology for design and implementation of educational programmes developed within the framework of the Tuning Project is gradually becoming the leading approach within the common European education space that is consistent with the Bologna Process principles.

Project "Tuning Russia" 2010-2013 was the first large-scale project in Russia on the application Tuning methodology for the development of educational programs. The project included four European universities (University of Deusto - Spain, Rijksuniversiteit Groningen - The Netherlands, Trinity College Dublin - Ireland, University of Padova - Italy), the Association of Russian classical universities and 12 Russian universities.

The essence of the TUNING-RUSSIA project is to use the tools of the Bologna process for a consistent description of structure and syllabus of educational programs at all levels on the basis of a competency approach in nine different subject areas: ICT, economics and management, psycho-pedagogical education, engineering, ecology, law, tourism, ecology, foreign languages, social work.

Under the project consortium the following steps were implemented:

- A list of 30 generic competencies for all nine Correspondence Groups was defined by an expert board of Russian universities with EU experts and specialists led by the TUNING Academy at the University of Deusto.
- A list of subject competencies for each correspondence group was set based on a literature review, the recommendations of the Ministry of Education, the new generation standards, and the existing European qualifications framework.

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- Every member university in the Consortium carried out a questionnaire survey of academics, employers, students, and graduates. Subjects evaluated the importance of each competency and the degree to which they had attained proficiency in each competency. Survey results were analyzed for each group of respondents.

Analysis of competences on the importance and performance level revealed the strengths and weaknesses of the educational program. This article compares of list of competencies developed by Russian and European universities.

This article also describes the results of a survey of Russian university academic staff and employers. The comparison of opinions of the employers and academic staff showed that it is necessary to solve the problem of changing the mentality of academics in Russian universities in order to create "innovative environment". A project-oriented course «Methods of Creativity in Engineering» was elaborated to correct this situation. The article discussed in details the structure of the course and results of the course mini-projects. Students peer review demonstrates that the competences have a good enough level of implementation in the course program.

1 COMPARISON OF A SET OF GENERIC COMPETENCIES IN THE EU AND RUSSIA

Of particular interest is the list of generic competencies specific to Russia and its degree of concordance with the EU. The greater the similarity of these lists, the more mobile Russian students would be to study in the EU.

The TUNING project divides competencies into two categories: generic and subject specific. This division corresponds with the approach based on the third generation Russian Federal State Educational Standards. In this classification, generic competencies are further divided into three types: Instrumental, Interpersonal and Systemic competencies.

Instrumental competencies include:

- cognitive (the ability to understand and use ideas and concepts),
- methodological (the ability to manage the environment: time, education strategies, to make decisions or solve problems),
- technical (related to the use or management of technology, competencies in the ICT field), and
- language (oral and written communication and second-language skills).

Interpersonal competence means a person's ability to express their feelings and to take stock of themselves, other people, and reality in general. It is divided into

- social (interpersonal skills, teamwork, social interaction skills, social and ethical attitudes and beliefs),
- communication competencies.

Systems competencies include skills and abilities related to the systemic understanding of phenomena and processes. They involve a combination of knowledge, understanding and perception of the entire system on the basis of its interacting parts or elements -- the ability to plan changes for systems development and create new systems. Systems competencies are based on instrumental and interpersonal competencies that should be taken into account in the design of the educational process.

Table 1. Results of the comparative analysis of Russian respondents (teachers, employers and graduates) with the European-Tuning model.

Competency number		**GENERIC COMPETENCIES IN BOTH EUROPEAN AND RUSSIAN SURVEYS**
Russia	**Europe**	
R1	E1	Ability for abstract thinking, analysis and synthesis
R2	E16	Ability to work in a team

R3	E13	Capacity to generate new ideas (creativity)
R4	E14	Ability to identify, pose and resolve problems
R5	E23	Ability to design and manage projects
R6	E2	Ability to apply knowledge in practical situations
R7	E6	Ability to communicate in a second language
R8	E7	Skills in the use of information and communications technologies
R9	E5	Capacity to learn and stay up-to-date with learning
R10	E9	Ability to communicate both orally and in written form in the native language
R11	E22	Ability to work autonomously
R12	E15	Ability to make reasoned decisions
R14	E20	Appreciation of and respect for diversity and multiculturalism
R15	E30	Ability to act with social responsibility and civic awareness
R16	E26	Ability to act on the basis of ethical reasoning
R17	E29	Commitment to the conservation of the environment
R18	E19	Ability to communicate with non-experts about one's field
R19	E3	Ability to plan and manage time
R20	E27	Ability to evaluate and maintain the quality of work produced
R21	E11	Ability to be critical and self-critical
R22	E10	Ability to search for, process and analyze information from a variety of sources
R23	E24	Commitment to safety
R24	E17	Interpersonal and interaction skills
R25	E8	Ability to undertake research at an appropriate level
R26	E4	Knowledge and understanding of the subject area and understanding of the profession
		GENERIC COMPETENCIES ONLY IN THE RUSSIAN SURVEY
R13		Ability for critical thinking
R27		Ability to resolve conflicts and negotiate
R28		Ability to focus on quality
R29		Ability to focus on results
R30		Ability to innovate
		GENERIC COMPETENCIES ONLY IN THE EUROPEAN SURVEY
	E12	Ability to adapt to and act in new situations
	E18	Ability to motivate people and move toward common goals
	E21	Ability to work in an international context
	E25	Spirit of enterprise, ability to take initiative
	E28	Ability to show awareness of equal opportunities and gender issues

Table 1 shows the similarity of the two lists of competencies according to their rank. In the columns under "Competency number" the list of Russian competencies is compared to the corresponding European competencies. Near the bottom of the table are five competencies that were found only in the Russian lists and other five found only in the European respondents lists. We can conclude, therefore, that 25 out of the 30 generic competencies shown in Table 1 (83%) are common between the Russian and European lists of generic competencies. This degree of similarity suggests that there is a possibility of convergence and mobility between European and Russian educational programs.

2 RESULTS OF EMPLOYERS AND TEACHERS REVIEWS

In the framework of TUNING-RUSSIA project 358 employers and 187 professors of Russian universities included into the consortium were interviewed. The questionnaires listed 30 generic competences, formed by experts from the European and Russian universities on the basis of European competences Tuning project with stress on the Russian specific [2]. The questionnaire required to indicate the importance of every competency in ICT labor market according to respondent's professional experience. The scale was from 1 – "zero importance" to 4 - "high importance".

Analysis of the most important competencies for two focus groups (employers, university professors) reveals the divergent views of these groups, and to direct the efforts of the University to more fully into account the views of employers in the formation of an educational program (Fig. 1).

An review analysis shows that of the employers and university professors has the closest opinions (divergence of views on the importance of competencies is 0.01) refers to the following competences:

- Ability to find, process and analyze information from different sources (R22 or E10),
- Ability to identify, pose and resolve problems (R4 or E14),
- Ability to design and manage projects (R5 or E23),
- Ability to be critical and self-critical (R21 or E11).

Below is a list of competencies that employers consider important, and university professors do not. The last column demonstrates the score difference of opinions. Table 2 arranges competencies in a descending order of importance from the standpoint of employers:

Table 2 The list of competencies with the highest difference of opinions between respondents.

Number of comp.		**Competency**	**Divergence**
Russia	**EC**		
R29		Ability to focus on results	0,10
R20	E27	Ability to evaluate and maintain the quality of work produced	0,15
R28		Ability to focus on quality	0,11
R2	E16	Ability to work in a team	0,17
R23	E24	Commitment to safety	0,12
R18	E19	Ability to communicate with non-experts about one's field	0,11

Thus, it is necessary to solve the problem of changing the views of university teaching staff in order to create "innovative environment", aimed at the generation and implementation of ideas; commercialization of the results; growing leaders who know how to build teams and successfully complete projects, manage small innovative enterprises.

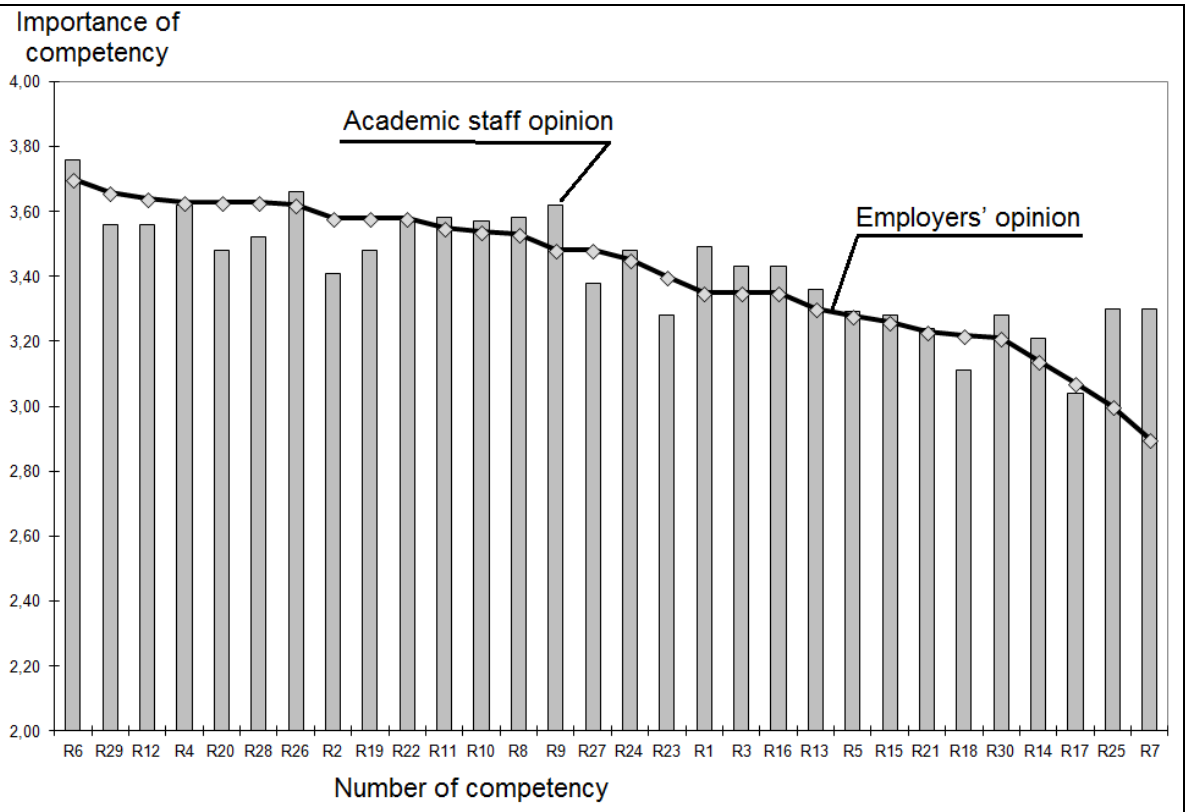


Fig.1. Summary diagram of the generic competences assessment. Russian academic staff (grey column chart) and employers (solid line)

3 EDUCATIONAL MODULE "METHODS OF CREATIVITY IN ENGINEERING"

Results of the dialogue with target focus groups (employers, university professors), which was held in the framework of the international project Tempus TUNING-RUSSIA [1], have been used by authors for elaboration of the course «Methods of Creativity in Engineering» for engineering and natural science degrees (information technology, robotics, electronics, etc.). The purpose of this course is the development of a creative approach to solving non-standard technical tasks and forming a complex understanding of activity and problems in scientific and technical innovations. The complexity of the course is 3 ESTC, the volume rate is 108 hours, including 42 classroom hours and 66 hours of individual work of students.

This course provides students with a practical introduction to the methods of engineering creativity (brainstorming, Delphi method , morphological analysis and synthesis , Theory of Inventive Problem Solving - TRIZ , etc.). The second part is devoted to the study of a new class of software products designed to support innovation processes in enterprises - Computer Aided Innovation, CAI [3]. CAI software accelerates innovation processes in the workplace and ensures the quality of potential solutions. CAI software implemented various methods of engineering creativity that provides engineer information support in solving technical tasks and creation of new technical devices and inventions .

The authors have developed an information system titled “Intellect Pro”, which can be attributed to CAI systems. It is based on the energy-information method of conceptual design [4].

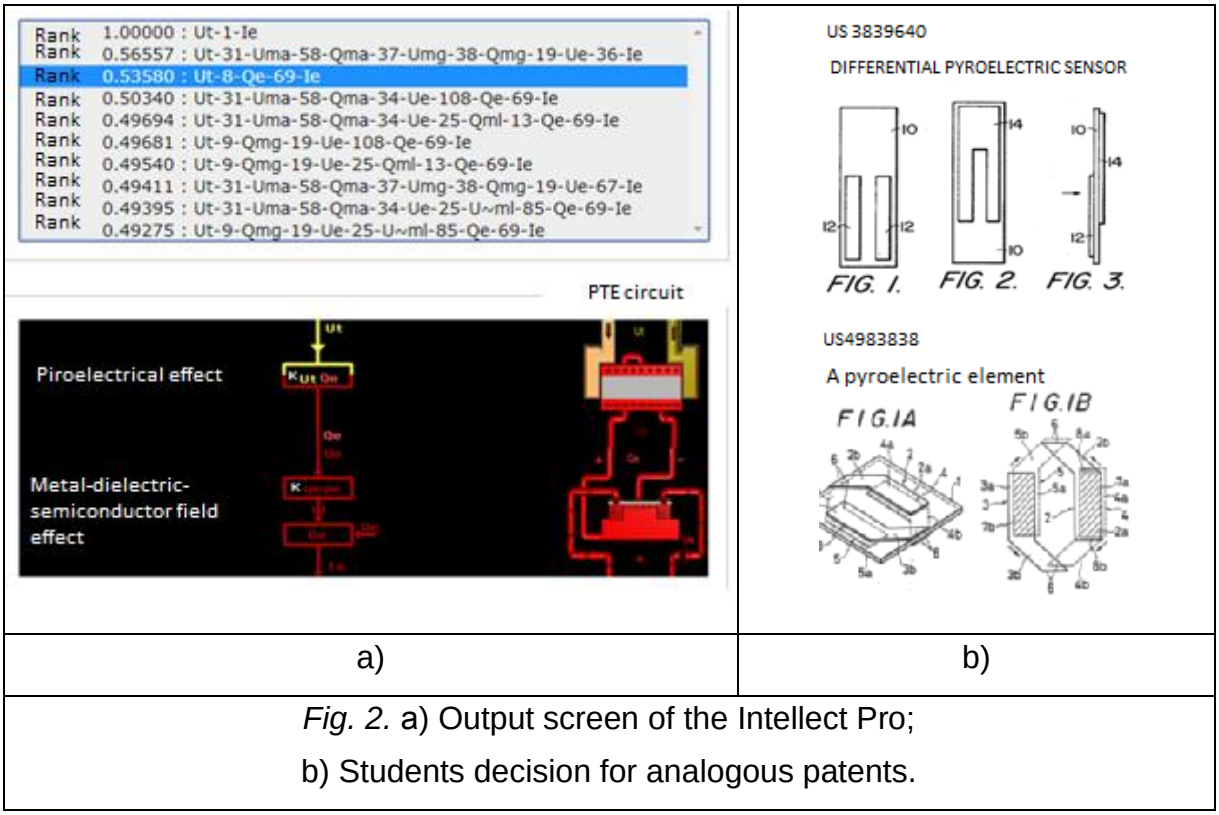
Digital libraries - Intellect Pro - computer – aided synthesis of technical inventions. This is a method of conceptual design of new technical devices on basis of digital libraries consisting of physical effects, phenomena, and a variety of its constructions. Distinctive features and principles of the present method:

- Every device functioning is based on a sequence of certain physical effects and phenomena

- Mathematical model of processes in a technical device should be being invariant to the physical nature of these processes;
- Digital library consist of common description, description of the activity principles and variety of constructions of physical effects and phenomena constructions
- Single model of database element description including text, static and dynamic pictures and formulations
- Computer-aided synthesis of alternative models of the device physical action and its alternative constructions on basis of the database and user requirement
- Potential for estimation of device's performance in accordance with user's criteria and selection of the optimal decision variant.

The teaching process is based on organization of project work of small teams (3-5 students) in order to create a prototype of a new technical device or improving the technical parameters of the existing one.

For example, Figure 2 shows the "Intellect Pro" output: ten various synthesis solutions of temperature converter, which convert the temperature difference (Ut) into an electric current (Ie). In the upper part of the figure these solutions are ranked by the aggregate performance (sensitivity, weight, reliability, accuracy, etc.). Students' task is to choose one of the options (eg. option 3) to describe the principle of the device, find analogues - patents (Fig. 2b) and try to offer a new version of the technical implementation or operational principle of this device. The selected option appears at the bottom of the screen (Fig. 2a) in block diagram form (center) and in a form of animation of the operating principle (right side). This allows the student to better understand the principle of the device operation. As a result of analysis of prototype analogs (Fig. 2b), students proposed differential circuit of the metal-insulator-semiconductor field-effect transistor (MISFET) with a pyroelectric's gate.



a) b)

Fig. 2. a) Output screen of the Intellect Pro;
b) Students decision for analogous patents.

The course "Methods of engineering creativity" forms following generic competencies:

- R1 Ability for abstract thinking, analysis and synthesis,
- R2 Ability to work in a team,
- R3 Capacity to generate new ideas (creativity)

- R20 Ability to evaluate and maintain the quality of work produced
- R28 Ability to focus on quality
- R29 Ability to focus on results.

After completing the course students were asked to fill the same questionnaire as mentioned above. The questionnaire listed 30 competencies, and students had to specify, according to their experience, the degree of importance of each competence for their future profession and the level of educational program in achievement of the given competency in the field of ICT. The scale was from 1 - "zero" to 4 - "high".

Figure 3 shows a diagram of the overall assessment of the competencies list by the whole student group (27 people) after reading the course "Methods of engineering creativity" (7th semester).

The diagram analysis shows that all the competences, targeted in the "Methods of engineering creativity" course have enough level of implementation in accordance to the students' opinion (above average value equal to 2,966 - the dotted line in Figure 3).

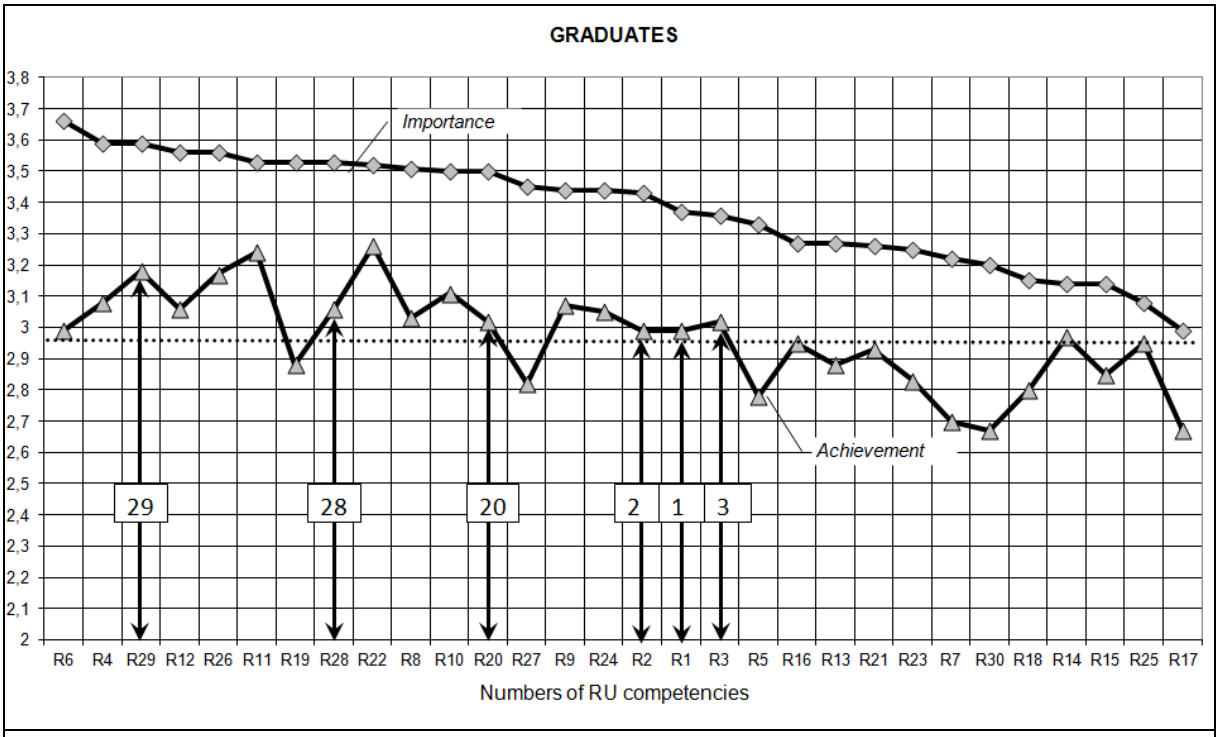


Fig. 3. The diagram of the generic competencies estimation by ICT students (27 students) after course "Methods of engineering creativity".

4 SUMMARY

In the field of university educational there is a consistent global trend toward the integration of national systems, the convergence of educational programs and training cycles, and the formation of common approaches to assessing and maintaining the quality of education. Based on the comparison between the TUNING Project list of competencies, it is possible to conclude that the European and Russian higher educational systems formulate their generic competencies in a very similar way (87% of similarity). This suggests that there are good prospects for convergence and collaboration between Russian universities and universities in Europe.

The comparison of opinions of the employers and academic staff showed that it is necessary to solve the problem of changing the mentality of teachers in high school in order to create "innovative environment", which is aimed at the generation and implementation of ideas, commercialization of the results, growing leaders who know how to build teams and successfully complete projects and manage small innovative enterprises.

The introduction of the course «Methods of Creativity in Engineering» allows to increase the level of competencies growing and match the level of students education to employers' requirements.

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