# COMPETENCE-BASED MODEL OF LEARNING FOR ENGINEERS AND THE FUTURE OF UNIVERSITY EDUCATION.

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## ABSTRACT

The goal of graduate professional educational is to develop student competence. Competencies are a dynamic combination of knowledge, understanding, skills and capabilities. Some researchers have divided competencies into generic and professional categories. Generic competencies are those that apply across a variety of disciplines and play a crucial role in education, providing wider opportunities for graduates to find good jobs and advance their careers. This suggests that universities should pay considerable attention to increasing their students' proficiency in these generic competencies. This article compares a list of generic competencies developed in Russian universities with a similar list developed through a consortium of Russian and European universities (project TUNING-RUSSIA). It then makes a second comparison with a list of competencies drawn from the CDIO Syllabus. This comparison indicates the degree of similarity among these lists and the possible convergence among Russian, European, and American universities. The results are presented from a survey that was conducted among Russian employers, academics, and recent university graduates. The survey asked them to rate each listed competency by its importance and also by the degree to which graduating students are perceived to have achieved proficiency in that competency as a result of their university education. Finally, this article describes how university courses were developed at Astrakhan State University to increase student proficiency in specific competencies. Results show that there is significance convergence of opinion on which competencies are important, that it is possible to identify those competencies on which students show lower levels of proficiency, and that courses can be developed to increase proficiencies in selected competencies.

## KEYWORDS

Competency-based education, Project Tuning, Lean production, Creativity, Computer-Aided Innovation (CAI)

## INTRODUCTION

Astrakhan State University (ASU) is a major university in the south of Russia. It is a classical university with a balanced selection of courses in the natural sciences, liberal arts, engineering, and pedagogical specialties. Since 2000, Astrakhan State University has been taking part in international projects related to the implementation of the Bologna process and new practice-oriented approaches to education. During that time, ASU has implemented 10 EU TEMPUS programs. It has also accumulated vast experience in cooperation with regional commercial enterprises while implementing the following EU TEMPUS projects:

- JEP_26108_2005: “Network for universities and enterprises cooperation (NEUC)”,
- JEP_25070_2004: “Modernization of Education in ICT at South Russian Universities”,
- JEP_27082_2006: “Network of centers for training of innovative project management”, and
- 511135-TEMPUS-I-2010-1-ES-TEMPUS-JPCR: «TUNING RUSSIA».

Since 2007, ASU has offered four Masters Degrees in cooperation with foreign universities:

1) Master’s Degree program MBDS (Mobiquite, Bases de Donnees et integration de Systemes) is taught in Russian and French in cooperation with Sofia Antipolis University, Nice, France.

   The program is aimed at training engineers in wireless information services design. The uniqueness of MBDS is the high level of interaction with industry and business. A list of professional competencies has been developed on the basis of the Skills Framework for the Information Age (SFIA). SFIA was developed in 1999 with the support of the British Government, is the industrial standard of skills management in the sphere of Information and Communication Technologies (ICT).

2) Three Master Degree programs implemented jointly with Clark University (Worcester, Massachusetts, the USA):

   - Master of Public Administration (MPA),
   - Master of Informational Technologies (MSIT), and
   - Master of Professional Communications (MSPC).

Implementing these programs allowed ASU’s faculty to gain substantial experience and to adopt methods from Sofia Antipolis University and Clark University colleagues. As a result the educational methods in ASU were enriched with new interactive teaching methods, like the case study methodology, the use of teamwork, and group projects. The introduction of these methods into the educational process has resulted in higher evaluations by students, employers and instructors.

As of 2011, the curriculum at ASU consisted of 248 educational programs at different levels, including 129 of bachelor degrees, 30 Master degrees and 62 specialties of postgraduate studies. The list of training initiatives includes the liberal arts, natural sciences, as well as pedagogical, engineering and economics specialties. All Russian Universities transitioned to a two-level (bachelor, master) curricular model in 2011, which necessitated the development of new curricula derived from competency-based learning models [1, 2].

Competencies are dynamic combination of knowledge, understanding, skills and abilities. The development of student competence is the aim of educational programs. Competencies are divided into “generic” and “professional”. Generic competencies are essential because they are exactly what graduates need to widen their opportunities for successful employment.

Thus it was necessary to give maximum attention and effort to include these generic competencies and abilities in the offered programs.

A list of generic competencies confirmed by the experts from the European Union was developed in 2010-2011 in the framework of the implementation of ASU's international TEMPUS program titled TUNING-RUSSIA [3]. The goal of this program is to coordinate European and Russian models of education in 8 different subject areas:

1. ICT (Information and Communication Technologies),
2. Economics and Management,
3. Education,
4. Environmental Engineering,
5. Law,
6. Tourism,
7. Languages,
8. Social work.

To test the completeness and reliability of the list of generic competencies, the authors also studied the experience of American Universities. Especially interesting was the "The CDIO™ INITIATIVE" (http://www.cdio.org ). The CDIO concept of engineering education improvement (Conceive, Design, Implement, Operate) was developed in the late 1990's at Massachusetts Institute of Technology (MIT). It was developed with the cooperation of scientists, representatives of industry, and students. At the time of writing, it is implemented in more than 50 Engineering universities in 25 countries of the world. The CDIO concept is based on the premise that the graduates of Engineering University programs should be ready to conceive, design, implement, and operate complex engineering projects that create new technological devices and systems as finished products through team work. A four-level list of competencies has been developed in the framework of the CDIO project [4, 5].

ASU established the goals of defining a common list of generic competencies for all areas of training, comparing it with known international models, carrying out an analysis of the priority and feasibility of these competencies in the university, and then defining teaching modules that can be implemented to support the development of these competencies in future students.

This article compares of list of competencies developed by Russian and European universities with the CDIO list of competencies. It also describes the results of a survey of Russian university graduates, employers, and pedagogical staff. The importance of each competency was measured, along with a subjective estimate of the degree to which graduates of Russian universities had achieved competence in each of the items. ASU's experience is described and recommendations are given about the development of teaching modules implementing these competencies.

## A COMPARISON OF THE LIST OF GENERIC COMPETENCIES IN THE TUNING-RUSSIA PROJECT WITH THE CDIO SYLLABUS

The TUNING-RUSSIA project, which is a program of the EU's TEMPUS program, is a consortium of 16 universities, 12 of which represent various regions of Russia, and four from Europe (Spain, the Netherlands, Ireland, and Italy). This collaboration allows ASU to analyze various approaches to the principles of the Bologna Process and the TUNING methodology. The twelve Russian universities range from technical to classical disciplines. The seventeenth member of the project is the Association of Classical Universities of Russia that represents 44 universities of Russia.

The project objectives are:

- the promotion and sharing of the TUNING methodology experience among the academic community, and
- the implementation and development of the TUNING methodology at a number of Russian universities by organizing TUNING Centers at the participating universities.

The participating universities are divided into Correspondence Groups that focus on specific areas of inquiry such as Economics and Management, Psychology and Pedagogic Education, Engineering Ecology, Jurisprudence, Tourism, and Ecology.

Astrakhan State University is the Coordinator of the Correspondence Group on Information and Communication Technologies (ICT). Other members of this Correspondence Group are the North Caucasus State Technical University, Moscow State University of Railway Engineering, Novgorod State University, Tver State University, N. I. Lobachevsky State University of Nizhny Novgorod, and the L.N. Tolstoy State Pedagogical University in Tula. Alexander Rayon, a professor at the University of Deusto (Spain), is a group expert from the EU. ASU plans to open a TUNING Center in ICT on its campus in Astrakhan in the near future.

Under the project consortium the following steps were implemented:

1. 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.

2. 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.

3. Every member university in the Consortium carried out a questionnaire survey of teachers, 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.

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

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 (RFSES). In this classification, generic competencies are further divided into three types: Instrumental, Interpersonal and Systemic competencies.

1. **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).

2. **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) and
   - communication competencies.

3. **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 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. A similar comparison was made with the lists of generic skills competencies provided by CDIO Syllabus v2.0 [4]. The results are shown in Table 2.

Table 2
Comparison of the Generic Competencies Lists Russia-Europe-CDIO

| **№№ Competence** | | **GENERIC COMPETENCIES BOTH IN EUROPEAN AND RUSSIAN SURVEYS** | **CDIO** |
|---|---|---|---|
| **Russia** | **Europe** | | |
| R1 | E1 | Ability for abstract thinking, analysis and synthesis | 2.3 SYSTEM THINKING |
| R2 | E16 | Ability to work in a team | 3.1 TEAMWORK |
| R3 | E13 | Capacity to generate new ideas (creativity) | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility; 2.4.3 Creative Thinking) |

| | | | |
|---|---|---|---|
| R4 | E14 | Ability to identify, pose and resolve problems | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty; 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility) |
| R5 | E23 | Ability to design and manage projects | 4.4 DESIGNING<br>4.5 IMPLEMENTING (4.5.6 Implementation Management)<br>4.6 OPERATING (4.6.1 Designing and Optimizing Sustainable and Safe Operations) |
| R6 | E2 | Ability to apply knowledge in practical situations | 2.1 ANALYTICAL REASONING AND PROBLEM SOLVING |
| R7 | E6 | Ability to communicate in a second language | 3.3 COMMUNICATIONS IN FOREIGN LANGUAGES |
| R8 | E7 | Skills in the use of information and communications technologies | 3.2 COMMUNICATIONS (3.2.4 Electronic/Multimedia Communication; 3.2.5 Graphical Communication) |
| R9 | E5 | Capacity to learn and stay up-to-date with learning | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.6 Lifelong Learning and Educating) |
| R10 | E9 | Ability to communicate both orally and in written form in the native language | 3.2 COMMUNICATIONS (3.2.3 Written Communication; 3.2.6 Oral Presentation; 3.2.7 Inquiry, Listening and Dialog) |
| R11 | E22 | Ability to work autonomously | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty) |
| R12 | E15 | Ability to make reasoned decisions | 2.1 ANALYTICAL REASONING AND PROBLEM SOLVING |
| R14 | E20 | Appreciation of and respect for diversity and multiculturality | 2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES (2.5.2 Professional Behavior; 2.5.6 Trust and Loyalty)<br>4.2 ENTERPRISE AND BUSINESS CONTEXT (4.2.1 Appreciating Different Enterprise Cultures; 4.2.5 Working in International Organizations ) |
| R15 | E30 | Ability to act with social responsibility and civic awareness | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty; 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility)<br>2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES (2.5.1 Ethics, Integrity and Social Responsibility; 2.5.2 Professional Behavior) |
| R16 | E26 | Ability to act on the basis of ethical reasoning | 2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES |

| | | | |
|---|---|---|---|
| R17 | E29 | Commitment to the conservation of the environment | 2.3 SYSTEM THINKING (2.3.1 Thinking Holistically)<br>4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT (4.1.1 Roles and Responsibility of Engineers; 4.1.2 The Impact of Engineering on Society and the Environment; 4.1.7 Sustainability and the Need for Sustainable Development)<br>4.5 IMPLEMENTING (4.5.6 Implementation Management)<br>4.6 OPERATING (4.6.1 Designing and Optimizing Sustainable and Safe Operations; 4.6.6 Operations Management) |
| R18 | E19 | Ability to communicate with non-experts of one's field | 3.2 COMMUNICATIONS (3.2.1 Communications Strategy; 3.2.7 Inquiry, Listening and Dialog; 3.2.8 Negotiation, Compromise and Conflict Resolution; 3.2.9 Advocacy; 3.2.10 Establishing Diverse Connections and Networking) |
| R19 | E3 | Ability to plan and manage time | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.7 Time and Resource Management) |
| R20 | E27 | Ability to evaluate and maintain the quality of work produced | 4.4 DESIGNING (4.4.6 Design for Sustainability, Safety, Aesthetics, Operability and other Objectives)<br>4.5 IMPLEMENTING (4.5.1 Designing a Sustainable Implementation Process; 4.5.6 Implementation Management)<br>4.6 OPERATING (4.6.4 System Improvement and Evolution; 4.6.6 Operations Management) |
| R21 | E11 | Ability to be critical and self-critical | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.4 Critical Thinking) |
| R22 | E10 | Ability to search for, process and analyse information from a variety of sources | 2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY (2.2.2 Survey of Print and Electronic Literature) |
| R23 | E24 | Commitment to safety | 2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES (2.5.1 Ethics, Integrity and Social Responsibility)<br>4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT |
| R24 | E17 | Interpersonal and interaction skills | 3.2 COMMUNICATIONS<br>3.3 COMMUNICATIONS IN FOREIGN LANGUAGES |
| R25 | E8 | Ability to undertake research at an appropriate level | 2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY |
| R26 | E4 | Knowledge and understanding of the subject area and understanding of the profession | 1 DISCIPLINARY KNOWLEDGE AND REASONING |

| GENERIC COMPETENCES ONLY IN THE RUSSIAN SURVEY | | | |
|---|---|---|---|
| R13 | | Ability for critical thinking | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.4 Critical Thinking) |
| R27 | | Ability to resolve conflicts and negotiate | 3.2 COMMUNICATIONS (3.2.7 Inquiry, Listening and Dialog; 3.2.8 Negotiation, Compromise and Conflict Resolution) |
| R28 | | Ability to focus on quality | 4.4 DESIGNING (4.4.6 Design for Sustainability, Safety, Aesthetics, Operability and other Objectives)<br>4.5 IMPLEMENTING (4.5.1 Designing a Sustainable Implementation Process)<br>4.6 OPERATING (4.6.4 System Improvement and Evolution; 4.6.6 Operations Management) |
| R29 | | Ability to focus on results | 4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT (4.3.1 Understanding Needs and Setting Goals, 4.3.2 Defining Function, Concept and Architecture, 4.3.3 System Engineering, Modeling and Interfaces, 4.3.4 Development Project Management) |
| R30 | | Ability to innovate | 2.4 ATTITUDES, THOUGHT AND LEARNING (2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility, 2.4.3 Creative Thinking )<br>4.2 ENTERPRISE AND BUSINESS CONTEXT (4.2.6 New Technology Development and Assessment) |

It is evident from Table 2 that all 25 generic competencies common between Russian and European universities are reflected in the competencies from the CDIO Syllabus v2.0. We can conclude, therefore, that the graduate professional educational systems in Europe, Russia, and America formulate generic competencies in a similar way. This suggests fertile ground for collaboration and mobility among these universities.

## RATING COMPETENCIES BY IMPORTANCE AND THE DEGREE OF STUDENT PROFICIENCY

It is necessary to keep close watch on society's needs for generic and professional competencies. The development of student competence in accordance with social and economic needs is a priority task of educational programs.

The concept of "competency" has appeared outside the system of higher education to characterize a person's set of skills and abilities that are relevant to jobs in the labour market. The competency approach in HR-management is aimed at staff selection, evaluation, training and development. Therefore the language of competencies is appropriate to use in consultation and dialogue with employers and university graduates to determine the objectives of educational programs and the requirements for successful adaptation of graduates in the labour market.

In the framework of the TUNING–RUSSIA project, a questionnaire was developed and distributed to the relevant target populations: employers, academics, and university graduate alumni. All 16 of the Russian universities in the TUNING project participated. In total, 358 employers, 187 academics, and 1788 university graduates were polled. The questionnaires contained the lists of the 30 generic competencies in Table 1 identified by the Russian universities.

Subjects were asked to rate each competence according to:

- the importance, in their judgment, of the competency for professional work in their field.
- the degree to which respondents believed university graduates had achieved proficiency in the skills and abilities required by that competency as a result of their educational program.

A 4-point rating scale was used, 1 (min) to 4 (max). In addition, respondents were asked to rate the five competencies that were of the greatest importance to them.

Analysis of the competencies according to their importance and their level of achievement makes it possible to identify the strong and weak points in university curricula, and therefore help to reform educational programs. The summary results of the questionnaire poll are shown in Figures 1 through 3.

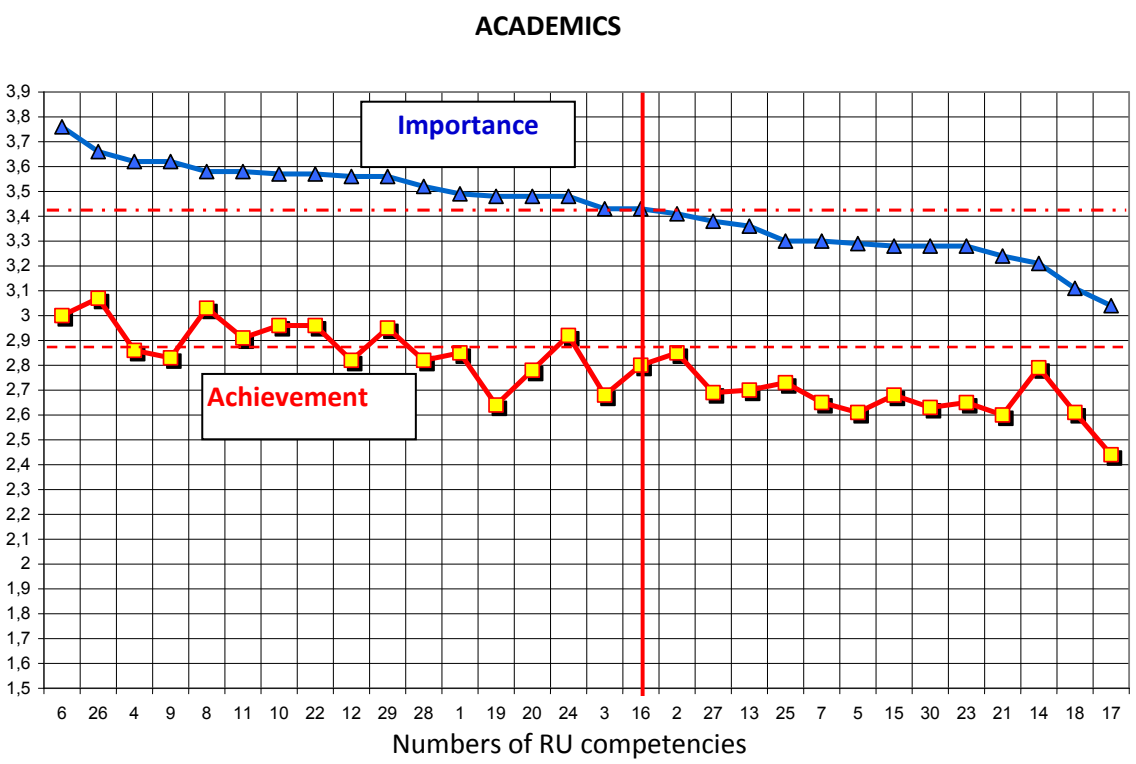


Figure 1. Summary diagram of the Generic competencies assessment (Russian Academics)

All the competencies are rated in accordance with their degree of importance. The mean values of importance for each competency are found in the top line of Figures 1 through 3 for each group of respondents. The average ratings on the 4-point scale across competencies for each respondent group are for academics, 3.43; employers, 3.41; and graduates, 3.38.

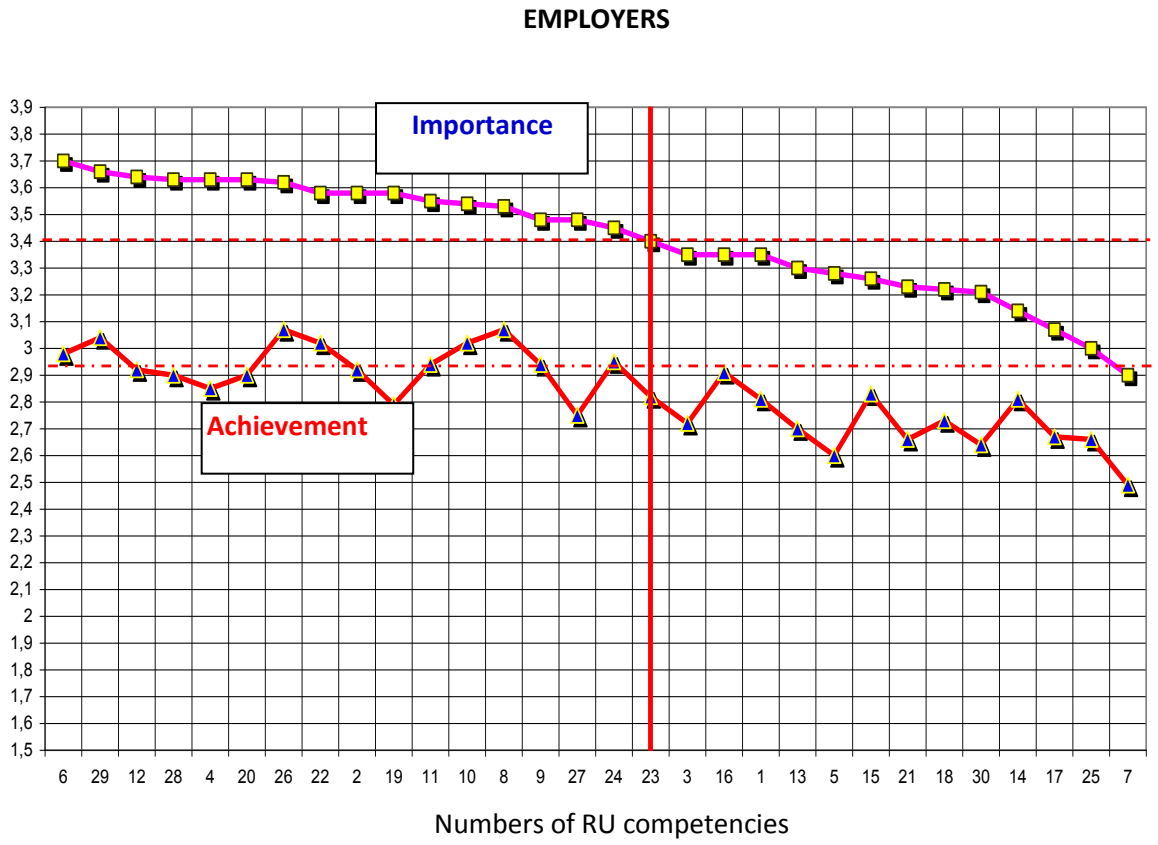


Figure 2. Summary diagram of the Generic competencies assessment (Russian Employers)

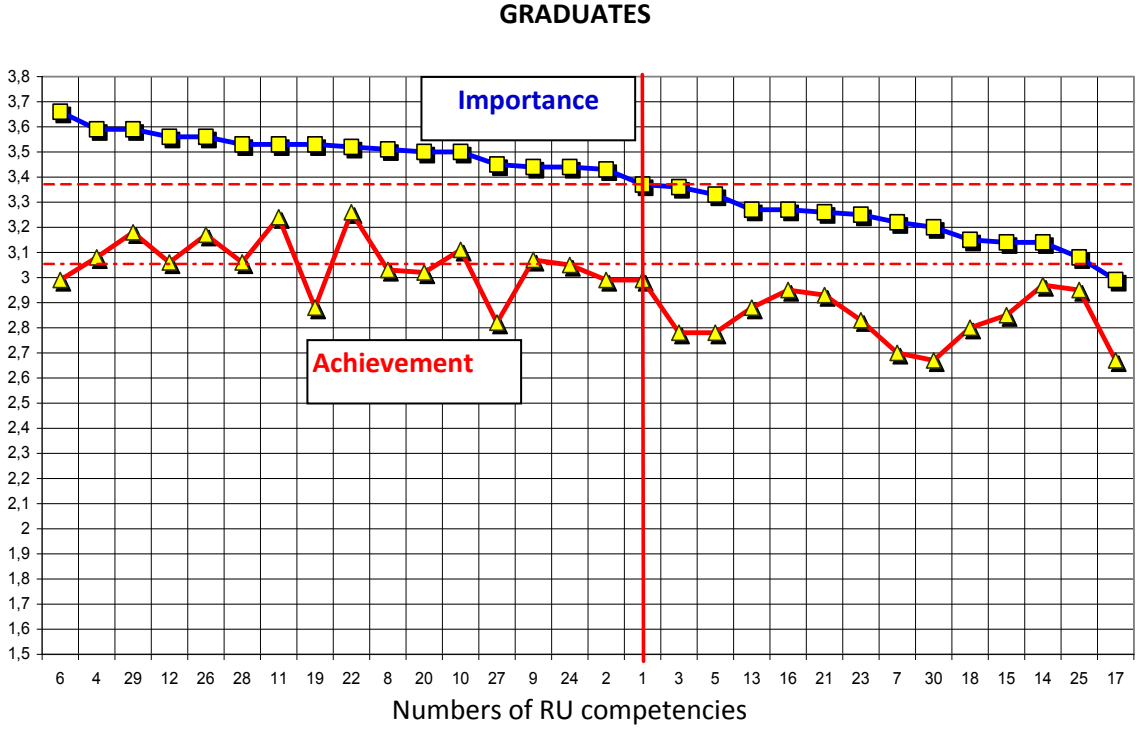


Figure 3. Summary diagram of the Generic competencies assessment (Graduates)

The competencies which received ratings below the average were considered less important and, therefore, were not included in the subsequent analysis. The division of the competencies into above and below average is marked with a red vertical line in the graph. For the competencies with above average importance levels, average ratings of student proficiency in the competencies were 2.88 for academics, 2.94 for employers, and 3.06 for graduates.

This analysis identifies competencies with below average levels of proficiency attainment. This suggests that Universities should upgrade or add training courses and modules which foster these competencies. It is possible to introduce some specialized courses and modules to do this.

All three groups of respondents gave a very low assessment of the level of demonstrated ability in competencies №R19 – “Ability to plan and manage time”, №R20 – “Ability to evaluate and maintain the quality of work produced”, and №R28 – “Ability to focus on quality”. (This last competency received below average assessments from employers and academics, though the graduates rated it a bit above average).

In order to increase proficiency levels in these competencies during the 2012/2013 academic year at Astrakhan State University, the University introduced a corrective course for all Master Programs called “Lean Production and 6 Sigma”, aimed at the formation of skills and competencies in the area of innovative management.

According to the university graduates’ estimates (Fig. 3), competencies №R1 “Ability for abstract thinking, analysis and synthesis”, №R2 “Ability to work in a team”, and №R4 “Knowledge and understanding of the subject area and understanding of the profession” have high importance but a below average level of proficiency at the university.

To improve this situation ASU developed a special course “Methods of Creativity in Engineering” that has been taught at ASU for the past 2 years to Master’s degree candidates in Engineering in the Faculty of Mathematics and Informatics. This course uses student teams of 3-5 persons working on a project creating new technical devices or improving technical characteristics of existing ones. These activities correspond to the “Conceive” and “Design” stages of the CDIO Syllabus v2.0.

## THE COURSE "LEAN PRODUCTION AND SIX SIGMA"

"Lean Production and 6 Sigma”, which was developed at the University, is focused on deepening students' knowledge in the field of modern industrial management. It focusses on developing skills and competencies for professional participation in the development of tactics and strategy in a company to increase its competitiveness.

The course includes training of the following competencies:

- №R2 Ability to work in a team
- №R5 Ability to design and manage projects
- №R11 Ability to work autonomously
- №R12 Ability to make reasoned decisions
- №R19 Ability to plan and manage time
- №R20 Ability to evaluate and maintain the quality of work produced
- №R28 Ability to focus on quality

Specific situations, analytical discussion, expert assessment and business games are used as the main methods of education to meet the requirements of the CDIO Standard 8.

At the beginning and end of the course, all ASU students are given a questionnaire for self-assessment of the competencies developed in lean production. A model of the education process and how someone masters new information was used in the construction of the questionnaire (Experiential Learning Model - ELM), proposed by the American scientist David A. Kolb and his colleagues at Case Western Reserve University [7].

Based on the Kolb model there are 5 levels (0-4) of knowledge proficiency:

0. The zero level - understanding (students do not have any experience (knowledge) in a certain activity, but show an ability to receive new information.)

1. The first level - awareness (students perform activities based on the description of the action, prompt, or hint).

2. The second level - reproduction (when students reproduce and apply information by themselves in previously discussed standard situations, their activity is reproductive).

3. The third level - application (when students know how to use acquired knowledge and skills in non-typical situations, their activities are productive.)

4. The fourth level - creativity (when students work in a field of activity, they know how to create new rules in emergency situations, and elaborate new sequences of activities in response to changing situations.)

The highlighted features of the levels relate to the appropriate levels of mastery: understanding, awareness, reproduction, application, creativity.

A total of 448 people took part in the self-assessment. Of these, 325 people were candidates for Master's degree (Group 1) and 123 people are representatives of Business, Government, heads of Social Institutions enrolled in a program of training and retraining (Group 2)
Table 3 shows the results of self-assessment of competence "before the course" and "after the course". Results obtained after the self-assessment convincingly show the impact of the proposed course on the development of the student competencies. However, the results for Group 2 are noticeably better than for Group 1. This higher level of achievement can be explained by the fact that the students in Group 2 have professional experience; they are top-managers of enterprises and the success of their organizations depends on them.

Table 3.
Results of self-assessment of Masters (group 1) and representatives of Business and Administration studying on the courses of advanced professional training (group 2).

| | **Level 0 (%)** | | **Level 1 (%)** | | **Level 2 (%)** | | **Level 3 (%)** | | **Level 4 (%)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gr.1 | Gr.2 | Gr.1 | Gr.2 | Gr.1 | Gr.2 | Gr.1 | Gr.2 | Gr.1 | Gr.2 |
| "Before" | 99,4 | 75,6 | 0,6 | 20,4 | 0 | 1,6 | 0 | 2,4 | 0 | 0 |
| "After" | 0 | 0 | 67,7 | 0 | 30,8 | 51,2 | 1,2 | 39 | 0,3 | 9,8 |

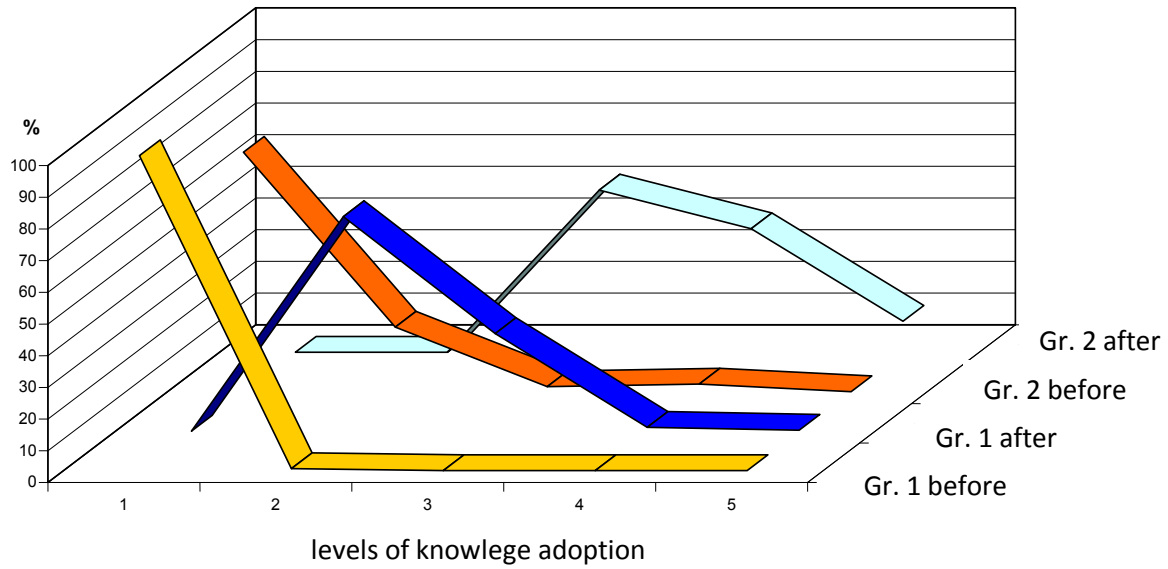


Figure 4. Results of the Self-Assessment of Masters students (Group 1) and Representatives of Business and Administration (group 2) in Advanced professional training courses

## THE COURSE "CREATIVE METHODS IN ENGINEERING"

The course "Creative Methods in Engineering" was introduced for Engineering and Natural Science Directors of training at ASU (information technology, robotics, electronics, etc.). This course provides students with a practical introduction to the methods of creative activity in engineering like brainstorming, the Delphi method, morphological analysis and synthesis, and the theory of inventive problem solving – TRIZ. The second part of the course is dedicated to the study of a new group of software products aimed at supporting the innovative processes of an enterprise - Computer Aided Innovation, CAI [8]. CAI Software speeds up the innovation processes at an enterprise and guarantees the quality of the possible solutions. The CAI software combines different methods of engineering activity providing information support to an engineer while solving technical problems, creating new devices, and inventions.

An information system that can be linked to CAI systems was developed at ASU. It is based on the energy and information method of conceptual design devised by the scientists at the University [9].

The course "Creative Methods in Engineering" helps students gain the following competencies:

№R1 Ability for abstract thinking, analysis and synthesis,
№R2 Ability to work in a team,
№R3 Capacity to generate new ideas (creativity)
№R26 Knowledge and understanding of the subject area and understanding of the profession,
№R8 Skills in the use of information and communications technologies,
№R22 Ability to search for, process and analyze information from a variety of sources
№R30 Ability to innovate.

The method of teaching utilizes working in student teams of 3-5 people on a project developing a new technical device or improving the parameters of an existing one. Work on this project corresponds to the Conceive and Design stages of the CDIO Syllabus v2.0.

Figure 5 shows the diagram based on the estimation of generic competencies by the students of ICT group (27 students) after the course “Creative Methods in Engineering” (7th term).

The analysis of the diagram reveals that, according to the estimates of the students, they have attained a sufficient level of proficiency in these competencies as a result of the course.

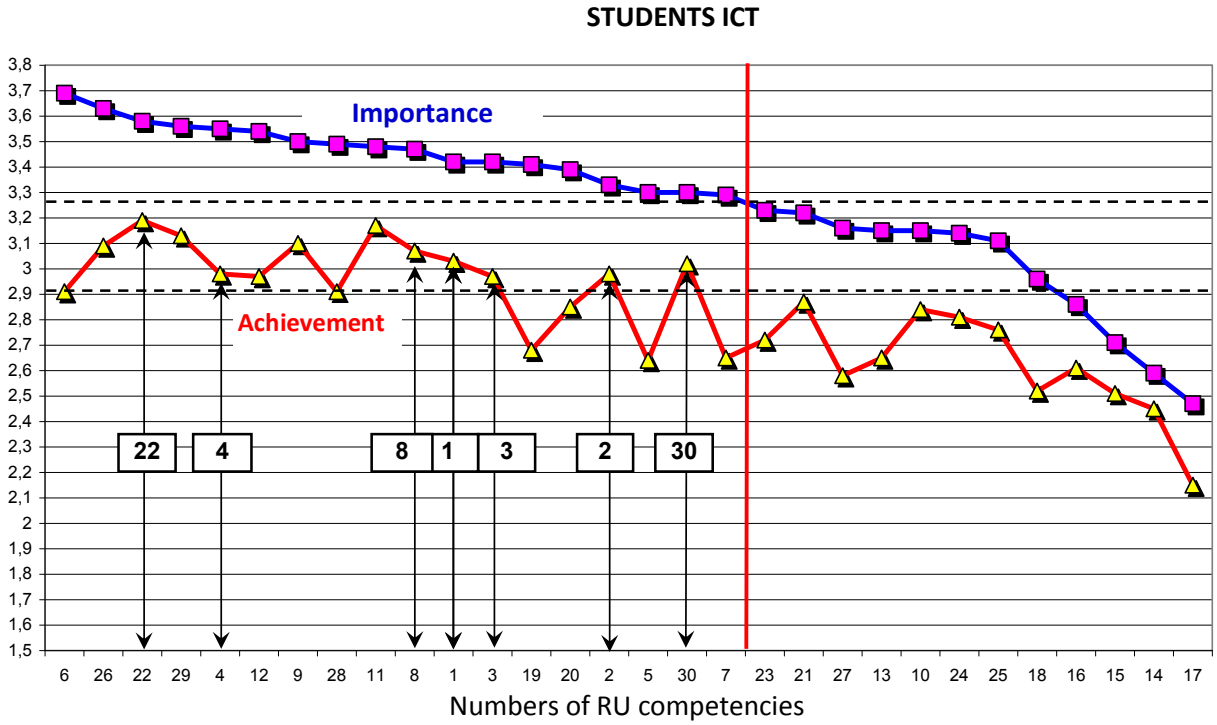


Figure 5. The diagram of the Generic competencies assessment (ICT Students)

## CONCLUSION

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 and the CDIO list of competencies, it is possible to conclude that the European, Russian, and American higher educational systems formulate their generic competencies in a very similar way. This suggests that there are good prospects for convergence and collaboration between Russian universities and universities in Europe and the U.S.

The survey of employers, academics and graduates described above shows that all three groups of respondents have similar perceptions of which competencies are important, especially when we look at those competencies that are rated as having higher than average importance. This survey was also shown to be an effective method for identifying those

competencies that need more improvement. The two special masters courses developed at ASU, "Lean Production and 6 Sigma" and "Creative Methods in Engineering", were designed specifically to address the need for more intensive training in several targeted competencies. The data show that these courses were effective in raising student proficiency in these targeted competencies. This leads to the conclusion that it is possible to identify weaknesses in the training of students and to develop courses that are effective ways of improving student proficiency in specific competencies. To the extent that these competence "gaps" are similar in universities students around the world, these courses could be shared between universities, leading to further possibilities for collaboration and cooperation.

## REFERENCES


[1] McEvoy G., Hayton, J., Wrnick A., Mumford T., Hanks S. and Blahna M. "A competency-based model for developing human resource professionals", Journal of Management Education, Vol. 29, 2005, pp 383–402.

[2] Universities contribution to the Bologna Process (An Introduction), 2nd Edition, Publicaciones de la Universidad de Deusto, Bilbao, Spain, (ISBN 978-84-9830-132-8), 2008, pp 25-55

[3] Tuning Educational Structures in Europe, http://www.unideusto.org/tuningeu/subject-areas.html

[4] Crawley E.F., Malmqvist J., Lucas W.A. and Brodeur D.R., "The CDIO Syllabus v2.0: An Updated Statement of Goals for Engineering Education", http://www.cdio.org/files/project/file/cdio_syllabus_v2.pdf

[5] Crawley E.F., Malmgvist J., Lucas W.A. and Brodeur D.R. "The CDIO Syllabus v 2.0. An Updated Statement of Goals for Engineering Education", Proceedings of the 7th International CDIO Conference, Technical University of Denmark, Copenhagen, June 20—23, 2011.

[6] McClelland D.C., "Testing for Competence Rather Than for 'Intelligence'", American Psychologist, 1973, Vol. 28, pp 1-14.

[7] Kolb D.A., Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall Inc., Englewood Cliffs, N.J., 1984.

[8] Hüsig S. and Kohn S., "Computer Aided Innovation – State of the Art from a New Product Development Perspective", Computers in Industry Vol. 60, Num. 8, 2009, pp 551–562.

[9] Candido, J., Murman, E. and McManus, H., "Active Learning Strategies for Teaching Lean Thinking", Proceedings of the 3rd International CDIO Conference, Cambridge, MA, June 2007.

[10] Petrova I.Y. and Zaripova V.M., "Systems of Teaching Engineering Work on the Basis of Internet Technologies", Proceedings of the International Conference "Modern (e-) Learning, Varna, 2006, Sofia, FOI-COMMERCE – 2006, pp 89-96.

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