PERSPECTIVES AND CHALLENGES FOR RUSSIAN SYSTEM OF ENGINEERING EDUCATION

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Abstract: *Over the last decades Russian higher education institutions have been actively working in global education world and facing problems of adapting its education system to it. Specifically it concerns system of engineering education which has to overcome problems of the past and face modern reality of Industry 4.0. One of the major problems is low flexibility and adaption ability to rapidly changing external circumstances as well as liner and strict curricula structure. To overcome problems successfully, Russian engineering education has got substantial support of Russian government; system is going to be modified in leading Russian universities. General approach that needs to be implemented is focusing on re-adjusting curricula as the set of alternating study courses and work on engineering tasks. University networking supported by interactive platforms in close cooperation with industry should be also the basic for modernization.*

Keywords: TQM IN UNIVERSITY, EDUCATION REFORM, EDUCATIONAL CYCLE, UNIVERSITY NETWORKING

Introduction

The problem of returning global and national economies to sustainable economic growth is universal. In accordance to different expert analysis, economic growth can be ensured by design and introduction of new disruptive technologies and newly developed goods and services. Though in comparison to previous technological mode, the modern one differs in terms of lifecycle period, time for entering market and commercial usage, mutual integration of technologies. This situation poses considerable challenge to the universities' training system as the lifecycle of technologies and products has become comparable with the educational cycle. The increasing amount of distributed knowledge and simplified remote access to this knowledge forced to change traditional paradigm of universities and its training system.

Background

Modern Russian system of engineering education is traditionally based on features and achievements of soviet system of higher education. One of the peculiarities of traditional system was its linear character when expected result of education and relatively narrow specialization had been defined at the beginning of educational cycle. Educational cycle as a rule lasting for 5,5 years contained a lot of basic and specialized knowledge with gradual convergence with practical activities on upper level of education. Practical involvement into the solving of engineering problems had been rather limited and it led to situation when graduates had possessed a lot of theoretical knowledge but had not been able to use it practically. Finally, it took another 2-3 years to combine theory and practice to be really certified as an engineer.

Epic collapse of manufacturing industry in Russia in the early 90-s led to destruction of previously established links between universities and industrial sector. Losing part of public funding forced universities to look for other financial non-public resources along with considerable weakening of centralized university government [12]. Partly independent in terms of financing and acting new units started to born in universities being fully responsible for future survival and having rather low propensity to cooperation with other units. Generally speaking the whole university structure sometimes much more reminded holdings of independent entrepreneurs rather than educational corporations with centralized management system [3].

Since the beginning of 90-s number of state and non-state universities was doubled [18] mainly for the account of non-state universities, who were specializing primarily in Humanities, Business and Economics. The number of institutions as well as number of students reached the maximum in the year 2010.

Table 2.1 Number of students and institutions of higher education in Russia, 1990-2015 г.

Years	Number of institutions	Number of students, thousands	i.e. by form of education			Per 10000 pax
			Full-time	Partly full-time	Part-time	
1990/91	514	2824,5	1647,7	284,5	892,3	190
2000/01	965	4741,4	2625,2	302,2	1761,8	324

2005/06	1068	7064,6	3508,0	371,2	3032,0	493
2010/11	1115	7049,8	3073,7	304,7	3557,2	493
2011/12	1080	6490,0	2847,7	263,4	3289,7	454
2012/13	1046	6075,4	2724,3	229,7	3051,4	424
2013/14	969	5646,7	2618,8	189,2	2838,6	393
2014/15	950	5209,0	2575,0	158,5	2475,5	356

Analysis of structure of graduates' specialties shows sustainable growth of graduates in such areas as Humanities, Business and Economics from the year 2000. It ultimately led to the oversaturation of such specialists on labor market, increased number of over skilled employees, necessity to hire them at mid-professional level. Thus, in 2010 the number of graduates in Humanities achieved 178,0 thousands, Business and Management – 386,0 thousands, Energy Engineering – 24,0 thousands, Transport Systems – 34,7 thousands, Electronics – 14,7 thousands, Information Science and Computing – 22,3 thousands.

Due to unsatisfactory situation the Ministry of Education and Science of Russia initiated structural reform of higher education system after the year 2010. The reform was aimed at decreasing number of higher education institutions by indicating inefficient institutions as well as merging relatively small regional institutions with identical areas of training [7]. As a result, the number of students over the period from 2010 to 2015 was reduced by 26%, the number of educational institutions by 15%. While the number of teaching staff declined significantly faster in public than in private educational institutions, partly as a result of employees transition from public to private institutions.

Table 2.1. Teaching staff in institutions of higher education

1990/91	2000/01	2005/06	2010/11	2011/12	2012/13	2013/14	2014/15
Public Higher education institutions							
219,7	265,2	322,1	324,8	319,0	312,8	288,2	271,5
Private Higher education institutions							
-	14,4	36,7	32,0	29,2	29,2	31,1	28,2

The period of relatively low state regulation and participation in higher education had both positive and negative results [14]. The acquisition commercial and market skills by university staff, entering international market, maintaining teaching staff can be considered as a positive. Permanent weakness in integrating new educational techniques, low flexibility in designing curricula and low ability to diverse different resources should be noted as negative. Unfortunately quality of education also had lost its priority.

In the framework of traditional system the issue of quality had been interpreted more as a necessity to fulfil curricula rather than follow students' needs and requirements of potential employers. One of the major priorities in implementation university policies was given either by university management or Ministry of education to maintaining teaching staff and retaining it in universities. Due to implementation of those policies in the past nowadays universities encounter problems while trying to implement European approaches in quality management, in particular student-centered conception in study process. In fact it means advancing interests of students and employers over the interests of institution and its staff.

Since 2011 the major trend in reform of higher education system can be described as strengthening the role of government organizations but re-focusing its regulative efforts more on final results rather than current processes, yet Ministry of education and science retains sufficient control over the educational procedure.

Development of Total Quality Management System (TQM)

Over the long period professional qualifications had been described in Russian educational standards while representatives of business and industry did not strongly participate in creating new competences. In fact it meant professional qualifications had been issued by university without serious expertise of professional society (except for medical specialties). Nowadays situation is changing, at least new educational standards (to be issued at the end of 2016) will not contain professional requirements, which will be transferred to professional standards of the National Qualification Framework.

Training and re-training system is much related to development of quality management system and matching difference between European and Russian approaches. Being carefully considered Russian Federal educational standards and the Framework standards for engineering programs EUR-ACE show its equality in general with some obvious differences [13]. Learning outcomes in Russia and Europe are assessed in different "coordinate systems", i.e. in the Russian Federation learning outcomes are classified by types of activities (research, design, management etc.) but in European standards they are divided into phases (knowledge and understanding, engineering analysis, engineering design, research, engineering practice).

Russian standards do not specify procedure of monitoring customers' and employers' demands even do not identify any requirements to quality of resources and internal management systems, which are obligatory for EUR-ACE (ESG 2015). In addition, it seems reasonable to have aggregated criteria to describe ability of educational institution to modify its curricula within limited time and adapt it to updated market requirements with ensuring the same quality level.

Both Russian industry and education system face qualitatively new challenge that requires new mentality and approaches on different levels. Russian higher education system encounters the situation when it needs to overcome systematic problems of the past and change the whole paradigm of engineering education taking into consideration realities of Industry 4.0.

Development of engineering education

In the year 2013 Russian Ministry of Education and Science launched ambitious project entitled "Program 5-100-2020" aimed to having at least 5 Russian universities in the ranking list of TOP-100 world universities. Group of 15 candidates (in 2015 was extended to 21) was carefully selected among dozens applicants. Within the framework of this project series of education and creative seminars in cooperation with Skolkovo Business School were organized to work out various development projects in different areas. Priority was given to university education and innovation policy, student and staff recruitment activities, engineering education development and international branding and marketing.

One of the expert groups with representatives from Peter the Great St. Petersburg Polytechnic University, "MISIS" National University of Science and Technology, National Research University of Information Technologies, Mechanics and Optics, Kazan Federal University, Ural Federal University, Novosibirsk State University and Tomsk State University was focused on elaboration modern principles of engineering education in Russian universities.

Modification of engineering education was initially based on alteration of engineering cycle and its composition parts. In conditions of previous technological modes prototype model had been designed, produced and tested. The process of improving (see Fig. 1) was then implemented as the process of disassembling to integral parts with further modification. Within the framework of Industry 4.0 conception [17], [11] the number of decomposition cycles (disassembling – improvement – assembling - testing) and period of each particular stage have to be minimized. Computer modeling combined with technologies of prototyping could make characteristics of prototype model almost ideal and further decomposition redundant. New paradigm of engineering work might require qualitatively different engineering skills and knowledge, interdisciplinary and foresight mentality.

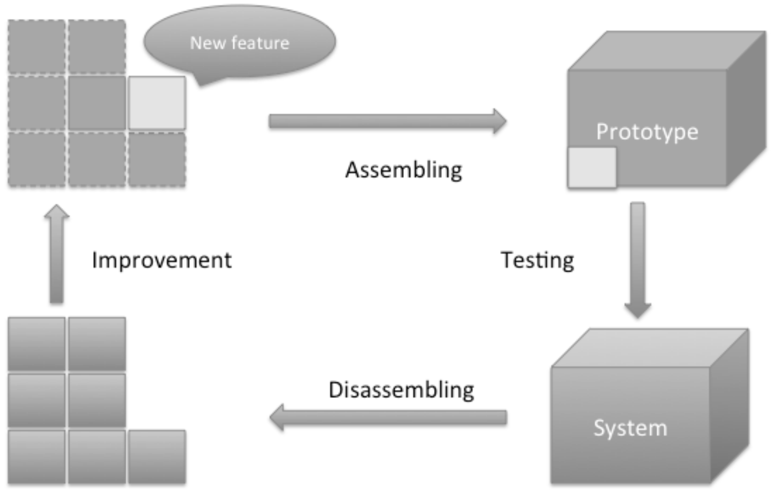

Fig. 1. Engineering cycle

Achieving appropriate level of qualification in previous technological modes was similar to engineering cycle in traditional Russian system. Thus initially student had been filled with massive set of different knowledge from different areas with comparatively low practical skills. Then required attainments and skills were enhanced, those not required became passive or even lost. This process can be identified as the process of knowledge and skills decomposition similar to decomposition of modules of prototype model.

Theoretical assumption for elaboration new concept of engineering education was that university system can efficiently communicate with external objects if universities' production cycles, organizational and management system, corporate culture and other characteristics would not seriously contradict similar characteristics of external objects. Though full coincidence is not required or even can be disadvantage because teachers' and scientists' mentality and labor substance would differ from those in business and industry. In terms of staff training it means training should be more effective in environments generally coinciding with those where graduates would be employed.

Making summary of all mentioned above, engineering education in new technological mode should be optimized in terms of having exactly those skills and attainments which required for engineering problems solving. Having enabling environment for future success is a must. Though the issue of having knowledge deposit is still discussible. From the one side to store knowledge has become very expensive due to its obsolescence, from another – without fundamental ontological and axiological basis solving future engineering problems seems to be unproductive.

Practical recommendations

Major assumptions for further elaboration practical measures were the following:

- modern manufacturing process requires joint activities and cooperation of different types of engineers – researchers, innovators, designers and engineers of full lifecycle,
- acquisition new competences must be based on engineering tasks initiated by industrial sector, new competences should correspond to lifecycle stages,
- process of engineering task solving is cycled and divided to navigation course – engineering task solving – final course and testing (Fig. 2),

-forming new engineering competences requires transformation of linear model of study on early stage to linear-matrix model with extended variety of study courses on higher level. Networking, using on-line open courses in combination with study modules as knowledge cluster can substantially widen access to new knowledge.

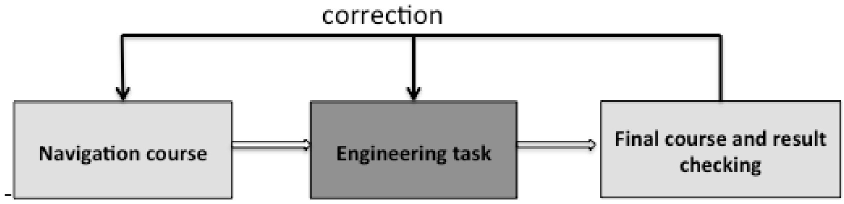

Fig. 2. Education based on engineering tasks

Expert group planned piloting it for Computer Science &Software Engineering in cooperation with Kazan Federal University, Peter the Great St. Petersburg Polytechnic University, Ural Federal University and Tomsk State University. For launching the pilot project the interactive platform providing full access to constantly updated study courses and engineering tasks was designed. Full access is available for all universities participating in the project. Engineering tasks are initiated and supplied by industrial companies but before being placed on the platform they have to be examined by university and probably adapted to current study purposes (see Fig. 3). The platform is used as an integrator providing optimal ways of problem solving, collecting various decisions, disseminating new knowledge for self-organized sub-consortia.

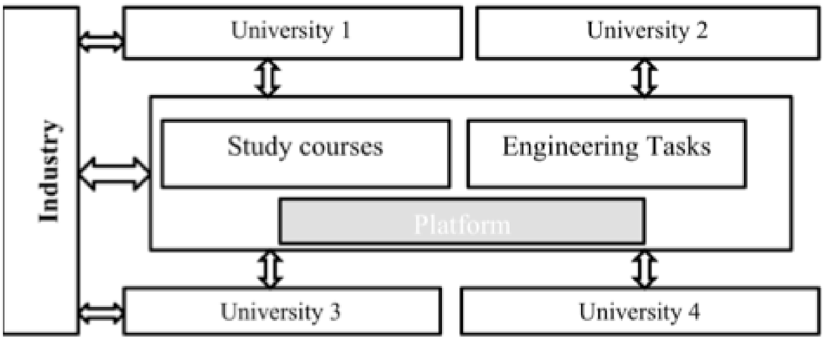

Fig. 3. Education platform

Approaches described allow enhancing quality of education and acquired competences but they formally focus on modifying forms of education and organizational model. Not mentioned aspect of engineering psychology should be noted here. Role and place of psychological aspects in engineering tasks was unfortunately underestimated in traditional system. For example, Theory of Inventive Tasks Solving (TRIZ) elaborated in the middle of XX century by outstanding Russian engineer and scientists Genrich S. Altshuller draws much more attention in foreign universities than in Russian ones, being an essential part of engineering study. In this context the work of Institute of Wideband Study located in St. Petersburg can be the case of interest. Institute has an official status of non-state organization but actively cooperate with state universities.

In addition to traditional aspects of educational activities the Institute of Wideband Study develops new approaches in so-called thinking management and resource state of future engineer. In traditional educational system the priority had been given to formulation of natural-science, systematic and logical types of student's thinking whereas such kinds of thinking as heuristic, divergent, strategic foresight were hardly used. The value of the IWS's techniques is much better self-tuning for a particular type of thinking (thinking as a project) and then comparing the "projects" results with further selection the best one. Self-management skills to manage resource state of an engineer are also unique. Management of resource state means management of the physical, cognitive and emotional states based on the perception of space as infinite, wave flow, a plurality of discrete objects or objects of chaos.

Final solution of engineering problems is improved by means of the best combination of traditional methods of engineering and thinking management and resource state. The integration tool is an interactive platform that allows improving and combining the range of academic disciplines, optimizing the educational route, learning outcomes and resource state.

One more aspect of manpower training should be considered here. It is the use of supercomputer technologies in training modern engineering competences. It is primarily connected to the growing role of the different modeling approaches that are basic for producing engineering products within the concept of Industry 4.0. The usage of the methods of mathematical modeling can reduce the product manufacturing cycle through rapid prototyping and testing engineering properties without making real model. At the same time, the complexity of the models, which can be calculated using supercomputer technologies can significantly improve their degree of detail and take into account the various aspects of their operations, which in turn enables interdisciplinary interaction. For example, Computer center of the Polytechnic University ranks third in Russia for the efficiency and within its activities up-to-date task performance is carried out. It uses mathematical modeling methods in the calculation of the strength characteristics of different constructions, hydro-aerodynamics, the analysis of large data, complex 3D model building.

Conclusions

The efficiency of Russian universities' training systems is determined by their ability to overcome the systemic problems of the past, to identify and develop the most valuable achievements of the traditional system of higher education, to adapt and implement the best international developments in university engineering education.

University management systems need to be modified in terms of strengthening centralized government, universities themselves need to be considered as corporation for knowledge and human capital production. The quality management system should be the basis for developing corporate culture. QMS must be primarily based on interests of employers and students.

Practical application in the process of engineering education should be implemented through solving engineering tasks. At any level educational cycle is starting with basic course – then work on engineering problems - then final course, testing and assessment. Switching to the modularity can shorten each of particular stages, for example from 1 term to 1 month.

Development of engineering education is impossible without development of engineering thinking based on psychological models (e.g. Theory of Inventive Tasks Solving), interdisciplinary collaboration with other educational establishments. The basis for overcoming traditional isolation of universities is in networking for the effective exchange of knowledge, engineering problems and their solutions, and the experimental results of high-speed computations and calculations. A possible solution is the foundation of real or virtual intercollegiate engineering centers, coordinating inter-university collaboration and cooperation.

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