ENGINEERING EDUCATION IN RUSSIA: TRADITIONS, EXPERIENCES, CHALLENGES AND OPPORTUNITIES

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Russian engineering education is proud of its 300-year rich history and traditions. The foundation for engineering education in Russia was laid by the well-known Russian outstanding engineers, e.g. Peter the Great, founder of the School of Mathematics and Navigation Sciences, polymath Michail Lomonosov, inventor of radio Alexander Popov, aerodynamics founder Nikolay Zhukovskiy, leading Soviet rocket engineer Sergey Korolyov, pioneering Soviet aircraft designers Andrey Tupolev and Nikolay Kamov, inventor of steam machine Ivan Polzunov, naval architect Alexey Kryilov, first author of Russian jet aircraft project Nikolay Kibalchich, aeronautics pioneer Yury Kondratyuk (Alexander Sharigei), architects Nikolay Nikitin and Vladimir Shukhov and many others. Russian engineering school has always provided rank-and-file engineers. These great minds have succeeded in the development of aircraft engineering, exploration and development of mineral deposits and mineral resources, hydroelectric and atomic power engineering, space exploration and so on. Russian engineering has long lasting traditions, creativity, and inventive enthusiasm together with excellent educational programs, talented faculty, scientists, and engineers.

Russian engineering education traditions are:

- Integrated academics and research;
  Technical universities put emphasis on collaboration between scientific researchers and faculty, where high ranked and experienced scientists share their practical knowledge with future engineers through lectures and seminars, and faculty members are encouraged to participate in research activity in the field of their expertise. Such educational approach creates environment for a more thorough understanding of modern trends of engineering science and provides scientific world with a wider range of scientists.

- Profound practical education;
  Russian experience of practice-driven education focuses on involving in teaching not only faculty, but practicing engineers, hands-on technical staff, industrial managers and other experts from the real market to be full-time, part-time or guest lecturers and tutors. Mandatory internships at real industrial companies, practice-oriented educational technologies and applicative thesis papers allow students to acquire practical skills, become competent specialists during the studying process and shorten or dissolve the adaptation period once they become employed.[9]
Strict requirements for students, faculty and educational programs;
The Ministry of Education and Science of the Russian Federation is working towards standardization of basic requirements for education in Russia by providing Federal State Education Standards concerning educational programs, quality of education, faculty requirements, students’ evaluation methods and criteria, etc. All universities are obliged to get state accreditation and are advised to receive public-professional accreditation of each educational program. In most cases technical universities issue a set of inner requirements that complement to the federal standards. High level of demand from faculty to students results in high rate of expelling from universities in case of low performance or interest in studying; in some universities this figure goes up as far as 40 percent. [18]

High-level training of students in fundamental disciplines;
Educational process at Bachelor's level is generally divided into two stages: fundamental science and humanities, and major engineering disciplines. The first two years of studying are mostly dedicated to the development of fundamental engineering knowledge and provide a common set of competences for almost all engineering specialties. The basic knowledge received during this period gives students a wider perspective on technical science and engineering before they start the specific training. High level of fundamental technical knowledge is a key factor for better understanding and collaboration in multidisciplinary projects. [4]

Focus on innovations;
Russian inventors, scientists and engineers are well-known for their off-standard, unusual, creative ideas and solutions. From olden times there have been many national proverbs stating that “material difficulties sharpen the wits of the investigator” or “idleness is the mother of invention” (similar to the English proverb “necessity is the mother of invention”). Russian inventors’ competitive advantages have always been their quick wit, ingenuity, inventiveness that come naturally and help them overcome day-to-day difficulties. Engineering education system puts effort to develop and support these unique but highly beneficial qualities. One of the corner stones of innovative thinking development in Russia is Altshuller’s TRIZ (Theory of Inventive Problem Solving) that is commonly used as an engineering education technique providing creative problem solving approaches. [19]

It is of no doubt that engineering education plays a great role in the economic growth of the country and ensures economic independence. In terms of market economy, engineering education and level of society’s intelligence are the core assets
guaranteeing success in the competition both on national and world levels. The state of knowledge and education in society, especially in the sphere of technology and engineering, defines the level of its general and engineering culture, “technologic sensibility”, and “innovative resistance” and, hence, defines the vector of society development. Engineering education allows production and allocation of competitive goods of intellectual labor on the international markets, fortifying country’s position in world economy. At the same time it provides an opportunity to accept and use efficiently innovative and up-to-date results of international intellectual activity and science-driven industries creating a smarter and more advanced society. [1,16,20]

Russian history demonstrates many examples of engineering education becoming a precondition for social, technological, economic and even political development of the country. Engineering graduates explored and developed Siberia region territory, exploited its mineral resources and established coal, chemical, metal, and oil-and-gas-processing industries. Developments and solutions of Soviet engineers made a great contribution to the Victory in the World War II. High-quality engineering education makes it possible to progress in exploration of near-Earth space and further universe. Engineering graduates work in power industry, exploit thermal, hydroelectric power, nuclear power plants, power lines, utility facilities, etc.

Sustainable development of Russia is infeasible without engineering education. Russian educational society embraces an understanding of sustainable development as it has been agreed by the European Commission and Sustainable Development Strategy: “Sustainable Development stands for meeting the needs of present generations without jeopardizing the ability of future generations to meet their own needs – in other words, a better quality of life for everyone, now and for generations to come”. The sustainable development strategy should be taken into account by each state, each institution, and each person in the country. Technical universities in Russia play a key role in engagement and dissemination of such sustainability principles, as resource efficiency, ecology protection, nonproliferation and disarmament, engineering ethics, etc. Educational process is arranged in a way that technical disciplines include aspects of social awareness, lean production technics, smart cities ideas and many others. Therefore while studying technical disciplines and working on professional projects future engineers develop, for instance, such competencies as ability to apply a systems thinking approach for complex problem solving with acquiring graduate attributes of understanding the need for a high level ethical, social, cultural, environmental and wider professional responsibility. [2,5,7,8,10]

The experience of Russian universities in training engineers shows that Russian engineering education has the potential to meet the grand challenges successfully.
With the aim to transform educational system and improve the quality of engineering education various educational technologies have been efficiently applied. Modern educational technologies are designed to ensure students' involvement, team-working and independent-working skills, ability to achieve results, communication skills. Engineering education is enhanced by use of the following technologies and models [9,12]:

- Integrated educational systems;
  Collaboration between industry and universities is sometimes realized through Higher Technical Educational Establishments, where students combine part-time work position and functions with engineering program related to the job. A block-modular educational system is proposed by such establishments with variations of work/study periods, for instance, month-by-month system or two-week study period every 3 months.

- University departments at industrial enterprises;
  A wide range of technical universities in Russia allocate their departments on premises of corresponding industrial enterprises or factories, acquiring key strategic resources for training of competent and ready-to-work engineers – laboratories and up-to-date equipment, professional experts and tutors from the field, places for internships, and, most of all, vital present-day industrial problems and challenges for problem-oriented learning. In such case head of department is usually the head of production or industrial division. [19]

- Research and development laboratories in higher education institutions;
  Starting from small research labs to large partly independent Scientific Research Institutes, engineering schools in Russia create different types of R&D centers to support the development of fundamental and applied technical science as well as technological innovation. R&D centers and incubators attract world-known scientists creating new knowledge and giving students an opportunity to be at the cutting edge of modern science. 15 leading Russian universities have transformed Scientific Research Institutes to the next level of integration creating Scientific Educational Institutes and allowing deeper collaboration of researchers, faculty and students.

- Practice-oriented and interactive training technologies;
  Implementation of practice-oriented educational technologies: master classes, brainstorming sessions, round tables and expert seminars, discussion forums, case studies, team work, decision-making and problem-solving business games, contextual learning and learning from the experience, all allow universities to train students focusing on obtaining core competencies,
developing the ability not only to acquire academic knowledge, but also to put it in use as professional engineers. Undergraduates, postgraduates and doctoral students are interactively involved in engineering design, research and development activity with the use of technological incubators of universities and strategic partners' potential. [9,11]

- Problem and project based approaches;
  Core idea of these approaches is to integrate knowledge assumption with students’ involvement in real-life professional projects allowing them to practice their engineering skills and abilities, work as a team member and team leader, build up communication system, identify technical problems, i.e. get an idea of future work environment. Execution of real individual and collective projects is based on involvement in the training process of experts from leading national research institutions, business and industrial companies. Problem-oriented approach assures formation of future specialists’ skills to determine complex engineering problems and challenges, and to select proper means for their solving. [3,9,11]

- Special training programs for engineering faculty;
  Each university proposes a set of actions for continuous professional development of engineering faculty that corresponds to the national requirements on the matter. Training programs take place at least once every 5 years at different establishments, from alma mater to other universities in Russia and abroad to industrial partners. Staff development programs include skill improvement in terms of educational technologies and communication with students, foreign language learning, research conduction technics, and practical trainings (acquiring and development of practical competences by means of short-term industrial internships). [9,13]

Russian engineering education system is generally characterized by its ability to give adequate responses to the existing challenges; however, some of these responses are made with a stitch in time. Association for Engineering Education of Russia (AEER) is an all-Russian public organization, whose prime objective is to promote the development of engineering education in Russia. AEER regularly carries out system research on engineering education and its quality in Russia, holds local and international seminars and conferences on engineering education problems. The information obtained gives an opportunity for the community of professionals to determine weak points of engineering education system and to find optimum solutions to improve its quality.
Changing world creates a wide range of challenges requiring quick accurate responses from Russian engineering education. Engineering education consolidates its role in economic competitiveness of the country. In a competition of two nations the one with lower level of civilization and culture is to be the losing party. But to a great extent it is the education that determines the cultural and civilization level of a country. Level of engineering education and technical awareness of the society becomes a prerequisite for the technological and innovative progress of the country and assures its economic development. Engineering education has to face modern challenges and be able to overcome them timely and efficiently. [6,16,20]

In recent years Russia came across the number of challenges of global and national character, among which the most urgent are [12,17,20]:

- Massification of engineering education;
- Globalization and internationalization of engineering education;
- Transition to a level-based education systems;
- Contradiction between quality of specialists in technical spheres and employers' requirements.

Fig. 1 presents complex nature of the formation of contradiction between quality of education and employers' requirements, that results in development of problems standing in a way of technical and technological progress. The major hassle is the contradiction between the quality of engineers’ training and employers’ requirements. Employers are interested in such specialists' characteristics as: ability to think systematically and autonomously and solve the production problems using the competencies developed in university; ability to work in a team; awareness in business processes and business environment in general; ability to generate and adopt innovative ideas; ability to present ideas with reasons; foreign language skills. [12]

Although the assessment criteria of future engineers’ training in universities are adjusted to include practice-oriented assessment, they still are shifted towards the assessment of knowledge with a greater extent than needed. In all fairness, it has to be told that in recent years the so called “competence approach” including development of future specialists’ necessary competencies is being used when developing the curricula. However, when the competencies are interpreted as a readiness to demonstrate ability in solving these or that production problems, but not a real ability to solve them in real production conditions, employers’ expectations are not met. Besides, nowadays bureaucratization of training processes has increased sufficiently when implementing this approach; thus resulting in an essential increase in volume of teachers’ low-efficient paperwork. [12,18]
Figure 1 - The Systematic View of the Problem Situation in Engineering and Engineering Education of Russia [12]

AEER has held a number of conferences and expert seminars on current problems of engineering education that brought together over 500 participants among which were university rectors and vice-rectors, directors of institutes, deans, professors, industrial and governing bodies’ representatives, students. As a result a range of advisory means to improve Russian system of engineering education has been proposed. It is recommended to:

- Develop amodern engineering education strategyto train future specialists who will be in demandin Russia;

Several development strategies on engineering education have been proposed by different organizations, such as AEER and Russian Rectors Union. However there still is no official unified state strategy on the matter. Such engineering education strategy should concern specification and elaboration of educational programs and plans for educational technologies enhancement that would allow training of engineers to assure sustainable development. [12,14,15,19]
• Advance engineering educational programs and educational technologies by applying competence approach and ideas of CDIO (Conceive – Design – Implement – Operate) Initiative;

As of February 2015, there are 13 Russian leading and innovative universities that have joined the CDIO Initiative implementing and disseminating CDIO ideas, standards and syllabus not only at home university, but throughout the country. Competency approach has been widely spread in Russia and served as a base for Federal State Educational Standards. However the majority of midlevel technical universities face significant complications in the full-scale implementation of these concepts. [3,11]

• Promote international recognition of national system for public-professional accreditation of engineering educational programs;

There are several organizations involved in these activities in Russia, in particular National Accreditation Agency and Agency for Quality Assurance in Higher Education and Career Development. The most long-running non-governmental accreditation organization in Russia is the Association for Engineering Education of Russia. AEER is a full member of many respected international alliances and conventions, such as ENAEE (European Network for Accreditation of Engineering Education), Washington Accord, APQN (Asia-Pacific Quality Network), and many others. 316 engineering programs of 54 universities situated from Vladivostok to Kaliningrad and in Kazakhstan were given public-professional accreditation by AEER, 235 of them received the EUR-ACE label. Results of accreditation are presented in Fig. 2. Nevertheless, the proportion of programs acknowledged internationally is rather small.
Figure 2 – AEER Accredited Engineering Education Programs in Russia and Kazakhstan (from 2002 to 2014)

- Improve professional and federal educational standards for HEIs; Federal State Educational Standards have been developed by the Ministry and, unfortunately, lack a point of view from professional and educational society, which creates difficulties in standards compliance. The professional opinion should be taken into account when revising the Standards. When implementing the professional and educational standards it is needed to focus on its realization in accordance with the CDIO and practice-oriented principles. This is the main activity to be supported and assisted. [18]

- Advance the forms and methods of cooperation between higher education institutions and employers, develop mechanisms for public-private partnership; The cooperation model shall result in foundation of all engineering education programs on basis of project-based learning and widespread use of multidisciplinary communications and projects. [1,2,20]

- Develop foreign language teaching systems at engineering universities; Regretfully, HEIs have to include foreign language training in their educational programs due to insufficient language skills of high school graduates. A profound system of foreign language teaching should put emphasis on professional language skills and overcoming language barriers. Foreign language communication should be a part of engineering education process, not a separated linguistic training.
- Enhance training and certification of the faculty for engineering universities;

The responsibility of engineering educators in Russia as well as worldwide can be proven by achieving the «International Engineering Educator ING.PAED.IGI» status. IGIP principles are distributed through 14 accredited centers for engineering pedagogy in Russia and several annual conferences and symposiums on the matter (Annual International IGIP Conference on Engineering Pedagogy in Moscow, Annual International IGIP workshop in Kazan, etc.). Yet the percent of educators with «ING.PAED.IGI» status in Russia is not sufficient; and further development of pedagogical skills together with practical abilities of faculty is needed. [9,13]

Conclusion
Russian engineering education has high potential for improvement embracing hope for its successful development. Scientific and educational society has a realistic view on the engineering education problem situation and rationally analyzes national and global engineering challenges. The society has a clear understanding of the means to be used to improve specialists' training in the field of engineering and technology.

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