I.A. Monakhov

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Engineering Educational Practices to Train Future Engineers in the USA

I.A. Monakhov[1]

[1]Tver State University, Tver, Russia

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Abstract

Based on the analysis of engineering educational practices in the USA as well as the governmental support of education programs, the article reveals strengths and weaknesses of stimulating the youth to choose engineering education and engineering professions.

Key words: educational practice, best practices, engineering education, university, the USA.

Human capital is one of the factors for providing competitiveness of a country in the market of high-tech production and in the fight for technological leadership. In this context, training of personnel for those industries, whose development enables the transition to the new technological stage, is of particular importance.

In the given research educational practices are taken as a study object. It should be noted that there is no common definition for "educational practice" in the national and foreign literature [1, p.77].

By best educational practices The National Governors Association Center for Best Practices (NGA Center) means a wide range of particular events, approaches, and strategies to provide positive changes either in students' attitude to learning or in their learning behavior. The following types of educational practices are distinguished: *promising education practices* that have not been assessed yet; *validated education practices* that have successfully been introduced independently on the number of applications in education and positively evaluated by students; and *exemplary education practices* that are distinguished by scaling-up and students' positive evaluation in every application [2].

Therefore, in the given research under *educational practice of engineering profile* we mean the events, means, techniques, and other types of activity aimed at students' practical acquiring special subject competencies in the sphere of engineering and natural science education as well as their introduction to definite jobs. In our case, exemplary education practices that were introduced at different institutions and can be scaled-up have been analyzed.

At present, the American universities are at the top of international university ratings in terms of specific engineering subject areas – Academic Ranking of World Universities [3], Times Higher Education ranking in the sphere of engineering and technology [4], the ranking of top world universities in the list of British consulting company Quacquarelli Symonds (QS) QS World University Rankings in the area of mechanics, aerospace and industrial engineering of 2016 [5].

Hence, based on the analysis of international ranking one can conclude that the USA, on the one hand, show high performance indicators in the spheres of disciplines related to natural science and mathematics (according to the analysis of scientometric data), on the other hand, the quality of engineering training at leading American universities meets the highest expectations of employers.

The US government pays increased attention to development of natural science education in general and engineering education, in particular. Thus, as early as in November, 2009 President of the US Barack Obama announced the beginning of campaign to gain the US advantage in development of natural science, engineering, and mathematical education (Science, Technology, Engineering, and Mathematics (STEM) Education) called "Educate to Innovate".

In January, 2010 in the message of the President to the US Congress B. Obama extended the list of events in the frame of the given initiative with a view of achieving qualitative and quantitative indicators for the USA to become a leader in terms of school natural science and mathematics education within 10 years, to train more than 100 000 teachers of natural science subjects and math over the indicated period by means of public-private partnership, involvement of leading companies, universities, funds, non-governmental and governmental organizations in solving the problems of attracting, supporting, upgrading (including awarding system) highly qualified pedagogical staff teaching in STEM-fields [6].

In 2010 the amount of federal financial investment in development of natural science and mathematical education was 3.4 billion of US dollars. In 2013 80 % of resources allocated by the state for the strategic project were invested in the National Science Foundation, United States Department of Education and United States Department of Health and Human Services [7]. Moreover, in 2016 about 80 % of state expenditure allocated for support of natural science and mathematical education were also intended for these institutions. The 2017 budget provides 3 billion of US dollars to solve these problems [8].

Therefore, the strengths of the American system of engineering training are as follows:

- Governmental support of youth motivation programs for engineering professions. Since 1999 the National Science Foundation has implemented the program "Graduate STEM Fellows in K-12 Education (GK-12) Program)". In 1999 since the implementation of the given program more than 200 projects developed by 140 different universities of the US and Puerto-Rico were supported [9].

The amount of grant for this program is 600 000 US dollars within 5 years. Besides, the graduates working at schools receive annual allowance of 30 000 US dollars. In addition, a post-graduate's expenditure for medical insurance and study is compensated in the amount of 10 500 US dollars. The maximum post-graduate's work with pupils at schools do not last more than 10 hours per week, extra 5 hours per week are assigned for some other activities related to the project [10].

- Public participation in implementation of the projects and programs that are aimed at providing equal opportunities and motivating engagement of children of disadvantaged families and representatives of national minorities.

For example, the faculty members of University of Kentucky have launched the project "Utilizing STEM-camps and STEM-clubs to promote adolescent girls' and colored pupils' interest in STEM-fields". The project was supported by the National Science Foundation with the amount of 750000 US dollars. The goal of the project is to increase middle-grades students' interest and motivation in natural sciences by means of developing students' ideas about learning these spheres, work of scientists, mathematicians, and engineers. The main objectives of the project include research in the influence of learning informal environment of STEM-fields on the schoolchildren of the 5-8 grades (10 – 14 years old), particularly, girls and colored students through involving them in practical events held within summer STEM-camps and STEM-clubs open for schoolchildren all academic year long [11]. The project is to be implemented over 5 years – from 2013 till 2018.

Since 2010 the authors of the project have arranged summer STEM-camp "See Blue" with the support of College of Engineering, College of Education, College of Art and Science, University of Kentucky as well as teachers from the neighboring federal schools, representatives of expert communities. This camp was initially intended for 5-8 grades schoolchildren from low-income families. During a week children learnt such subjects as engineering design; visual mathematics based on evidence-based reasoning; neurobiology; sustainable development; astronomy and robotics using Lego.

■ High development of horizontal linkages in both engineers' professional spheres and among the institutions when implementing the projects in the field of youth's research-engineering activity.

In the USA various professional engineering associations and communities are established and operate. They are profession-, gender-, and race-based: Society of Biomedical Engineers, Society of Women Engineers, National Association of Black Engineers, Society of Hispanic Professional engineers, etc. Many of them organize university-based clubs/branches of the associations.

Hence, the students of engineering profiles have the possibility to participate in different programs of these associations, expand their professional network. The booklet published in 2013 for the students of Arizona State University contains information on 50 students' clubs and engineering associations with the representatives in this university [12];

Some American non-profit organizations develop educational modules to be used at school classes on natural sciences, mathematics, engineering, etc. For example, in 1997 non-profit organization "Project Lead the Way" developed the curriculum "Pathway to Engineering Program" for 12 schools of New-York. In 2012 United States Department of Education adapted the educational programs developed by "Project Lead the Way" as an example of conducting classes in STEM-fields [13, p.11].

At present the organization is implementing the curriculum in the field of engineering for the upper grades including different educational modules in such disciplines as aerocosmic engineering, civil engineering and architecture; engineering design, etc. This program is integrated in education program US Community Colleges that allows upper grade students who studied and passed the university exams on such subjects as engineering, biomedical science, and information to receive bonuses for university entry [14]. A student's score is taken into account when enrolling the university. For example, to get three points in 5-point scale established by the US Community Collages an upper grade student has to learn a course of Community Colleges curriculum, one of "Project Lead the Way" and the third chosen from educational programs of these organizations. Three points define the student's readiness for university training [15].

The Museum of Science (Boston) developed the curriculum "Engineering is Elementary" for elementary students funded by the National Science Foundation and partner companies. The curriculum includes several educational modules that can be used in classes and extracurricular work in such profiles as "acoustic engineering", "aerospace engineering", "mechanic engineering", and etc. [16] Educational modules were developed in terms of the standards for technological literacy of International Technology and Engineering Educators Association [17] and the standards of scientific literacy [18].

■ Developed facilities and resources of universities and research centers to be used in research and education.

One of the most successful practices in organizing clubs of research-technical art for the youth in the USA is the program of *Center for Bits and Atoms, Massachusetts Institute of Technology* to develop the network of invention laboratories (fab lab) – small work-shops fitted with special equipment that allows learners to perform numerical modeling and production operations using adaptive and subtractive methods. The program was launched in 2001 supported by the National Science Foundation. Nowadays there are 705 fab labs in 88 countries all over the world [19]. The members of the American fab lad network (U.S. Fab Lab Network) are more than 50 colleges, universities, and other educational institutions and research centers in 27 US states [20].

In addition, a number of US private universities have clubs of 3-D print arranged similarly to fab labs and fitted with various kinds of 3-D modeling and printing equipment. This club was opened for students of Brandeis University for a fee. The fee depends on the time spent for work with equipment [21].

■ A wide range of research-engineering competitions held at the federal and regional levels.

For example, Ohayo Northern University arranges the competition TEAMS (Tests of Engineering Aptitude, Mathematics, and Science) for middle and high school students. The competition is held for one day and aimed at development of students' creative skills in solving complex problems that have been defined by the US National Academy of Engineering as priorities [22]. They include improvement of cost efficiency of solar energy, energy production from synthesis, development of carbon sequestration methods; nitrogen cycle control; pure water supply; reconstruction and improvement of urban infrastructure; development of health communication; artificial intellect; design of virtual reality, etc. [23].

The drawbacks of this system are as follows:

■ Low performance of educational practices, one of the reasons for which is absence of unified standards for engineering training in STEM-fields, low youth's interest in engineering professions.

The experts pay attention to the fact that there are no unified school training requirements as opposed to those for mathematics and engineering. Therefore, engineering is still a weak link in the strategy of school education development and a missed letter in the abbreviation STEM [24, p. 38].

■ Lack of integration of practices into school and university educational programs since different clubs of research-engineering art do not serve as a tool to enhance academic performance of schoolchildren and students, but perform a function of vocational centers for training and networking among the specialists in STEM-fields. The exception is educational programs of Community Colleges and "Project Lead the Way". However, the score received by high school students within the course is not an admission score for university, but it only contributes to an applicant's portfolio.

Despite the highlighted challenges, implementation of educational practices in the US engineering training allows increasing the number of highly-qualified specialists in STEM-fields in a medium-term perspective.

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