

"Russian Method" of Training Engineering Personnel: Historical Experience and Modernity

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Abstract—This paper in the historical retrospective presents the “Russian method” of training engineering personnel, which is inextricably linked with the activities of the Bauman Moscow State Technical University (BMHTS). The stages of formation and development of this approach to education in pre-revolutionary Russia are highlighted. The attitude to the tradition in the Soviet period is analyzed; the adaptation of the “Russian method” to the domestic realities in the 1990s and at the present stage is traced. Based on the study, this paper proposes to highlight several stages in the evolution of the “Russian method” of training engineers, to evaluate the contribution of the Bauman School to the process of updating domestic technical education and to generate new international standards for training modern engineers.

Keywords—*engineering; CDIO program; Bauman Moscow State Technical University; "Russian method" of training engineers; theoretical and practical training; innovative educational technologies; international science and technology*

I. INTRODUCTION

UNESCO declared the 21st century the “Century of education”, which served as an impetus for the beginning of serious analytical and practical activities in a number of areas. Thus, in 2010, a report was prepared at UNESCO “Engineering: Challenges, Difficulties, and Opportunities for Development.” It was initiated by non-governmental professional organizations — “Engineers Without Borders”, WFEO (World Federation of Engineering Organizations), ICEATS (International Council of Engineering Academies and Technical Sciences), IFCE (International Federation of Consulting Engineers). This document outlined a range of problems in engineering education. He stated that the overwhelming majority of difficulties are common to all countries. The special role of the engineer in the modern crisis world was emphasized, and the compilers set the task of fundamentally changing the existing systems of technical education [1].

Russian scientists, like their foreign counterparts, are actively discussing topics related to engineering in scientific literature. Among the problems addressed are: the specificity of the historical approach to engineering activity (O.V. Kozlovskaya and V.I. Martinkus); philosophical understanding of engineering work (G.Ya. Bush, V.F. Gorbachevsky, B.I. Kudrin); various aspects of engineering activity (V.V. Alekhin, D.O. Gusev, E. Krik, I.K. Kornilov, E.Z. Mirsky, K.S. Pigrov, L. G. Titarenko, GI Shemenov, L.V. Yatsenko). The subject of higher engineering education is no less significant in science (A.G. Bondarenko, Yu.A. Dmitriev, I.P. Kaloshina, P.F. Kravchuk, A.B. Kurlov, A.I. Pozdnyakova, V.B. Starzhinsky, S.I. Shabalin, V.F. Shepetko) [2].

The existing developments in the study of this topic suggest that each state had its own system of engineering education. It is obvious that in the past laid the foundation for modern innovations. That is why today it is necessary to turn to the study of the history of the model of Russian technical education, which is considered to be one of the best in the world.

The center of this paper puts forward the problems of the evolution of the “Russian method” of training engineering personnel developed and successfully implemented throughout the XIX-XXI centuries, in Bauman Moscow State Technical University. The novelty of the work is to consider the various stages of teaching students on the basis of this educational concept, to identify the features of each of them in chronological order. The dating of historical periods allows one to scientifically substantiate the contribution of each of them to the improvement of technical education, and to explain the success of the application of the “Russian method” throughout the University’s activities.

II. "RUSSIAN METHOD" IN THE XIX CENTURY: FROM TEACHING THE CRAFTS TO THE FORMULATION OF THE TASKS OF HIGHER EDUCATION AT IMPERIAL TECHNICAL SCHOOL

Russian engineering schools at all times were the pride of the educational system of the country. In this connection, the history of Bauman Moscow State Technical University serves as a resource for creative approaches to the current problems of modern higher technical education [3].

To understand the essence of the "Russian method", it is necessary to refer to the beginnings of the University, which has been based on the pedigree since 1830, from the Moscow craft education institution (MCEI). A special approach to the study of sciences and crafts began to emerge in its depth, which was called the "Russian method of teaching crafts", which was based on the comprehension of theory through practice. The essence and criteria for the classification of the stages of development of the "Russian method" of learning are based on the degree of development of the principles of combining science with practice and the stage of scientific and technological progress. Its first stage covered the period of the 1830s – the end of the 1850s – the birth, and development in the conditions of the beginning of the industrial revolution in Russia.

At this time, the industrial revolution was just beginning in the Russian Empire, the country needed skilled engineering personnel. In June 1868, the MCEI became an institution of higher education, having received the name of the Imperial Technical School, the teaching was based on the "Russian method of teaching". The first director of IMTS, A.S. Ershov (1859-1867) and his colleagues: D.K. Sovetkin, A.M. Mikhailov, A.M. Markov, A.P. Platonov, G.I. Goslau, F.D. Edelman made a great contribution to its formation. Their approach was a fusion of domestic and European experience. The essence of the system consisted in the practical study of complex production and technical stages from drawings and model making to industrial products. It should be noted that in the period of formation of the industry in a peasant country, the Moscow approach to teaching engineering was very promising.

Modern researchers agree: the "Russian method" took into account the fact that in the 19th century, the huge agrarian Russia did not have good means of communication, and the engineer had to take responsibility for all decisions on the spot. By the end of the 1860s, the "Russian method" acquired a certain algorithm, structure, and sequence. He was supported by outstanding domestic scientists. It is important that this approach to technical education never existed outside the engineering community.

We emphasize that the engineering education of the country developed, based on the needs of the state, supported by the authorities, which contributed to the rise of the Russian economy in the late XIX - early XX centuries. [4].

In the 1870s, the verbal formula "the Russian method of training engineering personnel" arose and became stable, which modern scientists of Bauman Moscow State Technical University is defined as "the mentally structured educational

technology" [5]. Foreign figures of technical education got acquainted with the developments of IMTS at the World Exhibitions, international awards received by IMTS, testified to the competitiveness of Russian engineering education, which gained fame in the western teaching and industrial community. In 1876, the President of the Massachusetts Institute of Technology John Runkl published a brochure with a detailed analysis of the features of the "Russian method" — from the organization of training workshops to schedules, from filling the library to the staff of lecturers.

This approach to education was set to "perpetual motion", as the industrial requirements for the engineering profession changed. Following this, there was a change of programs and improvement of teaching methods. IMTS constantly improved its material base.

The development of industry in the Russian Empire in the early twentieth century led to a rethinking of previous developments. The team of IMTS, headed by the director A.P. Gavrilenko (1905-1914), outlined ways to reform education. It was based on the introduction of the subject system; development of an experimental teaching method; change the system of practice. For the first time, the question was raised about the polytechnization of education. In these designs was an understanding of the then trends of world engineering. The tsarist government refused to provide the necessary allocations. And then in the School independently began training in seven specialties. Lecturers understood that a delay in the path of progress would threaten the global lag of Russian industry.

The second stage of the application of the "Russian method" in the context of the completion of the industrial revolution in Russia (1905-1914) was accompanied by fundamental innovations: the transition to the subject system; permission of free attendance of classes, introduction of examination sessions; limit the number of retaking of exams. The practical training of students now had three levels: classes in workshops, work at a pilot plant, and industrial externship. Among the partners of IMTS were state and private enterprises. The new system developed the skills of independent work among young people.

In 1914, on the eve of the First World War, V.I. Grinevetsky (1914-1918) became the director of the School. [6] The formation of the third, unfinished stage of application of the "Russian method" (1914-1918) is associated with him. Under his leadership, there was a draft reform of vocational technical education, aimed at strengthening the specialization, was drafted "The project of development of the Imperial Moscow Technical School in a polytechnic type school." By this time, an understanding of higher technical education as a type of special education, aimed at the development of scientific and practical knowledge in various industries for the training of highly qualified specialists for administrative posts, was already determined. Industrial recovery of the 1890s caused the biggest changes in domestic engineering education. In the first decades of the 20th century, there were more than 20 higher educational institutions in the country. IMTS found

itself in a competitive environment and sought to retain leading positions in engineering education.

Thus, in the second half of the 19th – early 20th century, a unique “Russian method” of engineering training was finally formed within the walls of the Imperial Technical School. The constant of the method became: deep practical training based on the real work of students in conditions as close as possible to those with whom they will have to deal in production; a serious study of fundamental courses at a level not inferior to the teaching of these subjects in classical universities; constant multilateral communication of the higher technical school with industry [7].

IMTS graduates were invited to work in foreign companies. Many of them, having gained experience, returned to IMTS and improved the “Russian method” of training engineering personnel. That is why the training system at IMTS was highly competitive and caused genuine interest in the world. The third stage of development of the “Russian method” during the clash of the military-technical potentials of the warring countries in the First World War did not get completed due to the beginning of the Russian revolution and the coming to power of the Bolsheviks in 1917.

III. "RUSSIAN METHOD" TRAINING ENGINEERING STAFF IN THE USSR

The first years of Soviet power were marked by the ongoing revolution, civil war and military intervention. Hard times affected the education. So in the Moscow Higher Technical School (formerly IMTS), Soviet innovations were reduced to the abolition of all pre-revolutionary achievements. The team resisted such changes; there were two strikes in 1921 and 1922.

But the authorities managed to take the higher school under party control. In 1928 and 1929 plenums of the Central Committee of the Communist Party of the Soviet Union were held, which launched a mechanism for the reorganization of universities. Polytechnic structures recognized unnecessary. On March 20, 1930, by order of the USSR Supreme Economic Council on the basis of MHTS, more than twenty organizations appeared. The decision was in line with the policy of the state to create specialized universities for accelerated training of engineers during the period of socialist industrialization and the formation of the Defense-industrial complex in an aggravated international situation. The team managed to defend the unity of the auditory lessons and the research and production practice, helped by the introduction of the evening form of training in 1928.

MHTS eliminated. The MIM (Moscow Institute of Mechanics and Engineering) appeared in December 1930 and was named after N. E. Bauman. The “Russian method” seemed to be forgotten. But the faculty tried to keep the roots of their educational system. The professors’ team was able to defend the unity of classroom and research and production practices, helped by the introduction in 1928 of the evening form of education. Throughout the prewar period, professors defended the basic tenets of the “Russian method”.

In fact, the fourth stage of the “Russian method” (1917-1942) began and it became the period of protection of the acquired approaches in engineering education. Thanks to this asceticism, the university proved its worth and usefulness during the Second World War, when the country needed to quickly begin to solve military technical problems. Moreover, research work has reached a new level. The transition to a more rational processing of metals, the widespread introduction of welding, and the creation of new designs of defense equipment should be mentioned. It is also necessary to note the work to improve the maneuverability of tanks "IS" and "T-34", the replacement of traditional fuel for internal combustion engines with generator gas. There were other inventions, innovation proposals, discoveries. Here it is the real result of the “Russian method” of teaching, which was owned by academician E.A. Chudakov, professors I. M. Besprozvanniy, G.A. Shaumyan, M.K. Christie, V.M. Kovan and their colleagues.

In early 1943, the Moscow Mechanical Engineering Institute named after N. E. Bauman presented its operating time on the expansion of specialties for the training of engineers and petitioned the government to return him to the old name, MHTS. Professors again, as in the XIX century, laid the foundations of the movement of their university to the polytechnic. Thereby, they revived in full the “Russian method of teaching” engineering personnel, which was not forgotten in the most difficult days for the university.

On May 22, 1943, the university was returned to the former name of the Moscow Higher Technical School, was allowed to expand the number of specialties, by strengthening the general scientific and general engineering training of students. The communist government recognized the importance of successful engineering training of the highest level, began to invest in it a lot of money, rightly expecting that they will be multiplied many times. The Great Patriotic War was still going on, but the MHTS was already turning towards post-war problems, towards the scientific and technological revolution. It was a return to the origins, to the “Russian method”. The next stage began - the fifth stage (1943–1991) of the effective use of the educational system under the conditions of the third wave of scientific and technological revolution.

The scientific achievements of the postwar period are inseparable from the history of the MHTS. It is enough to name the founders of practical cosmonautics S.P. Korolev (1907-1966) and nuclear power N.A. Dollezhal (1899-2000), metal scientist A.A. Bochvar (1902-1984) and aviator A.N. Tupolev (1888-1972).

In the postwar years, the development of science and technology has accelerated. The production changed. Education had to radically restructure the training in engineering specialties. Students began to study for five and a half years. New programs were introduced at MHTS. There was a search to strengthen the practical component of education: the number of evening faculties, which allowed workers in industrial enterprises to receive a diploma on the job basis, increased. The influence of the “Russian method” also manifested itself during the creation of so-called branch

departments, which were organized at a number of enterprises — flagships of Soviet manufacture. In total, there were five such faculties at the Moscow Higher Technical School. The system of engineering personnel training that was progressive at that time, based on the integration of the educational process, science and production, was carried out on the basis of the long-term program-target development of the enterprise on which this or that department was based.

"Russian method" in the years of Soviet power had a serious impact on the training of foreign engineers. In the world, a diploma in engineering of a Soviet university was considered prestigious.

MHTS again prepared specialists able to adapt to real production conditions, able to solve problems related not only to the received specialty, but also in related areas of technology, susceptible to scientific innovations and inventions, ready for design and research.

In Soviet times, professorship MHTS named after Bauman managed to preserve and increase the achievements of the "Russian method". It must be emphasized that the state played a major role in its support. The main efforts were then aimed at ensuring the smooth operation of the country's defense-industrial complex. In Soviet times, MHTS received the name "Rocket College on the Yauza" in the West.

In the second half of the 1980s in the USSR, restructuring begins. Initially, the changes had a positive effect on education, the convergence of classical university and technical education began. Universitization is a new step, undoubtedly commensurate with the polytechnicization of the beginning of the 20th century, a significant step in the development of technical university education in the new economic and social conditions. At the new stage of social and economic development in 1989, Bauman Moscow State Technical University becomes the First Russian technical university [8].

The breakup of the USSR in 1991, the transition to a market economy had a serious impact on the engineering community, and led to a difficult situation in Russian education. Technical universities at that time existed at the expense of previous developments.

The merits of the management of the Bauman Moscow State Technical University in a period of the last decade of the 20th century lies in the fact that it managed to preserve the foundation of the faculty, who in turn managed to defend the best teaching and methodological traditions of the "Russian teaching method". The success of the university, even in difficult years for national education, was based on real integration with strategic partners in the production sector [9].

This selfless work allowed saving Bauman Moscow State Technical University among the reputable institutions of higher education. And in 1997, the University entered the Top Industrial Managers for Europe (T.I.M.E.) Association of Engineering Universities of Europe.

IV. "RUSSIAN METHOD" AND ITS MODERN UNDERSTANDING

After the formation of modern Russia during the collapse of the USSR, the sixth stage of applying the "Russian method" in the conditions of digitalization of the economy and world globalization begins (1991-present).

Under the conditions of a radical transformation of engineering and technology, an engineer of the 21st century makes a significant contribution to the creation of a new reality [10]. The national scientific community has repeatedly discussed the problems of technical education. A mechanism has already been created for quickly bringing general professional and professional competencies into compliance with the requirements of professional standards and the demands of promising labor markets [11].

In this regard, the "Russian method" of the Bauman Moscow State Technical University comes to the fore again. Professionals have an understanding that the "Russian method" is not an unshakable axiom. Rather, it is a guide to action, an exact engineering calculation, based on a prognostic understanding of the trends of scientific and industrial development. Bauman Moscow State Technical University is an innovative team. This is where the approbation of specific programs, techniques, various practices that meet modern requirements. Let's stop on some of them.

First of all, the leadership of the university understands that lecturers and students should strive to participate in research and development, research work. In this situation, it is important to have modern scientific laboratories and to interconnect with leading campaigns. At the moment in high school there are 15 Scientific and educational centers.

However, in modern conditions the decisive role is played by the maximum approximation of vocational education to real production [12]. Recall that in the BMSTU in Soviet times, faculties were created where students were completely immersed in the professional environment of the enterprise's creative team. The continuity of this education has been preserved: on a number of defense research and production associations represented branches of the University departments. Such a student learning system provides a transition from cognition through the reproduction of information to cognition through understanding the essence of the phenomena and processes being studied based on thinking and practical experience. Note that this learning process is based on the interaction of the lecturer and the student, at the core of which is the synergy of the learning activities of the first and the learning activities of the second [13]. The same path was chosen in the West. General Electric Aviation (GEA) and Massachusetts Institute of Technology (MIT) have developed and are implementing a long-term engineering training program — "CDIO Initiative — Conceive, Design, Implement, Operate". This concept — "Conceive, Design, Implement, Operate" — is similar to the Russian developments of BMSTU, which testifies to the competitiveness of domestic approaches to education.

Another reserve for the improvement of engineering education is targeted training under the program “New Personnel of the Defense Industry Complex”. Conceived by 2014 and prolonged until 2020, it is aimed at the close interaction of a particular student, the University and the enterprise. At the moment, more than twenty additional training modules have been compiled, including a cycle of theoretical and practical classes, which are implemented at the unique laboratory base of Bauman Moscow State Technical University [14].

A digital learning environment is being successfully formed at BMSTU. One of the first was the creation of unparalleled educational multimedia materials in support of the disciplines “Perspective Renovation Technologies” and “Technology of Construction Materials” [15]. Work in this direction continues successfully.

Professionals believe that modern domestic higher technical school should proceed to the preparation of “innovative engineers”, that is, developers of high technologies and high-tech industries who own mathematics, methods of modeling, computer science, management, the ability to generate and perceive innovative ideas, justify them [16] [17].

Today, when there was an awareness of the global importance of preserving the ecological status of the Planet, it is at BMSTU that they prepare an erudite and broad-minded professional who can not only make various predictions about the state of the environment, calculate the extent of its impact on humans, but also know how to design means of protecting nature and man from adverse situations [18] [19]. “In modern conditions, environmental education is an integrating factor that determines the strategic goal and the leading directions of global sustainable development” [20]. In addition, a modern graduate is ready to go beyond a specific enterprise or even a specific industry and to tackle the complex problems of interaction between man and the technosphere. “...Education for sustainable development should ensure that everyone can participate in improving the quality of his or her own life, the life of the community around him or her and of all mankind” [21].

The humanitarian training of future engineers is also important, which should help students develop a holistic view of future professional activities, the ability to perceive engineering creativity in unity with the social and spiritual needs of society. In Bauman Moscow State Technical University successfully operates the Faculty of Social Sciences and Humanities (FSSH). At the University, there is an understanding that the competence-based approach to the professionalism of engineering and technical profiles presupposes the unity of the natural-technical and humanitarian beginnings: high quality of work as an embodiment of material culture is impossible without spiritual culture and citizenship [22].

The vast majority of modern universities pay special attention to language learning. BMSTU has a unique project of mastering English language “Professional English in the business world” (PEBW BMHTS). This author's school aims to cultivate engineering elite capable of acting in the interests

of Russia. PEBW BMHTS students, in addition to acquiring professional skills in a foreign language, develop experience in holding international meetings under the auspices of BMSTU, develop professional communication skills, and develop self-discipline and responsibility [23].

In fact, all these approaches to the training of specialists are a modern interpretation of the “Russian method”.

V. CONCLUSION

Bauman Moscow State Technical University is constantly improving the learning process in a methodological manner, and at the core of this approach is a unique “Russian method” of engineering training, historically formed within the walls of the University.

From the twentieth to the twenty first century, this method of preparation went through several basic stages that were associated with the development needs of the country and epoch-making events in its history. However, the University remained faithful to its model of Russian technical education and in practice proved its scientific viability.

The teaching staff is aware that education is becoming a continuous matter. Therefore, the programs, the entire methodological apparatus, the system of fundamental, professional, humanitarian training are constantly restructured so that, along with the specialization, the student gets an understanding that a professional can take place, first of all, as a person capable of self-knowledge, self-development and responsibility for the world of technology and man in this world.

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