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Professional Culture of the Specialist of the Future

RUSSIAN ENGINEERING EDUCATION IN THE CONTEXT OF THE SOCIAL DEMAND TRANSFORMATION

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Abstract

The paper is devoted to a sociological study of Russian engineering education in the context of the sociology of professions and the conditions for the transformation of social demand. The paper focuses on the sociological research of Russian engineering education in the context of the social demand transformation. The authors clarify the concept of the 'social mandate in engineering education', its' actors are specified. The basic characteristics of the new institutional design of the modern technical universities and the new role of the knowledge economy are discussed, their economic and social functions are determined. The authors conducted a mass and expert sociological survey of all stakeholders involved in the social mandate interaction (engineering education - science - industry - state - society), carried out an analysis of the regional specifics of engineering education in terms of transformation, taking St. Petersburg as an example. The basic provisions for the modernization of Russian engineering education in the context of the national innovation system have been developed.

Keywords: Social demand in the engineering education, innovative infrastructure, universities transformation, knowledge economy, national innovative system, engineering elite.

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1. Introduction

The engineering education in the modern world is the basic potential for the strategic development of any state. It affects all aspects of the country's functioning as a subject of innovative activity, as an economic player in the system of global competition, as an object for investment, as a special sociocultural space and phenomenon.

Assessment of the place and the role of the engineering education in scientific literature has acquired a special relevance and significance for the Russian national economy since the early 1990s. The change of the priorities vector in professional training towards the humanities subjects actually provoked the loss of institutional memory of the local scientific engineering schools. Apart from this, Russian engineers having a deep potential and traditions of inventive engineering, but not demanded by the state, have broken away from one of the main suppliers of engineering tasks – the market.

The markets globalization, competitiveness, educational and industrial standards, financial capital and high-tech innovations have nowadays actualized in the scientific discourse both the transformation of the education sector in general and the engineering education in particular (Alexankov, Trostinskaya, & Pokrovskaia, 2018; Brisset, 2018; Egorova, 2015). The challenges of the global knowledge economy and the fourth industrial revolution appeal to the demand for a new roadmap of the Russian engineering education on the one hand, and to the fundamental difficulty and social inertia that the higher technical school is facing, on the other. These factors could include:

- unregulated social demand, which causes both contradictions between the real demand for technical specialists and the demand of the population (applicants and their parents) in choosing prestigious professions, as well as introduces a disruptive factor into the system of effective interrelationship between the universities and the needs of the real economy;
- lack of a network / cluster nature interaction of all relevant stakeholders of the innovation process (education, science, industry) demonstrates their economic independence;
- drastically increased requirements for the basic training of engineers, the quality of their intellectual, creative, volitional and organizational skills (which was laid down in the ‘classical concept’ of the engineering education, developed in the 18th-19th centuries and reached its peak in the beginning of the 20th century);
- generating a demand for the new types of competencies and new forms of training: increasing requirements for the integrity, versatility and breadth of training of an engineer who simultaneously acts as a scientist, technical expert and head of an enterprise, which expands his area of responsibility;
- increased proportion of the students who see no valuable reason for a science and technology career, for the engineering education and have low motivation to study (which consequently leads to such students’ employment in other professional areas), on the one hand, and we have the increased proportion of motivated students who are aware of the importance of self-development, are ready for the new socio-economic challenges and are not ready to take the ‘package solutions’ of a particular educational institution (bachelor-master-graduate student);

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- reinforcement of the ‘personnel vacuum cleaner’ strategy (based on the results of the MOOC-based programs, internships, grants, etc.) by the leading world universities - the McKinsey ‘war for talents’ principle - extracting the best personnel from the national economies;
- immigration restrictions and poor diversification of the engineering activities within the country.

At the moment the technological needs of the global economy of knowledge dramatically change the nature of the Russian national engineering education towards the institutional modernization, qualifications and training quality of the technical specialists, determine the concept of ‘engineering stratification’ and the ranking of the universities engaged in the technical specialists training. In the context of the scientific search for a model of competitive Russian engineering education, it is advisable to coordinate efforts in order to create a research platform for its analysis in the context of the transformation of the social demand and the prospects for the infrastructural development and growth points of the knowledge economy. The authors of the research have to admit that the problems of the Russian engineering education in the context of the transformation of the social demand has not practically been studied in the sociology of management, making the research both theoretically and practically significant.

The proposed research is one of the first attempts to address the issues in the context of a comprehensive sociological analysis: systemic, institutional, and cross-cultural. Within the institutional approach, the authors will expand the understanding of the place and social role of the engineering education in the modern social system. Within the systematic approach, it is proposed to study the relationship between the development strategies of a technical university and the strategies for managing innovative development of Russian regional territories in terms of solving its main tasks and achieving their goals (i.e. all stakeholders of the interaction: engineering education - science - industry - state - society). As part of the cross-cultural approach, the authors focus on culture and value component of the social demand in engineering education, on the retrospective analysis of Russian classical engineering education as an effective educational model, as well as on the study of the ‘best practices’, sociocultural innovations of the modern engineering education in Russia.

All this determines the relevance of the research topic chosen by the authors and the legitimacy of scientific research in the context of the sociological approach, the theoretical and methodological potential of which is currently not sufficiently realized in the sociology of management, especially in relation to the profession analysis, which brought the elements of novelty to this research. The research also becomes up-to-date due to the lack of unambiguous interpretation of the concept being studied in the national scientific literature, an important consequence of which is to clarify the definition of ‘social demand in engineering education”, which will significantly push the boundaries of the stated problem in the research area.

2. Problem Statement

The research topic determined, above all, the need to address the works of scientists whose theoretical and practical work was inextricably linked with the establishment and development of Russian polytechnic education: S.Y. Witte, V.I. Kovalevsky, D.I. Mendeleev, A.G. Gagarin, V.G. Shukhov and others. The works of these scientists allowed the authors to formulate a theoretical and methodological position in the study of Russian engineering education in the current context of transformation.

It is necessary to emphasize the significance of the works of the classical direction sociologists within the sociology of professions: M. Weber, E. Durkheim, T. Parsons, P. Sorokin, etc. The analysis of the innovation aspect of modern engineering education is reflected in the works of I. Fedorov, Y. Pokholkov, A. Chuchalina, M. Solovyova, B. Agronovich, O. Piralova. The works of A.I. Borovkogo, V.N. Knyaginina, E.B. Kuznetsova, A.E. Volkova, M. Fullzaka, P.G. Schedrovitsky and others are devoted to the study of the effective Western and Russian models of engineering education.

3. Research Questions

Referring directly to the analysis of sociological research, one way or another affecting the social demand in education, the authors highlight three basic areas.

The first is the socio-economic area. The representatives of this direction (J. Ballantine, A.I. Osipov) consider the social demand as a specific personal economic interest articulated by a certain social group. The choice of profession in such a case occurs not from the position of matching individual abilities, knowledge and skills, but from the position of 'profitability' of the future job.

The second is the institutional area. The proponents of this approach (F.A. Hayek and others) believe that social demand is a symptom of the lack of freedom of society, where higher education institutions are doomed to choose the educational paradigm in favor of satisfying the needs of the direct customer 'applicant-student'.

The third is the culture and value area (O.V. Moreva and others). It proposes to address the cultural and historical, socio-situational, personal and individual aspects of the social demand.

4. Purpose of the Study

The proposed research is one of the first attempts to address the issues in the context of a comprehensive sociological analysis: systemic, institutional, and cross-cultural.

5. Research Methods

However, in the authors' opinion, there are very few studies on the matter for a comprehensive sociological analysis of the stated problem. The methodological issues and practices in interaction between science, business and society, the mechanisms and tools for effective inter-sectoral interaction remain on the periphery of the research field. For this purpose, the authors conducted a sociological study, in particular, mass and expert sociological surveys of all involved subjects of the social demand interaction (engineering education - science - industry - state - society). According to the authors, the fulfillment of this task, i.e. identification of demand and needs for new types of competencies and new forms of professional engineering training should demonstrate the dysfunction of actors/subjects of social mandate in engineering education today. This situation requires a sociological explanation and searching of options to build effective interactions among the participants of the social mandate, which partly provided the basis for the author's main concepts of modernizing Russian engineering education and partly outlined the task of understanding the essence, role and functions of a new institutional model of a technical university in a new economy.

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6. Findings

Assessing the current state of the research field on the problem analysis, the team of authors acknowledges that it is largely non-systematic. Many researchers do not set themselves the task of answering the basic theoretical and methodological questions of the social order essence and procedure, they focus mainly on the specific practical educational models (lyceum, college, technical university). But, as it is well known, it is impossible to move on to solving specific issues without finding answers to general questions.

Consistent with the systematic, socio-economic, institutional and cross-cultural approaches, being at the same time an integral part of vocational training and a product of socialization, engineering education has a direct economic significance and is considered as a tool for global, subregional and regional competition. In addition, much depends on the specific actor of a social inquiry. That is why the structuring, modeling and measuring the request share of all the participants of the social demand interaction (engineering education - science - industry - state - society) is of a particular importance, and not only scientific, but also of applied one – marketing and managerial, which will allow us to proceed to the deliberate development of the social demand, marketing and management of its targeted and accelerated development in public processes. The question on the nature and role of the engineering education in public processes is becoming the key to understanding the economics of the new technological order and the sociology of the new technological generation, in which the engineering education in the context of globalization acquires new value-developing professional orientation and receives new social responsibility.

The value-developing imperative brings the engineer back to a manager status: he becomes who he was meant to be at the turn of the 19th-20th centuries, and the new context of engineering activity sets new roles for him. The rapid response to the technological challenges, the speed and the quality of meeting the challenges at the global level require that a modern engineer possesses a much wider range of key competencies, become not only the 'core source of innovation', but also a researcher, a team work organizer, and finally a versatile supervisor. An engineer today is the principal carrier of scientific and technological progress, who transforms his innovative ideas and laws into specific constructive-technological forms and solutions. The competence of an average 'from nine to five' design office engineer, bending over the drawing board and cleverly using a slide rule to perform algebraic operations, has already become a rudiment. The global trend of the fourth industrial revolution dictates a clear scenario to engineering: wider, faster, shorter. The situation requires a much faster pace of development, short cycles, low prices and high quality than ever before. In order to be in the 'first' and 'best' team, an engineer must become a global innovator, a leader, a member of a multidisciplinary team of highly qualified specialists, creating algorithms, technologies and innovations – these are the "here and now" competencies (Rudskoy, Borovkov, Romanov, & Kiseleva, 2017; Kuznetsov, & Engovatova, 2016; Rudskoy, Rozhdestvensky, & Arkannikova, 2019).

Staying in line with the considerations of Hughes (1984) sociology, the authors proceed from the fact that in a broad interpretation, social demand in engineering education is interaction that involves susceptibility to others (p. VI). In the strict interpretation, this is the aggregate demand of the social actors, each of which, at both institutional and personal potential levels, is able to initiate, produce and reproduce

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the positive experience of a changing social reality, taking into account the interests of all its main actors: engineering education - science - industry - state - society, subject to the leading role of industry. Taking into account the experience of sociological science, for example, Bykanova (2006), Anisimova (2012), the authors also consider the 'social demand in engineering education' in two aspects: the structural and the process-based. The structural aspect is expressed in the quantitative and qualitative characteristics of engineering specialists — science and technology graduates fully relevant to the needs of the labor market, as well as in the technical universities ranking. The process-based aspect is presented as a mechanism of mutually beneficial interaction of all the main actors, taking into account their interests and determining the result of such interaction in the categories of social-economic and innovation efficiency. In other words, engineering education represent itself a social institution as 'an operating enterprise in which some people keep it in motion, others are moved by or to it from time to time and also allow it to move' (Helmes-Hayes, 1998, p. 621).

Like any other social institution the education in its development reflects the problems of the society as a whole. Thus, the dynamics of socio-cultural development and the dynamics of educational systems development, which ideally should coincide, in practice nowadays are moving asynchronously, which leads to a gap between the social demand and its implementation. Previously guaranteed labor relations become unstable and unprotected, the identity of a specialist as a professional becomes flexible and unwarranted, and the choice of a specialty, training and job search are far from being connected with each other by social practices. A look at the profession has changed long ago: the center of gravity of a professionals' social attitudes has shifted towards his personal demands. The prevailing motive 'to become a cultured and highly educated person', 'to have a profession' have long been replaced by such a motive as 'to succeed in life'. The situation is being further aggravated by the frustration, currently growing in our country (including the violation of the hierarchy of needs), the depreciation of incentives for creative activity, the dominating inclination to focus on the day, the priority of individualistic values directly related to the development of market relations.

Apart from this, it should be noted that education, including engineering education, embodies a number of conflicts (interests, values, needs) between different social groups. Neither before nor at present (both in Russia and in other countries) education is the guarantee of life success, but being an important symbolic and practical resource, significantly affects the probability of the latter. Education still has a high rating in the system of life values of young people, but the pragmatic attitude towards it has increased as well, which reduces its socializing opportunities. Thus, being a product of rational activity based on scientific knowledge and knowledge of technology in its sphere, and serving as following a moral vow on the one hand, on the other hand, of scientific, technological development and social changes, including the changing social demands of the end of the 20th - beginning of the 21st century, professionalism as a sociocultural phenomenon is becoming the decisive factor in the productive interaction with the new social reality and activity.

Considering the given factors, the sociocultural image of the engineering activity professionalism should be based on the new social demand, on the image of culture in general and pedagogical culture in particular. The culture of engineering professionalism of the future can and should be an environment of 'growing and nourishing personality', the result of the dialogue and cross-cultural diffusion of the past,

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present and future cultures, the interaction of human, ethnic and mass culture, the conditions of innovative technological development, motivation to labor activities, providing individual-semantic development of a person, supporting his creative uniqueness and originality broad humanitarian and engineering competencies that form the key elitist ability in the image system of an engineer-creator – the ability of an ‘engineer to think symphonically’.

By the professional engineering elite, the authors understand the community of specialists, professionals, who set up samples, the highest levels of the professional engineering activity in the society. The elite engineering education is being understood as the unified targeted process of educating and training, characterized by the defining features, as well as a set of acquired knowledge, skills and abilities, values and competencies of high scope and complexity in order to develop a specialist in engineering and technology, ready for the innovative activity and competition in high-tech industrial markets, for self-development, ready to change the areas and types of professional activity throughout his life (Rudskoy et al., 2017).

It is no secret that in the face of the increasing competitive pressures in the world, the demand for highly skilled labor is also increasing. Already, the high-tech industrial sectors (aircraft and automotive engine-building, machine building, instrument-making, oil and gas industries) in a number of countries with a fairly high unemployment rate, are experiencing a shortage of qualified personnel – mainly engineers and specialists in such areas as mathematics and computer science. According to a survey conducted by PWC experts in 2014, up to 85% of enterprise managers are concerned about the shortage of the qualified personnel. According to some reports, the demand for STEM specialists in the US labor market in 2009-2011 exceeded the supply by two times, and by 2018 the gap amounted to about 8.65 million people. The most in-demand are specialists in such areas as computer data processing (71%), engineering (16%), physics (7%), biology (4%) and mathematics (2%) (Department of education and skill, 2016). In general, according to the McKinsey Global Institute specialists, the global economy will lack from 38 to 40 million specialists with higher education by 2020 (Center for Economic Development and Certification Institute of Economic Strategies RAS, 2014). Also, a potential shortage of 85 million people with high and medium qualifications in the labor market is predicted (Barton, Farrell, & Mourshed, 2013).

In Russia, the shortage of engineering personnel is estimated at about 800 thousand people. They are needed by the innovative sector of the Russian economy that is already operating in a limited quantity, they are necessary for the adequate staffing of the federal innovation development programs, which were first approved by the Russian Government back in 2002. Today Russia urgently needs to achieve the status of an innovation pole of the world. It is worth nothing that only up to 5% of graduates of Russian engineering universities have the world-class competencies for designing and creating, in the shortest possible time, the globally competitive and sought-after products of the next generation.

De jure it is possible to detect prerequisites for reducing the gap between the set of professional qualifications received at university and what the market demands. Thus, new university development trajectories were set in particular by the concepts of National Programs (NP 5-100-2020), collaboration examples (National Technological Initiative, Technet direction in particular), the system of the world and national rating indices (QS World University Rankings, QS BRICS, Webometrics, US News Best Global Universities Rankings, Global World Communicator RankPro, National University Ranking, Rating of the

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English Content of the Russian Universities Sites, Three University Missions, etc.). At the same time, in recent years, the state authorities made certain strategic steps in the field of engineering education in terms of creating a new legislative base that is more in line with modern realities. All this affects the tangible changes that can be observed in higher and further vocational education: the variability of educational strategies in schools, development of various scientific centers of technical creativity and FabLabs, the interest of the non-profit sector in the field of engineering creativity of young people, etc.

De facto, according to the experts in the science and technology policy, Russian technical high school does not yet respond the demands of the global market, neither for the network collaboration, nor for the effective change management: 'with the rare exception in several local universities, there has not yet been a qualitative change in the environment of Russian universities, in the achieving of a critical mass of supporters and like-minded people, which would change the system of higher education in Russia as a whole' (Kuznetsov & Engovatova, 2016).

The pilot study of the regulatory and methodological support of engineering education in Russia showed a lack of regulatory support for the implementation of educational programs in the network form, as well as the activities of the main departments of universities in industrial organizations. As a result, universities encounter problems passing through financial audits, licensing and accreditation. It is the absence of the concept of "basic (responsible) organization of the federal educational and methodical association" in the Standard Statute on Federal EMAs in the system of higher education, approved by order of the Ministry of Education and Science of the Russian Federation No. 505 of 18.05.2015, which makes it difficult for federal educational and methodical associations to perform its main functions, including the development of the FSES 3 ++ and suggested basic educational programs. In particular, the authors note the insufficient orientation of some educational programs towards the creation of new products and services for the market not only in Russia, but also in other countries.

The solution to the complex problems in the high-tech industry today is no longer possible through traditional ('highly specialized') approaches, which contributes to the integration of the separate scientific disciplines in the inter- / multi- and interdisciplinary research areas, development and integration of the individual technologies in the integrated technological chains of the new generation. A number of new economic challenges require the search for additional solutions, namely: 1) the task of creating a national system for the formation of engineering thinking among future engineers, starting from the preschool age and professional selection when entering the engineering training courses; development of a rating control system for all stages of future engineers training; 2) the task of maximal geographical proximity of vocational education to actual production, creation of opportunities for the internal Russian academic mobility of students and teachers, increasing the practice focus of educational programs by taking into account the requirements of the labor market (including those formulated in professional standards), opening specialized departments of leading Russian universities at high-tech manufacturing enterprises; 3) the task of improving the education system, which should provide the digital economy with competent personnel by formation of the so-called "engineering special forces" and highly qualified personnel who own world-class technologies and able to solve the unique production problems of the economy of a new technological order - the digital economy.

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A different kind of personnel is needed to solve the new multidisciplinary tasks – system engineers with world-class competencies (‘engineering SWAT team’) and technological entrepreneurs knowledgeable in high-tech science-related business., Technical universities, however, use mostly traditional approaches to education, involving industry-specific and fairly narrow specialization. Thus, the competencies of the trained professionals do not meet the requirements of the market the main development trends of which are multidisciplinary: industry-specific and professional specialization gradually lose their relevance, as technologies are often being borrowed from the related industries, and a specialist is required to have skills and competencies that previously assumed a clear separation of the professional areas. The rapid development in the world of high-tech multidisciplinary technologies is also one of the significant problems of the modern engineering education, as it leads to a more rapid obsolescence of any set of engineering and technological competencies – technologies appear, change and develop much faster than the traditional cycle of an engineer training (4 years of the bachelor degree, 2 years of the graduate) (Borovkov, 2012; Rudskoy et al., 2017).

The Russian system of engineering education does not consider STEM as an integrated whole, does not take into account the interaction between separate areas of science and as a result scientists and engineers are being trained separately. This leads to the rupture of interconnections between specialists in different fields, interconnections that are so significant for the successful functioning of the modern high-tech industries, since the training of future specialists in the basic science does not take into account how and to what extent their knowledge can be used in the real sector, and engineers training does not provide the opportunity for the implementation of the scientific sector potential and fruitful cooperation with it. The set of STEM components essentially reflects the production life cycle – scientific research creates the foundation for creating new and improving the efficiency of existing technologies, then these technologies are used in R & D, in which the scientific component can also be very significant. Ultimately, the competitiveness and efficiency of separate industries and entire branches will increase both at national level and globally. Thus, it can be stated that the well-established interaction between specialists and organizations representing various STEM-areas is the key to competitiveness of the industry, and this statement is especially true for its high-tech sector.

Modern trends in the global innovation environment, markets globalization and competition, the apparent exhaustion of the traditional educational model, as well as the exhaustion of the previously existing way of thinking – all this sets new roles for the technical universities in the world, indicating the need for the new development strategies. Moreover, their mission and social significance remain in the same institutional field: to be the centers of science, culture and education. They remain to be valuable agents of socialization and mobilization, they also form social values and set social attitudes.

The new institutional design of the modern technical universities has defined an important role for them - the role of innovative hubs in the country's economic system (Kuznetsov, & Engovatova, 2016). The potential of such society institutions is unlimited: from the establishment of a 'new type of education' as a person's ability to 'build himself' to the establishment of the key institutional players of the national innovation systems in the context of the 'triple helix of innovations' (implemented by universities, industry and the state), as well as a multidimensional model in which the audiences that create and consume innovative and complex products become the key actors.

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Such a type of the university model is manifested primarily in the goal-setting of the university management — shared governance, which takes into account the new context of the social demand. Separate university divisions, capable of reflection, become the development drivers of the entire university environment, basic, supporting services for their regions and core industries. That is what creates optimal conditions for the next generation competitive specialists, for the development of the creative personality of an adapted to modern realities man-activist, an independently, creatively-minded researcher and inventor with a leading vision of the rapidly changing social and economic processes of the global world, knowledgeable in his professional field - the engineering elite of his country.

In the context of the new social demand of all the stakeholders: engineering education - science - industry - state - society, the university is not only generates the modern knowledge, but also ensures its transfer to the national system of social development, forms a special innovative, social, cultural and intellectual environment. Managing such a collaboration is a new challenge which was highlighted by the national economy, and which was addressed primarily to the technical colleges administration and to the research community.

For this purpose, the authors conducted a sociological study, i.e. mass and expert sociological surveys of all subjects involved in the social mandate interaction (engineering education - science - industry - state - society). First of all, it should be noted that in the course of the preliminary analysis and pilot study a lack of clarity and structuredness of the subject of the study was identified, as well as a lack of information from the target public groups about the main parameters of the social mandate, including the subjects - the main initiators of the social mandate. The authors suppose that one of the reasons for the current situation is the lack of integration of the positions of parties, i.e. the stakeholders of the social mandate interaction, when each of the groups, despite the common object of interest, builds its own terminological boundaries for future engineers' core competencies and a strategy for their new form of professional training. The test of this supposition has identified the implementation of the stakeholder approach in the study, in which the analysis of the situation is presented from the standpoint of the parties interested in discussing and solving the problem. Thus, the authors of the study used an expert survey method, which is recommended to research poorly studied problem areas, and to obtain information.

From March to October 2018, a series of 53 interviews with representatives of various organizations from Moscow and St. Petersburg was conducted, these organizations are professionally interested (or potentially interested) in engineering education. A prerequisite for the selection of an organization was its activities related to the subject of the project (implementation of social mandate management programs, support for universities, participation in working groups, initiation and integration of new forms of professional training for engineers, etc.). From the representatives of these organizations a purposive sample was formed, which met the following expert requirements: a) representatives hold an important position related to the theme of a study; b) if possible, they are involved in various structures (working groups, commissions, organizing committees of conferences, etc.) created in the field of engineering education and in the field of infrastructure development, growth points of the knowledge economy. Representatives of the selected categories were included in the final list of experts in order to reduce the probability of a one-sided consideration of the problem. After the conduction of interviews, it was considered expedient and reasonable to unite and consolidate expert categories.

Thus, for the subsequent analysis the following types of organizations were identified, among which experts were shared:

1) Structures created by the initiative or with the participation of the state, which realize state policy in the field under study (11 interviews). Here are combined: a) a variety of structures aimed at supporting all kinds of scientific and creative activity of students, personnel federal and regional projects; b) specialized funds/agencies/centers; c) unique projects created with the aim of obtaining breakthrough innovations in engineering.

2) Business structures and organizations affiliated with them (23 interviews), namely: a) large Russian companies and corporations, including state corporations, focused on the development of the country's industrial potential; b) digital/information technology companies; c) venture entrepreneurs, whose activities are aimed at supporting innovative projects; d) recruitment agencies focused on working with young and highly qualified personnel; e) business associations. The authors intentionally expanded the expert audience by respondents from the number of business associations, since they occupy an important position as an institution for coordinating the external relations of enterprises. As an institution for coordinating the enterprises relations with the state, associations are in an intermediate position: they have to constantly satisfy both the preferences of member enterprises and the needs of state authorities with which they interact. Business associations are entrusted with important socio-economic functions: compensation for state failures in ensuring the protection of property rights, increasing government efficiency and infrastructure development through collective pressure of business on the state, and compensation for “failures associated with the absence or underdevelopment of adequate market institutions”. This may be the absence of mechanisms that provide information about new markets and new technologies or stimulate the organization to implement and adhere to quality standards, the weakness of the system of advanced training of employees, the underdevelopment of venture capital markets. A business association often acts as the main intermediary in such interactions, and in this case they can be considered as agents of modernization.

3) Universities, educational, scientific and methodological centers (11 interviews), which are involved in scientific, innovative and entrepreneurial activities; are engaged in the preparation of Olympiads in specific subjects, work with their winners and participants.

4) A separate expert category are scientists (8 interviews) - researchers of Russian engineering education and the transformation of social mandate in education, whose opinions allowed clarifying some theoretical and practical issues of the problem under study.

Expert interviews were semi-structured, lasted from 45 to 60 minutes and engaged the practical understanding and needs of the "new competencies" of a modern engineer, as well as identifying trends, "best practices", new forms of professional training for engineers. The substantive similarity of the views of all involved parties and the multi-stage study of the sampling structure allow the authors to assert that the interviewed experts represent a complete range of opinions on the problem under study, which makes it possible to consider the collected interviews sufficient for the full realization of research goals.

First of all, the experts were asked to explain what they include in the concepts of “modern engineer”, “new competences of an engineer”, “new forms of professional training of engineers”. As for the first term, it turned out that this concept is usually used to perceive the expression: “key employees”,

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"personnel reserve", "leaders", etc. Only in a few cases respondents noted that they think it was incorrect to divide employees into "just engineers" and "modern engineers" since these concepts "sound like a certain stamp, temporary convention, are redundant and speculative". As expected, the modern engineer is interpreted in different ways by the involved parties. Experts were asked to express their opinion about who is usually called or considered as modern engineers. Within the first category of answers, a modern engineer is interpreted as broad as possible. In these cases, the following context is used: "all people are talented" or "everyone is talented in their own way". This approach is most consonant with the tradition of personnel management and declares the goal to develop and realize the potential of each of the employees in the organization. The second category of answers connects the modern engineer with their obvious manifestations (outstanding results and achievements in a certain engineering field). The most common is the third category of answers, which reveals the modern engineer through the demonstration of some specific qualities (personal, psychological, professional) or compliance with the requirements. This was noted both by those experts who use the concept of "modern engineer" in their practice, and by those who prefer to replace it with synonymous or not to use at all due to incorrectness. This is clearly seen in the following examples: "a modern engineer is a kind of speculation, a temporary entity, which is used to separate young people according to some criteria that someone needs" and "now in most cases no one uses such a concept as "modern", but "meets the requirements" or "does not meet".

To identify the structure of the "new engineer competencies", the following actions were taken. At the first stage, all descriptive characteristics of a modern engineer which were indicated by experts, were singled out twice and entered in the appropriate fields of the table, referring to the three identified parties. Thus, 9 unique characteristics were obtained from representatives of state structures, 12 characteristics from business representatives and affiliated organizations, as well as 17 characteristics from representatives of educational and scientific institutions. The answers given by scientists engaged in scientific research on the subject have not been subjected to such processing. At the second stage, the characteristics obtained were divided into two broad categories: psychological characteristics (personal qualities) and social aspects (social manifestations). Further, personal qualities were divided into four sections: innate abilities, creativity, communication skills, motivation and activity. The social characteristics were divided into: selection, scope, high potential and achievements. At the third stage of the analysis, the characteristics divided into sections were again attributed with the category of the corresponding experts that named them. Thus, information for categorizing the characteristics of competencies in accordance with the views of involved parties was obtained.

From the point of view of representatives of the state structures, a modern engineer is, above all, the significance and relevance of the sphere of his application. Experts pointed out that a modern engineer manifests himself in those areas that are considered as the most relevant and top-priority: in innovation, start-ups, entrepreneurship, in the field of digital technologies, etc. And this is the second component of the new generation specialist of this kind - interpersonal skills and leadership skills – that contributes to this goal. The remaining components of the modern engineer are less important for the representatives of the given expert category. A modern engineer is viewed by representatives of business and affiliated organizations in other way. The focus on the activity and its practical implementation is in the first place for employers. That is, in fact, productivity and efficiency is synonymous with a modern business engineer.

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With this approach, motivated activity is realized first in the demand for a person in some sphere of engineering activity (not necessarily modern), then develops into potential and, finally, is realized in certain achievements. For representatives of education and science sphere modern engineer is evolving in self-realization; he is based on a creativity, which is supported by intrinsic motivation, develops and brings results. Comparative analysis showed that the views of involved parties on the competence structure of a modern engineer differ significantly.

In general, a list of competencies of a modern engineer includes specific abilities and individual characteristics, as well as action orientation and pragmatic application of such orientation in order to achieve results or obtain a product. Nevertheless, there is still significant inconsistency in required competencies. In organizations established with government support the key requirements are congruence between a candidate`s work and the current business environment and the communication quality. Business establishments view a new generation of specialists as motivated and active experts whose potential will help to achieve the desired results in the future. Representatives of education and science institutions believe that a modern engineer should be judged on creativity-based accomplishments. In many respects these statements are highly consistent with the theory of differentiation of specialists in the emerging knowledge economy developed by R. Persson.

Regarding questions on new training forms for engineers, it should be noted that in the survey government institutions proposed five original techniques, businesses and affiliates proposed 10 techniques and education and science institutions proposed 11 techniques. The range of these forms is quite wide: from building creative competency through performing arts (for example, developing engineering thinking through studying music) to engaging in creative collaborations between all concerned actors of a social mandate.

Based on the conducted sociological survey, the authors summarized advanced education strategies that account for introducing new professional competencies. They are the following:

1) A holistic approach to developing engineering competencies (a competency-based approach, project-based learning, an inter- or multidisciplinary approach instead of highly specialised education, team learning, self-search for information, distance learning, online learning. and contextual education).

2) Engineering education through actual projects.

3) Virtual inter- or multidisciplinary project teams.

4) An innovative engineering project-based approach.

5) Interaction between industry and higher education institutions.

6) Creation of a distributed foresight structure for education, science and innovation in knowledge-intensive computing engineering.

In addition to this survey, a targeted mass survey of first-year engineering students of Peter the Great St. Petersburg Polytechnic University was conducted in October 2018.

The survey comprised 2896 Russian students, 26% of which come from Saint Petersburg and Leningrad Oblast and 74% come from other regions. Institution-wise, the distribution was the following: 814 students (28.1 %) were from the Institute of Computer Science and Technology, 512 students (17.7 %) - from the Institute of Metallurgy, Mechanical Engineering and Transport, 453 students (15.6 %) - from the Institute of Physics, Nanotechnology and Telecommunications, 447 students (15.4 %) - from the Institute of Energy and Transport Systems, 393 students (13.6 %) - from the Institute of Civil Engineering, and 277 students (9.6 %) - from the Institute of Applied Mathematics and Mechanics.

The questionnaire included open and closed-end questions. The survey findings showed that most first-year students (72%) consider a modern engineer, as a specialist of the new generation, to be an engineer actively involved in digital economy. This opinion is consistent with that of organizations established with government support. Among personal competencies, they chose motivation and creativity. The same competencies were named by businesses and affiliates as well as by education and science institutions. When asked if they considered themselves creative, 64% answered “yes”, 21% - “more likely yes than no”, 6% - “more likely no than yes”, and 9% - “no”. It can be concluded that first-year students believe their future career opportunities to be connected with advanced knowledge-intensive areas determined by today's market environment, while their accomplishments and results whereof to be largely depended on themselves and their personal competencies.

One of the purposes of the study was to specify the regional characteristics of engineering education against the background of transformations using the example of Saint Petersburg. The analysis showed that the training of qualified engineers in Saint Petersburg begins in school. This period includes such forms of trainings, as different educational programmes, courses, training in specialized schools, and city and federal competitions. As of 2018, additional educational programmes were available for 88% of Saint Petersburg citizens aged between 5 and 18, which was significantly higher than the national average of 70%. Moreover, 90% of those children were exempted from paying fees. Among specialized schools, the engineering school established by the Laboratory of Continuous Mathematical Education in 2016 stands out. The teaching here also includes such specialized courses, as “Engineering Creativity” and “Basics of Engineering”. Students learn to solve various engineering cases, to apply basic problem-solving tools and methods and to master basic skills in working with different materials. They acquire introductory knowledge in structural materials and strength of materials. Moreover, a new specialized school of engineering and technology No. 777 is to open in September 2019 that will enrol 2000 children. Furthermore, its supplementary education division will enrol 6000 children. According to Saint Petersburg City Administration, the operation of the school will be aimed at developing cognitive interest in children towards engineering and new technologies and promoting engineering education. In September 2018, Saint Petersburg saw the establishment of the Academy of Digital Technology. It is a supplementary institution that provides children and adolescents with education in IT, robotics, technologies of digital production, and economics. Students of the Academy are school students from Saint Petersburg and other regions of the Northwestern Federal District aged between 6 and 18. At the opening of the school, 1500 children were enrolled. By 2022 the Academy aims to provide education to more than 5000 students. There are more than 60 courses available, including “School of Young Engineer”, “Robotics”, “Artistic 3D, VR/AR”, “3D Modelling and Prototyping in Engineering”, “Repair and Maintenance of Vehicles”, “Industrial Design”, “Children's Film Laboratory”, “Children's Centre for Audio-Visual Technology”, and others. Moreover, four fabrication laboratories operate in Saint Petersburg today, two of which are affiliated with leading technical universities. They are open for students and young people and allow for realization of personal projects and development of skills in working with high technology equipment. The operation of such laboratories is not limited to working with equipment only as they regularly organize lecture courses for school and university students.

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In addition to active participation of students of Saint Petersburg in federal and national engineering competitions, they also have a chance to participate in the local stage of the JuniorSkills championship held in Leningrad Oblast. 939 students and pre-school children were involved in the competition in 2015-2016. Altogether, they participated in 31 categories in engineering simulation and information technologies.

As for today's university education in Saint Petersburg, it is characterized by a highly-developed network of education establishments of all levels and training programmes. It provides variability, accessibility and relatively high quality of education, as its key indicators are higher than the national average. The vocational education system ensures education and socialization of more than 420,000 students and is currently one of the largest economic sectors with approximately 80,000 workers and the total annual funding of more than 50 billion roubles. The growing trend of liberal arts education among students does not correspond to the current needs of the country's economy in human resources trained in technology and engineering. Experts predict that Saint Petersburg labour market needs for additional personnel will range from 75,000 up to 90,000 people in the medium term, and specialists with secondary vocational education (craftsmen and mid-level professionals) will account for two-thirds of them. Based on the report by Saint Petersburg Committee for Science and Higher School, in recent years there has been a decrease in economics and management students and an increase in engineering and technology students. Moreover, engineering programmes are experiencing growth as well (Barton, Farrell, & Mourshed, 2013). In higher vocational education, the percentage of engineering and technology majors grew from 24.9 % in 2006-2007 to 37.5 % in 2014-2015. In 2016 the Committee proposed to increase the number of state-funded places in engineering, technology and technical sciences by 400 for Bachelor's programmes, by 295 for Specialist's programmes and by 168 for Master's programmes. In addition to that, six universities in Saint Petersburg are involved in the presidential programme for advanced training of engineering personnel that received more than 8.5 million roubles in federal funds in 2014 alone.

The analysis showed that the regional characteristics are linked with positive changes undertaken by the city administration and aimed at improving effectiveness of the education system. They are the following:

1) Saint Petersburg is one of the first regions to have developed and implemented new approaches to engineering education system management.

2) Saint Petersburg is highly experienced in providing interactions between education establishments (secondary and higher vocational schools) and key actors of a social mandate (science, industry and state sectors).

3) In order to improve competitiveness and the training quality of specialists, the educational system integration was introduced in 2013.

4) Pursuit of internal sources, development drivers and rational use of the accumulated potential added to the primary development and modernization directions of the regional education system.

7. Conclusion

In order to ensure the further engineering education development against the background of transformations of a social mandate and transition to a new technological paradigm of digital economy, we

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propose the following basic provisions of the Russian engineering education modernization taking into account domestic and international experience:

1) A national system of engineering thinking development in future engineers, starting from the pre-school age and including a list requirements for students entering engineering programmes, should be created through a) establishment of the national coordination committee on STEM-education; b) development of a pre-school and school STEM-education programme similar to K-12 (education from a kindergarten to the 12th grade); c) creation of conditions encouraging students to study STEM-subjects and take the state examination in them, for example, through changing the system of school performance evaluation on the basis of results of the said examinations; d) improvement of the selection quality of students applying for engineering programmes through increasing the importance of the examination results in major subjects; e) development and introduction of a national campaign aimed at improving the image of engineering education among the public.

2) A closer proximity of vocational education establishments to actual sites of production and practice orientation of educational programmes should be achieved through a) creation of major departments of the leading Russian universities in high-technology industrial facilities and scientific institutions and implementation of distance learning technologies, online education and academic mobility of teachers; b) improvement of the system of higher education establishment performance evaluation through separate consideration of results achieved by the main education establishment and its major departments in industrial facilities; c) improvement of the regulatory and legal framework of the education programmes realized in the form of a network.

3) The education system should be improved in accordance with the challenges of a new technological paradigm of digital economy, including better training of specialists and master's students in engineering and of world-class highly qualified personnel capable of solving unique production tasks, through a) changing the state funding standards of a social mandate by decreasing the teacher-student ration in order to promote the realization of Master's degree programmes on request from high-technology industrial facilities in accordance with world-class teaching technologies; b) modernizing the training system of teaching staff in postgraduate education and the qualifying examination in accordance with digital economy through introduction of a degree in Russia similar to a degree of Doctor of Engineering (EngD); c) development of the regulatory and legal framework for engineering education in accordance with digital economy; d) introduction of supplementary vocational education programmes aimed at creating new products and services for the Russian market as well as the international one.

4) The quality assurance system and the content of engineering education should be developed through a) modernization of per capita financing in educational programmes regarding the increase in allowable deviation of students enrolled from the enrolment plan; b) introduction of a requirement for a teacher involved in realization of Bachelor's, Master's and Specialist's educational programmes regarding the amount of educational publications developed by the said teacher, including electronic ones that are approved by federal Academic Methodological Associations and recommended for publication and uploading on online education systems of universities, electronic library systems, websites, and the like; c) extensions of rights and duties of federal Academic Methodological Associations in higher education; d) extending institutional capacities and increasing personal responsibilities of directors of federal Academic

Methodological Associations in higher education, including the possibility of appointing for the position rectors of specialist higher education establishments that practically perform the functions of basic organizations of federal Academic Methodological Associations, with the possibility of assigning the corresponding status to the specialist higher education establishments

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