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Development of Information Technologies in Medicine at the University Base: experience of the Samara State Medical University

Abstract. The article deals with the transformation of the role and place of universities in the current conditions of economic development and the demands of society on the example of a traditional medical university — the Samara State Medical University. The results of the university’s work in the innovation-technological area and their integration into the principal activities of the university (education, research) are discussed, as well as the implementation of the “third” mission of the university, i.e. development of the regional economy, the innovative ecosystem of the region, and human capital.

Key words. Knowledge-based society, medical university, university mission, the transformation of the role and place of the university, innovation, information technology in medicine, the digital economy, the development of the region, the markets of the future, human capital.

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Introduction

The Strategy for Scientific and Technological Development of the Russian Federation defines a number of priorities related to the development of Russian public healthcare: the transformation of science and technology into a key factor

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in Russia's development and ensuring the country's ability to respond effectively to challenges and external threats; transition to innovative technologies, robotic systems, new materials and design methods, creation of large data processing systems; promotion of machine learning and artificial intelligence; transition to personalized medicine, high-tech healthcare and health-saving technologies¹. A significant achievement of the fifth technological order is the development of information and computing technologies and their integration into all areas of life. The approach of these technologies to the area of cognition, the emergence of supercomputer technologies enable scientists at the junction of computing and medical science to talk about "superhuman" technologies of cognition, learning, synthesis.

The Strategy for Development of the Information Society in the Russian Federation for 2017–2030, approved by the Decree of the President of the Russian Federation of May 9, 2017 No. 203, is an orientation in such global transformations, which require a fundamentally new level of comprehension, as well as the formation of new economic structures (in particular, the healthcare sphere), scientific and technological development and the process of management of all parties to the process. In order to implement it, the program "Digital Economy of the Russian Federation"² focuses on *"creating conditions for the development of the knowledge society in the Russian Federation, improving the welfare and quality of life of citizens of our country by means of increasing the availability and quality of goods and services produced in the digital economy using modern digital technologies, increasing awareness and digital literacy, improving accessibility and quality of public services for citizens, and security both inside country, and beyond its borders."*

Hence rethinking the role of medical universities as an integral and most important socio-economic component of the process of formation of the digital economy in the area of healthcare, beginning with ensuring the level of training of medical personnel at a globally competitive level for getting a doctor with a truly university education (versatile, which includes general humanities, economics, law, the field of IT technologies and other related branches of knowledge of the natural science bloc). Such a transition of the healthcare system and, accordingly, the educational process for the training of medical personnel, requires a harmonious combination of traditional forms of doctor training and a radically new view on the organization of the educational process: project-oriented and continuous education, the growing role of humanitarian support for the scientific and innovative process and the formation of a modern management system for the entire process. This task is impossible without the introduction of new educational technologies and the exchange of best pedagogical practices

¹ Decree of the President of the Russian Federation V. V. Putin of 01.12.2016 № 642.

² Order of the Government of the Russian Federation of July 28, 2017 No. 1632-r.

using modern, in particular, IT capabilities and options for organizing the learning process. In complex, these technologies provide effective means for achieving the basic mission of universities (training of scientists and specialists) and form human capital.

This direction is closely connected with the elaboration of new knowledge and technologies, up to the formation of new spheres in medical science and technology, mainly through interdisciplinary approaches (for example, digital medicine) and, finally, the emergence of a new paradigm of knowledge in the “knowledge-based society”. In addition, the most advanced medical universities become centers of attraction for the “interface of science and practice” of universities and enterprises of the real sector of the region’s economy. These universities become built into interregional and international chains of scientific and technological cooperation — the exchange of competences (expert level), — the capitalization of their competences (educational, scientific, innovative, technological), — the development of knowledge-intensive businesses, — the formation of new industries. At the same time, such innovation-oriented universities are switching from the implementation of individual R&D projects to the formation of entire directions in the industrial sector (primarily the medical and pharmaceutical industries) and even take the role of coordinators of innovative and industrial clusters. These development-aimed universities, in particular, medical universities, which have a special social significance, are becoming centers of innovative development of their territories [Kotelnikov, Kolsanov, 2016].

The Samara State Medical University (SamSMU) currently has key competencies and infrastructure for successful training of competitive highly-qualified medical personnel on the basis of integration and reciprocal communication of the university with the organizations of practical public healthcare, including the field of information technology in medicine, and conducting breakthrough studies on the most actual directions of development of medical science. Many areas of scientific, innovative and educational activities are carried out in cooperation with both the leading scientific and educational and clinical centers of the country and abroad, and enterprises of the medical and pharmaceutical industries [Kotelnikov, Kolsanov, Volova et al., 2017; Pyatin et al., 2017].

One of the directions of innovative development of SamSMU is the creation of the *Volga NeuroNet Center* on the basis of the already existing developments in applied neurophysiology and neurocomputer interfaces. Besides research activities in the field, the *Center* is aimed at the organization of a coordination and methodological network, providing cooperation of all participants and partners of the Center with an emphasis on system and multilevel training of personnel, as well as import substitution and the formation of new markets for medical products, equipment and technologies (including rehabilitation) at the domestic

and, in the long term, international level in NeuroNet's profile [Antipov et al., 2017; Kolsanov, Avdeeva, 2017].

International cooperation is realized in the establishment (in partnership with Academician S. P. Korolyov Samara National Research University) of two international laboratories in the field of digital medicine: the international Russian-French laboratory "Additive technologies in medicine" (profile — development of high-tech bone-fixing elements with the deposition of bioactive materials, the manufacture of individual exoprostheses and endoprostheses) and the international Russian-German biotechnological laboratory for the cultivation of organs and tissues "Tissue Engineering" (profile — modeling and cultivation of tissue-engineering structures of organs and tissues, individual biomedical implants) [Kotelnikov, Kolsanov, Volova et al., 2017; Prikhodko et al., 2017].

Transition from individual projects to new knowledge and technologies

The SamSMU, is an innovative-type higher education institution; for the past 10 years in its education, research and medical activities it has been focusing on steadily growing demand of domestic healthcare for new technologies and products, which can provide adoption of new information technologies, biotechnologies, micro- and flexible electronics and additive technologies into clinical practice and educational process. The main integrative component is information technology in medicine ("IT-medicine") — a new area that lies at the junction of the latest information and communication technologies, precision engineering, the best medical knowledge and practices. In addition to the course taken at the current stage in the Russian Federation for the development of the "Digital Economy" (where the medical direction is designated among the top priorities), the innovative direction formed at the Samara State Medical University corresponds with the Strategy for the Development of Medical Science in the Russian Federation for the period up to 2025, the federal technological platforms, the National technological initiative (in particular, HealthNet and NeuroNet), and a number of other state development programs and strategies [Katorkin et al., 2017; Kotelnikov, Kolsanov, Ivanova et al., 2017; Prikhodko et al., 2017].

For example, the largest running or completed R&D projects (with financial support from the federal level) were formed with a focus on training and retraining of doctors and medical personnel in conditions of limitation of access to patients and cadaver material during training, an increasing number of pathologies and diseases, transfer to personalized medicine and the interdisciplinary nature of the new medical specialties; individualized diagnosis, as well as monitoring of patients' conditions that are territorially remote from qualified medical personnel, including situations requiring the establishment of a differential diagnosis and

the appointment of appropriate treatment by a geographically dispersed medical team of specialists; reduction of time for rehabilitation of patients, which can be solved by providing new technical tools that enable significantly accelerating the development and implementation of new methods of treatment and rehabilitation in practical healthcare (modeling on a simulation facility, creation of neuro-computer interfaces and robotic prostheses, planning and navigation interference technologies, etc.) [Antipov et al., 2017; Kolsanov et al., 2017; Kotelnikov, Kolsanov, Ivanova et al., 2017].

Based on the innovative infrastructure of SamSMU, the University's scientists and specialists, with the participation of a number of other organizations as a result of the project of the Ministry of Industry and Trade of Russia, have developed a unique hardware and software complex "Autoplan" (hereinafter — HSC "Autoplan"), within which computer X-ray tomography and magnetic resonance tomography, by using segmentation technologies, are recognized and transformed into three-dimensional objects. The HSC "Autoplan" uses personalized anatomical data of the real patient that is successfully applied in surgical interventions. It radically changes the approach to the operation: the surgeon knows in advance the location of the anatomical formations that have a variant structure [Katorkin et al., 2017; Kolsanov et al., 2017; Kotelnikov, Kolsanov, Ivanova et al., 2017]. Thanks to this approach, it is possible to plan the operation in advance, identify the optimal areas for resection, and prepare the necessary implants. For example, it is possible to optimize the selection of donor organs for the size, location of the vessels. At present, the HSC "Autoplan" implements automatic construction of bones, blood vessels, ducts, internal organs, as well as muscles and ligaments. Construction takes place with the help of the developed original algorithms and allows obtaining polygonal models of high accuracy at the output. The surgical module performs automatic detection of neoplasms in the liver. The traumatology module allows to build a model of prosthetic bones (hip and pelvic ring) at the stage of preoperative planning and to select the size of the bone channel, the angle of inclination, etc. to other parameters. The use of this module allows for significant reduction of the operation time, reducing the cost of subsequent sterilization of open prostheses, and improving the quality of the prosthesis. The dentofacial module enables preoperative preparation of a template for the implant of the jaw, which can be shaped into a standard prosthesis and does not waste time during the operation. An integral part of the project is intraoperative imaging. The original design of augmented reality glasses and tracking system enable combining the real image with the data of X-ray research. This HSC was implemented for the first time in Russia. Some software algorithms and design parameters in the tracking system and augmented reality glasses were made for the first time in the world. In the Russian Federation, with the use of this equipment, over a thousand patients have been successfully operated [Katorkin et al., 2017; Prikhodko et al., 2017].

Within the framework of the implemented project of the Ministry of Education and Science of the Russian Federation, scientists of SamGMU in cooperation with SPO “Leader” developed the first Russian simulators of endoscopic and endovascular surgery — HSC “Virtual Surgeon”. They are based on a dynamic highly realistic anatomical model of the human body. An important application of the HSC’s capabilities is their use in modeling surgical operations. The imported model, obtained by reconstructing CT, MRI or angiography data, is loaded into the endovascular simulator of SamSMU, in which “training” operations are performed, which are then reproduced in reality. So, simulators of endoscopic and endovascular surgery are designed to acquire complex knowledge and skills in these areas of surgery [Kotelnikov, Kolsanov, Ivanova et al., 2017].

The data obtained during the development of HSC “Virtual Surgeon” formed the basis for the highly realistic anatomical model of the human body in creating the first Russian atlas of the three-dimensional anatomy “inBody Anatomy”. The developed 3D atlas allows to study the anatomical layer entirely, rather than individual objects of the system, including the interconnection of organs and systems of the human body; significantly expands the scope of the training material by providing additional functions: the possibility of comparing different anatomical objects among themselves, studying additional diagnostic materials (CT, MRI and ultrasound data). The developed atlas is unique in its anatomical, topographical and clinical filling. The atlas includes models of 12 layers and systems of the human body, models of the ligamentous apparatus, intragroup structures of objects, including blood vessels, innervation, ways of lymph drainage, ducts, share and segmental structure of internal organs [Kotelnikov, Kolsanov, Ivanova et al., 2017].

Based on this model, SamSMU scientists have built a software and hardware complex for virtual work with a 3D model of the human body — the first Russian interactive anatomical table “Pirogov”, which is the contribution of Russian academic science to the world practice of studying anatomy. This device enables uploading digital data of real patients (computer radiography and tomography, digital radiography, magnetic resonance imaging tomography, positron emission tomography, etc.), according to which the program automatically builds a 3D model and displays an interactive table, which enables applying this device in clinical practice [[Katorkin et al., 2017; Prikhodko et al., 2017].

The Samara Tissue Bank of SamSMU was the first in Russia (in a number of positions — the first in the world) to create a unique clinical and technological complex for the restoration of lost bone tissue with the use of individual endoprostheses made from the biomaterial “Lioplast” [Kotelnikov, Kolsanov, Volova et al., 2017].

The SamSMU developments also allow implementing a personalized approach to medical rehabilitation of patients with body part defects using digital

prototyping and additive production, to speed up the process of rehabilitation of patients undergoing stroke, etc. [Prikhodko et al., 2017; Pyatin et al., 2017].

There are a number of other examples of knowledge-based interdisciplinary R&D in the SamSMU. The implementation of such projects has become a starting point in the development of new scientific directions in interdisciplinary areas and the development of new technologies in education and practical healthcare [Kotelnikov, Kolsanov, Ivanova et al., 2017; Kotelnikov et al., 2012].

The role of SamSMU in the formation of a regional innovation ecosystem and the development of scientific and technological potential of the region

One of the reflections of the development of national healthcare and its close relationship with scientific and technological progress in the field of science and production (primarily the medical and pharmaceutical industries) is creation of biomedical and biopharmaceutical clusters (industrial, innovative, scientific and educational) in the country and the world.

By 2012–2013 the scientific and technological cooperation in the field of IT in medicine (before the formation of the Cluster, the format was designated as the “small innovative belt” of SamSMU) began to influence the development of the region. It has resulted to the adoption by the Governor of the Samara Region of the decision to designate “IT medicine” as one of the key priorities in the development of the region’s economy. In December 2013, the roadmap for the development of a corresponding sector of the new economy in the region, was elaborated and approved by the Government of the Samara Region, including financial support, the formation of a supply infrastructure, and training of personnel. This support is systematically provided in the format of co-financing of all major projects in the direction of “IT medicine”.

To date, the number of Cluster participants has reached 75 members. It is important that new knowledge-intensive businesses have been formed in a number of areas, the total revenue of manufacturing enterprises and IT companies has increased by 15%, multimillion-dollar state contracts have been implemented by the Ministry of Industry and Trade of Russia and the Ministry of Education and Science of Russia, small and medium-sized businesses have developed, cooperation with the universities of the Samara region, and with the production enterprises of the region has risen to a new level. At the same time, a number of projects have become infrastructural in nature (the biomedical sector is included in the structure of the Nanotechnology Center of the Samara Region, the “Gagarin Center” Technopolis, etc.), their implementation includes partners from other regions with whom agreements on intercluster interaction are made (with the Vitebsk Medico-Pharmaceutical cluster within the frames of the “Medicine and Pharmaceuticals — Innovative Projects” Union; with SP

“Ural Biomedical Cluster”, with the engineering-production cluster “Biomed”) [Kotelnikov et al., 2016].

The Role of SamSMU in the development of the human capital of the region

In addition to the obvious social orientation of the university’s activity in training medical personnel for the region and beyond, performing R&D in the field of medical and social rehabilitation of citizens, the work of one of the strongest Student scientific societies in the country (we consider it as a reflection of the process of involving talented youth in science and upbringing civic position of medical students), as well as a developed volunteer movement, the University has unique content formats in terms of forming human capital, development of the nation’s intelligence and training the “personnel of the future” [Kotelnikov et al., 2012].

Thus, in the direction of human development and economic efficiency in the conditions of the third industrial revolution, the Center for Youth Innovation Creativity “Information Technologies in Medicine” (CYIC “IT-Medicine”) was created to work with talented youth in 2014. It is successfully functioning on the territory of the scientific and industrial technopark of SamSMU. CYIC was organized with the support of the Department for the Development of Small and Medium Enterprises of the Ministry of Economic Development of the Russian Federation, in conjunction with the Ministry of Economic Development, Investments and Trade of the Samara Region and is officially accredited organization. The CYIT “IT-Medicine” is an official participant of the “Association of the CYITs of the Russian Federation”, has agreements on cooperation with the leading CYITs from other regions of the Russian Federation. In addition, CYIT “IT-Medicine” cooperates extensively with other organizations involved in the development of children’s technical creativity in the Samara region (Regional Center for Children’s Technical Creativity, Regional Operator for Children’s Robotics “R2D2”, CYIT “Aquil”, Palace of Children’s Creativity of Samara Region and others). It has branches of selection and testing of children for inclination to various directions of technical creativity. Annually over 400 schoolchildren undergo three training programs developed in the Center. Three formats of cooperation agreements were signed with schools, universities and colleges of the region, and 8 major innovation projects were developed. Currently, the development of two training programs in the areas of “Virtual Medicine” as well as “New Materials in Medicine” is being finalized, a series of courses is also being prepared jointly with partners from other CYITs and centers of children’s technical creativity in robotic systems of the medical direction and neurointerfaces of “human- robot” interaction. A club of young

neuromodelists is being created to generate at least five projects of students from CYIT in the mentioned direction [Antipov et al., 2017; Pyatin et al., 2017].

The structure, which coordinates the activities of the CYIT and provides training and “upbringing” of future professionals is the “Startup Center”, a department of the Institute for Innovative Development. The activities carried out by the Startup Center are an important link in the chain from creation of knowledge to its capitalization, as well as one of the “bricks” in building the foundation for the social and economic development of the region through investing in the development of human capital, and at all levels — from a particular person (schoolboy, pre-student, student, scientist) up to the functioning of macrostructures and the entire state [Kotelnikov, Kolsanov, 2016].

The “Third Mission” of the University

Without weakening the positions in the traditional appointment of the university — in the educational and scientific area (two fundamental missions of the universities), the further plans for development of the SamSMU are dealing with formation and development of biomedical and biotechnological directions based on information technologies, in the interests of the nation’s health [Kolsanov, Avdeeva, 2017; Kotelnikov, Kolsanov, Volova et al., 2017; Kotelnikov, Kolsanov, Ivanova et al., 2017]. In this respect, the main tasks are:

- development and implementation of digital technologies in the healthcare sector to improve the quality and accessibility of medical care (including high-tech), in particular, the development of decision-making support systems using algorithms for processing large amounts of data for local use in medical institutions when providing remote medical services; development of telemedicine systems and products and the creation of hardware and software systems;
- development of biomedicine and medical and pharmaceutical biotechnologies along the lines of HealthNet to provide personalized, preventive medical and medication care to increase life expectancy and effective prevention and treatment of various diseases;
- creation of globally competitive products and services based on the development and use of end-to-end technologies, in particular, artificial intelligence technologies, neurotechnologies, virtual and augmented reality technologies;
- development of cognitive computing and cognitive engineering technologies as a technical and methodological basis for increasing volumes, reducing the time of creation and competitiveness of knowledge;
- develop globally competitive educational programs in interdisciplinary / multidisciplinary areas to train “personnel of the future” capable of working

- in a digital economy (and, in particular, digital healthcare) and create products and services for HeathNet and NeuroNet markets;
- participation in international research projects and collaborations;
 - access to global educational services markets with offers with high added value, such as the network program “Big Data in Medicine”, programs for training medical personnel in residency in “Doctor-cybernetics” and “Network Doctor” specialties, engineers specializing in “Medical Data Processing” etc.;
 - development of technological entrepreneurship;
 - development of advanced production technologies for the medical and pharmaceutical industry in the Samara region;
 - the activities of the University as an open platform and a methodological center for discussing the development of the region (regional healthcare and others) and the challenges of the third industrial revolution, and, in time, issues on the global agenda.

Thus, the example of the Samara State Medical University shows that universities of traditional forms of organization, with properly elaborated development strategies and state support, are able not only to “keep pace with the times”; but also to be generators and conductors of the most advanced ideas in the real sector of the economy, institutions that create future medicine, markets for the future and future personnel.

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