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ENGINEERING ECONOMICS AND TECHNOLOGICAL EDUCATION: A TRANSDISCIPLINARY APPROACH TO THE TRAINING OF MODERN ENGINEERS

The problem and purpose of the work. The acceleration of scientific and technological progress dictates new approaches to the training and retraining of specialists for the real sector of the economy, and primarily the elite - engineering personnel. The development of import-substituting industries imposes new requirements on the quality of education of modern engineers. Domestic engineers are faced with the task of not only updating the technopark, but also finding new markets for the implementation of modern science-intensive products. The purpose of the study is to understand the problems and prospects of technological education through the understanding of cultural traditions, the philosophical and historical foundations of the training of engineers.

Materials and research methods. The scientific content of the official websites of research and educational institutions in Europe and Russia, which title and content contain the terms "engineering economics", "engineering and economic education", "transdisciplinarity", "continuity", "knowledge management", "ecosystem of the university", as well as materials of the author's research.

Research results. The problems and opportunities for the modernization of engineering education based on the integration of highly qualified technical specialists into the existing knowledge management system, accumulation, storage and transfer of new knowledge, updated as intellectual property, are identified. The necessity of using the positive aspects of dual education and technological entrepreneurship, the creation of modern laboratories, information retrieval systems, interaction with industrial partners of the university, participation in project work, grants, start-ups and venture funds is shown.

Conclusion. The conducted research made obvious the need to develop and implement a new strategy for lifelong engineering education based on transdisciplinarity and integration of engineering, economic, linguistic and IT knowledge.

Keywords: *engineering economics, innovative development, engineering education, knowledge management, university ecosystem, digital tools, transdisciplinarity.*

Introduction. Engineering economics is a field of knowledge emerged at the intersection of natural, technical and economic sciences. It considers engineering capacity to ensure competitiveness of products and services in market conditions by using economic tools. Current tasks in engineering and economics require an individual educational model [1]. To our point of view, the concept of engineering and management dominating in the 19th century and which reached its top point in the beginning of the 20th century, when elements of economic science and management naturally entered engineering tuition (and we will talk about it below) is becoming relevant today again.

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Tasks which contemporary engineering economy is facing today requires from engineers and managers, and they are the major actors in production operation, transdisciplinary knowledge, comprehensive engineering and managerial training, which includes humanities, mathematical and natural sciences. Articulated priorities for the scientific and technological development of Russia set goals of technological renovation of its industry, development of knowledge-based sectors of economy and promote national innovative products to global markets [2]. Problems of engineering education in view of present-day requirements are obvious.

Transition of the economy to a new economic order sets new tasks in training and retraining of present-day engineering personnel [3].

First, it is necessary to know more than one foreign language. Today the English language is a communicator in global knowledge management system. The second foreign language is required as a key element in cross-cultural communication depending on the region selected by business goals. (In Europe - German, French, Spanish, and Italian to your choice; Chinese and Arabic in Asia) [4].

Second, a new type of computer competence for digitalization of production, procurement, sales in new reality of a “smart enterprise”, “smart region”, “smart country” [5]. Now this refers to harmonization of production operation, social infrastructure of all types, and services delivered by the state [6].

Third, the necessity to create a new economic reality creates new occupations like solar panels installer; wind turbine service operator; environmental specialist / scientist; cybersecurity specialist [7].

Fourth, a new model of higher education system is taking place. The development of students’ research work in higher education institutions is having a new type of infrastructure. Laboratories of a new type with levels of access and protection of information and librarian search engines are necessary for the effective participation of students in a new global knowledge system.

Fifth, in this approach tutors-researchers come to the front of the stage. They involve students in their work; invite experts from certain fields of knowledge or research to the university [8].

Sixth, this model of tuition dictates the necessity of facilities for practical training where students could continue work following the results of practice and qualification tests [9]. Here arises duality of training engineers of a new type, possibility of alignment of theoretical background with practical tasks on their future work place.

Seventh, here arise international aspects of engineering training. Globalization naturally brings technology transfer. However, due to the existing system of protection of national intellectual property international research projects are easier to declare than to implement. Even in countries where students go to study and intend to work later.

Therefore, the eighth, there required an up-to-date real time system of authorization of new knowledge, protection of intellectual property in a new environment where school and production enterprise are integrated into one system.

Quality of solving the above tasks will determine the efficiency of the nation transition to a new economy.

Methodology. Methodological base for the analysis of philosophical, historical and economic aspects in engineering education and drawn conclusions served scientific content of sites of Russian and European research and educational institutions where the headlines and content has such terms like engineering and economics, engineering and economic education, transdisciplinarity, continuity, knowledge management and ecosystem of university. We also used as a source of information views of national and international experts in engineering education on the concept of its transdisciplinarity and continuity which are available in cross references system.

Results. To our view transdisciplinarity is one of the important modern trends in engineering education. It is a frequently used term in scientific discourse. Boarder lines separating different fields of knowledge are becoming less tight and more permeable. Flows of information circulating despite rigid disciplinary limits are becoming powerful and acting more and more confidently. Open public discussion of important scientific information is gradually becoming a norm useful for solving vital issues of the society. There is no need today to prove that the world is complicated, multi-dimensional and changeable. It is logical that human consciousness is seeking means to reflect this complexity. Additionally, to the forms of cognition, the necessity to combine meanings located outside fields of specific subjects' is becoming a condition for the development of scientific and practical knowledge.

The concept of transdisciplinarity provides broad opportunities for the interaction of heterogeneous information and knowledge environments for solving integrative problems of Nature and Society. The potential for success of the research visible on meeting edges of different substantialities, reasoned moving beyond strict scientific boundaries, new directions of research that connect previously not intersecting fields of knowledge, real achievements of complex experimental teams - all these come from transdisciplinarity. Good perspectives of this direction of development of science and practical experience are proved by the positive results of breakthrough science and technology teams and can be considered as a competitiveness factor of the engineering economy.

It is impossible today to discuss such categories like “man”, “knowledge”, “consciousness”, “information”, and “communication” within a sole substantive area especially when worldviews combine [10]. Emerging transdisciplinary theories and concepts become a solid foundation for the innovative engineering designs. The fact is that transcendent considering of strictly disciplinary knowledge roots in the very nature of practices, which are conveyed by cultural tradition, and engineering is exactly such kind of practice. Man's capacity for invention and designing is promoted not only by science. Since the earliest times community services is supported by the people's wisdom, religion, philosophy, art, technique equipment, craft and even by “professional magic”. Experience of bright engineering designs in its essence is not limited to the rigid disciplinary boundaries, findings and discoveries occur due to the author's openness to different non-academic means of perception of the world. Examples of successful engineering decisions on complicated tasks implemented in transdisciplinary mode lift many methodological contradictions, which seemed insurmountable before.

We see continuity as another global trend in engineering education [11]. Starting from the 1960s of the 20th century and up today the idea and attempts to create a concept of "continuing education" is the main ideological, organizational and sociocultural concept in many countries. Continuing education emerged to certain extend as an alternative to the existing educational programs subordinate to the industrial tasks and preparing "specific" workers for the vacancies on labour market sees its tasks differently. It must be concerned with the universal education of people. This is the only way to develop individual's natural capabilities and use this limitless potential during all his working life to the benefit of society.

The idea and reasons of this approach are the following. Human being needs continuing realization of individual plans and undertakings, backed up by the required skills and knowledge but not a discreet dividing his life in stages - study, labour self-fulfilment, professional aging. This requires performing unbiased review and re-evaluation of the resources available in the system of education. Education has to be an active non-interrupted process within the whole lifetime of an individual, which means that it cannot be enchained and split by periodization. Knowledge is valuable if obtained in appropriate mode and in good moment, but not when released to be learnt in frame of certain period of life. This perception of the value of education calls for integrated social, political, economic and individual aspects.

French researcher Paul Lengrand attempted to formulate conceptually the idea of continuing lifelong education at UNESCO Forum in 1965 and summarized it in the book "Introduction a l'education permanente" [12]. The world is one whole thing and all its elements are interrelated and interdependent. Human being empowered with the reason, values, strivings and interests is the centre of all world processes. The world is becoming more and more complicated since human being is not only effected by society and nature but is an active subject himself. Human capacity to make quality decisions that are adequate to challenges of time requires new contents and respective means of cognition and hence a consistent review of goals, techniques and technologies of education and tuition. In the middle of the 90s there was published a book "Areas of Learning Basic to Lifelong Education" edited by Paul Lengrand. In this book, the authors sum up achievements of established models of engineering, economical and managerial education in Europe after the 50s of the 20th century and discuss possibilities of integration of different sciences for lifelong education. In this view a human being is seen as the main object of education and the goal is evolving capacities for self-realization interesting for him and useful for the society

Discussion. We see it appropriate to discuss philosophical and historical foundations of engineering education. Logic of contemporary life patterns leaves the question of concordance between what and how is implemented in educational institutions and what and in which way is going on outside them (while formal, non-formal and informal subsystems constitute continuing engineering and managerial education) is open today but it is not new.

The idea of constant enrichment of inner world is expressed in the texts of great philosophers. In their works on the problems of cognition, they talk about tireless perfection of man. These texts prove that the idea of continuing education did not emerge in present-day technological and managerial universities. The idea of life-long education is the result of continuing in time polylogue between heterogeneous cultures and manifested in specific educational systems. The ideal originated in antiquity presents an individual who improves his intellectual, physical, emotional well-being by means of education. Learning is a vital necessity for human spirit in the same way as food for the body.

Sense that the idea of continuity and wholeness of education is not new comes not only after reading ancient philosophical texts. Humanitarian views of Enlightenment philosophers probably express the idea of continuing engineering education in a clearer way. Philosophers and educators see the possibility of improvement of man and society through the development of sciences. This logic looks like this: there should be an expansion of knowledge; purposeful education of man who can handle the deficiencies of the society; it is necessary to change social reality in the interest of progress and improvement of civil society; and this is only possible by pursuing knowledge, natural history, humanist ideals, the possibility to fulfil and manage the proposed changes.

Jan Amos Komenský the great Czech reformer said that that the only true meaning in life is to set and achieve goals of cognition [13]. Any age suits to open yourself to the new. These views of the genius innovator on continuing education formed the basis of a respective educational concept, which turned into a class-and-lesson conveyor – a powerful didactic machine incomparable by its influence on minds to any later ones.

We can find a fore type of lifelong education in the works of Marie Jean Antoine Nicolas de Caritat, marquis de Condorcet - a philosopher and political figure in the period of French Revolution of 1789. In his programme of public education, described in the work “Sketch for a Historical Picture of the Progress of the Human Mind” [14], he puts forward the principle of universality that is of total education in different directions of all without any exceptions citizens. Such inclusiveness shall guarantee people the ability to maintain old knowledge and skills at suitable for their occupational activity level and acquire new knowledge and a confident look in future for their self-realization in the changing world.

To develop in future reformer a comprehensive picture of the world European tradition of training an engineer in 19th – beginning 20th century combined two approaches - scientific, technological and moral. The word “engineer” roots back to Latin "ingenium" (specifically in Petronius and Cicero works) and indicated first of all a bright mind, talent, broad outlook and not only the capability to devise and invent. Philosophy from Herder to Schleiermacher and Hegel saw "Wissenschaftliche Bildung" (academic learning) as a combination of scientific, musical, mathematical and engineering education. To the understanding of German classical philosophers, a universal, well-educated and industrious engineer is the man who is building his personality and carrying on a celestial process of Creation in history and culture. Gymnasiums and universities in Germany is quite an earthbound and a concrete implementation of the elevated idea of preparation of Maker, designer, a reformer of life and practice. "Educational province" by Johann Wolfgang von Goethe (as a relatively enclosed system, implementing humanistic model of raising and educating young people) became a prototype of Castalia – an unreal country emerged in a few centuries after the age of "epoch of feuilletons" in industrialized Europe. For Hermann Hesse in his famous "Das Glasperlenspiel" (The Glass Bead Game) Castalia is a locality isolated from the rest of the world where intellectuals received moral education and a lifelong tuition.

In the 18th century, Mikhail Vasilievitch Lomonosov promoted engineering by his scientific activities, educational views and his life itself given up to science and development of education in Russia. He strongly advocated the democratization including engineering education; he considered it important to advance engineering knowledge by lectures, published materials, libraries and museums. In this period, scientific method becomes the main in higher education. The main objective of "people's school" in addition to cultivating in children love for work, teaching them proper rules of behaviour, becomes setting out the ideas about the world order and causal relations between its phenomena.

The core of Russian engineering school of 18-19 century was a profound mathematical and scientific education with a considerable humanitarian component. Graduates of higher technical institutions received deep scientific knowledge, were knowledgeable, excellently knew philosophy, world history, literature, theology, foreign languages, played musical instruments, and drew. The base part of professional competences of a civil engineer in Russia of the beginning of 20th century consisted of technical and artistic disciplines. It should be noted that Russia was not the only country in this approach: engineering activity in France and Germany was thought of and implemented at the intersection of innovative research and technological practice. Here lies the distinction from the English approach strictly focused on practical training of technicians and artisans.

Before the First World War a future engineer was not guided just to the invention but to a comprehensive realization and a completion of the project (building, ship, bridge, engine etc.). Based on the materials of the design, organization of introduction of innovation students prepared study guides and circulated useful experience [15]. Universities fostered in their graduates sense of everyday diligent work and the desire of a constant increase of its effectiveness. It may look strange today but engineer's work was not only to invent but also to generate more economical technologies and decisions; to design while making the product cheaper, improve productivity. Moreover, an engineer did this in a strong alliance with an entrepreneur [16]. This productive cooperation of an engineer and a business person also fell apart together with the well-developed industry of pre-revolutionary Russia.

It is very important to note that higher engineering institutions in Russia trained not just good technicians, but were consistently preparing their graduates for the career of captains of industry, for military or government career, for serving Tsar and Fatherland. D.I Mendeleev, V.N. Ipatyev, V.G. Shukhov, A.N. Krylov, N.A. Vyshnegradsky are bright researchers-engineers, leaders of industry and education and were outstanding statesmen [17]. It is astonishing to see reading works of old school engineers how elaborate they were selecting partners, sources of financing, locations, materials, environment, safety modes in operations, costs controls, organization of transportation, personnel management on locations at construction of architectural installations. Such concentration on details, precision in calculations is easy to understand: it was a direct, first-hand conveyance of non-formal knowledge thanks to the family, dynastic tradition of education; and in addition technical curricula of engineering universities included compulsory social disciplines. It was mandatory for the lead engineering universities to have social psychology departments. Alternatively, there were engineering departments in big commercial institutes in large cities.

Economic development of Russia and the events of the 20th century amassed engineering education on the one hand and destroyed it integrity on the other. It should be noted that in the West there was also a visible movement from universality towards speciality, the development of high technologies was going in large corporations; occupation of engineer-researcher was becoming widespread [18].

USSR rejection of market based commercial production, development of sophisticated, knowledge- intensive technologies only in large state enterprises (heavy, chemical industry, military space sector) resulted in deterioration of engineer's economic and managerial proficiency.

An engineer with a core technical education could hardly count on a position of the manager of a large enterprise – controls there were handed over to the "party leaders", "academic scientists", "experienced managers". General Designers grown in old school also became directors. Old school should be commended: most of the managers of design offices were thinking on a big scale, could see things as a complete whole, understood strategic goals and could manage personnel and scientific research in high-technology enterprises.

Of course, in young big soviet country there should be a genuine training centre of professional managers. Moscow Commercial-Economic Practical Institute (State University of Management today) – is in fact the first higher engineering–economic institute. Alexander Commercial School of Moscow Stock Exchange Society founded in 1885, Nikolay Female Commercial School and Trade School after the emperor

Nikolay II name united in 1918 in Moscow Commercial–Economic Practical College. In 1919, it was renamed in institute. For hundred years this higher institution prepared tens of thousands of managers for key sectors of the national industry. But they were trained specifically for the key sectors and unfortunately with the rapid decline in quality of teaching engineering disciplines.

The research process natural for the traditional higher engineering and managerial institutions was redirected into research institutes and design offices (once again per sector principle and for mostly military tasks). Negative consequences of such transformation of the 20s became visible in fifty years after that. And today return of research in school and university as the main type of their activity is restrained by the fact that institutional framework of current research and development works is concentrated in network communication space between professionals from different fields of knowledge [19]. Current research more and more often is carried out by small breakthrough aimed teams, supported by a large database with the developing possibilities of their aggregation [20].

Conclusion. Industrial revolution brings new requirements to human capital and thus to the educational system too. The necessity of continuing retraining of personnel and first of all engineers caused the emergence of corporate educational systems all around the world. The brightest example in Russia is probably the Academy of the state corporation Rosatom. This educational institution is training 3600 reserve personnel without discontinuing their main professional activity and has 900 tutors, 13 of whom are from Top-30 management.

Further, we will see the development of a fusion of formal, non-formal and informal types of education, which will support a dynamic model of competences generated to technological and social requirements that has a long built constant as a base and a flexible, easily renewed variable component. Educational path of a future engineer is a good quality comprehensive engineering-managerial education and a methodical upgrade of his skills with additional professional education.

Diploma, which conforms to this model, will also be of dynamic nature and will consist of the base part and a modular tuned for the specific tasks of operation, reflecting soft and hard skills of its holder [21].

As for the educational activity of higher engineering institutions it is very important in our view to develop their business ecosystem where students and tutors temporally brought together by the course named “engineering enterprise” would contact parties in engineering and business sector of the economy, officials assigned responsible for the technological development of a city, region and the country. Such multi-sided format will allow to naturally select the best engineering projects, optimize engineering decisions, promote them in professional society and media, establish socially beneficial contacts, set up work groups and breakthrough teams and develop a culture of engineering business. The current strategy of technological development of Russia formulates a new strategy of continuing education.

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ИНЖЕНЕРНАЯ ЭКОНОМИКА И ТЕХНОЛОГИЧЕСКОЕ ОБРАЗОВАНИЕ: ТРАНСДИСЦИПЛИНАРНЫЙ ПОДХОД В ПОДГОТОВКЕ СОВРЕМЕННЫХ ИНЖЕНЕРОВ

Ускорение научно-технического прогресса диктует новые подходы к подготовке и переподготовке специалистов для реального сектора экономики и в первую очередь элиты – инженерных кадров. Развитие импортозамещающих производств предъявляет новые требования к качеству образования современных инженеров. Перед отечественными инженерами стоит задача не только обновления технопарка, но и поиска новых рынков для реализации современной наукоемкой продукции. Цель исследования – через осмысление культурных традиций, философско-исторических основ подготовки инженеров понять проблемы и перспективы технологического образования.

Методологической основой для анализа философских, исторических, экономических аспектов инженерного образования и изложенных выводов стал научный контент официальных сайтов исследовательских и образовательных учреждений Европы и России, в названии и в содержании которых имеются термины «инженерная экономика», «инженерно-экономическое образование», «трансдисциплинарность», «непрерывность», «управление знаниями», «экосистема вуза», а также материалы авторского исследования.

Выявлены проблемы и возможности модернизации инженерного образования на основе интеграции высококлассных технических специалистов в действующую систему управления знаниями, накопления, хранения и передачи новых знаний, актуализируемых в качестве интеллектуальной собственности. Показана необходимость использования позитивных сторон дуального образования и технологического предпринимательства, создания современных лабораторий, информационно-поисковых систем, взаимодействия с индустриальными партнерами вуза, участия в проектной работе, в грантах, в стартапах и венчурных фондах.

Проведенное исследование сделало очевидной необходимость разработки и реализации новой стратегии непрерывного инженерного образования на основе трансдисциплинарности и интеграции инженерных, экономических, лингвистических и ИТ-знаний.

Ключевые слова: *инженерная экономика, инновационное развитие, инженерное образование, управление знаниями, университетская экосистема, цифровые инструменты, трансдисциплинарность.*

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