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Engineering Education Development Paths for Innovation-Based Regional Economy

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The article justifies the importance of engineering education development for the innovation-based market economy both on regional scale and for the economic system as a whole. A set of actions for formation of a holistic engineering education environment in regions is systemized, encompassing the practices of Volgograd State Technical University (VSTU).

Key words: universities, engineering education, interaction quality, competency-based approach, development trends, economics.

Besides the phase-out of imports and retrenchment policy (in the face of external sanctions enforcement), the optimization of structure of state budget revenue sources (decrease of the income fraction of oil and gas export), and other, modern development trends of the Russian economy also intend commitment to development and commercialization of innovations as a result of R&D stimulation.

It goes without saying that from the position of national security and particularly economic security of the country, the key role is played by "engineering" (i.e. technical and technological) innovations that are expected to be developed by graduates of technical universities. Therewith, in this particular case we are speaking not only about future professionals of the military-industrial complex, but about other important societal spheres that involve theoretical and applied engineering knowledge, skills and attitudes. Competence-based educational concept is put into practice for successful acquisition of such knowledge, skills and attitudes.

Thus, for instance, the framework of national and economic security of Russia includes not only the issues of developing advanced types of various armaments, but also the issues of industry, production, quality assurance and availability of different types of food supplies and other fast moving consumer goods, quality and availability of medical and educational services, peacekeeping issues and many others. Nowadays, it is hard to imagine these and other societal spheres without scientific, technical and technological inventions, which, in their turn, arise from engineering activity and directly depend on the quality of engineers' mastership of soft and professional competences.

The importance of improving quality of engineering education for the economy of a country and assurance of its economic security, competitiveness, and focus on innovation development has been brought up repeatedly by modern practitioners and theoreticians of all the technical, financial, economic and socio-managerial scientific areas; by governmental officials from different branches and tiers of authority; as well as by representatives of various relevant associations and unions:

For instance, when bringing to light the practices of industrialized and economically developed countries, Pirumov A.R. argues in detail that "engineering is the basis of innovative economy". In leading European countries training of young highly qualified professionals for high-tech industries is set as a key objective for the nearest future…" [1].

Akatiev V.A. and Volkova L.V. state that "nowadays, in the context of sanctions

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concerning the embargo on high-tech equipment imports to Russia, there came an understanding that economic independence of Russia is tightly bound with a need to improve level of engineering education and technological reformations in Russia" [2].

Representatives of the Association for Engineering Education of Russia (abb. AEER), when specifying its mission for the forum of "New talents for Military-industrial Complex" program (2015), relied on thesis that "engineering education belongs to the nationwide strategic interests of the Russian Federation, and in the context of country's shift towards Sustainable Development engineers become key figures of the socio-economic sphere of the society" [3].

When speaking of the highest level of acknowledging the importance of engineering education for modern economy of Russia, it is worth mentioning the Meeting of the Presidential Council for Science and Education that took place on June 23, 2014 in Kremlin. It was then that Vladimir Putin, who chaired the Council, emphasized that in modern society "…the leaders of the global development (incl. economic development – authors note) are those countries that are able to create breakthrough technologies and form their own powerful industrial basis. Quality of engineering specialists becomes one of the key competitive factors of a state and, what is of utmost importance, becomes the basis for its technological, economic independence" [4].

The keynote idea of this Meeting was to find ways and methods to create and develop in the country such system of engineers' training that would to a big extent "…respond to the modern challenges, needs of economy and society, foster solutions of problems confronting today's economy, i.e. increasing competitiveness, technological re-equipment of industry, pivotal rise in labor efficiency…" [4].

Correspondingly, Rudskoi A.I., rector of Peter the Great Saint-Petersburg Polytechnic University, drew attention to the fact that "a need for improvement of engineering education is determined by the challenge of assuring global competitiveness of domestic products, and only then by the need for a quick phase-out of foreign products…" [4].

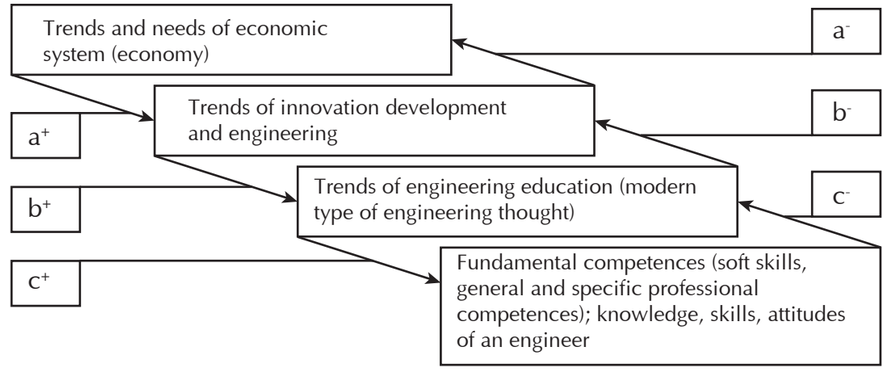
Thus, assurance and improvement of quality of engineers' training on a country scale ensures progressive development of its economy. Relatedly, as seen from the previous statements, it is impossible to assert univocally that this relation only has a one-side cause-effect root. These are not only the achievements of engineering thought, modern developments and intellectual 'products' of science and technology, engineering products that form the innovative economic environment. It is the economy that has to determine and stimulate the development of innovative environment, engineering education, by specifying "demand" for engineers and by creating conditions, prerequisites and incentives for development of engineering; it is the economy that has to be the driver of engineering education. In other words, relation between development of national economy and development of engineering education should be comprehensive, mutual, interconditional and reinforcing. Such cooperation is a close circuit, cyclic and synergetic.

Based on this, the conceptual model for determination of development paths of modern engineering education can be graphically described as follows on the fig. 1.

Besides objective factors, this argument can be supported by an opinion stating that a model of modern-type engineering thought (predetermining engineering), developed within the process of continuous education of future engineers and competence approach to educational process, has to be dynamic and adjustable due to the dynamics and specific needs, conditions of current economic activity.

As noticed by Lysak V.I., Gonik I.L., Fetisov A.V., Yurova O.V., Tekin A.V., "Due to an active and dynamic development

Fig. 1. Model for determining development paths in modern education to create innovative-driven regional economy



of modern technologies, commitment to innovation, acceleration and compression of production cycles, increase of scientific and data capacity of final products, amplification of local and international cooperation connections, a basis for modern-type engineering thought (in fact, modern engineer) is a dynamic, rather than static, economy encompassing a variety of trends and paths for further progressive growth" [5, p. 217].

As seen on fig. 1, the "a", "b" and "c" codes with upper index "+" in the framework of this model mark the quality of interfactor cooperation in an influencing direction "economic trends predetermine set of competences of modern engineers" on corresponding phases (between different stages of engineering education development paths with due regard for formation of innovation-driven economy). Correspondingly, the "a", "b" and "c" codes with upper index "-" determine the quality of cooperation in the context of interfactor connection chain, whose direction can be described as "Engineers' competences, knowledge, skills and attitudes form innovation-driven economic environment" on corresponding phases within preset scale and limited time period.

Comparing with cyclic model and evident synergy effect of engineering education quality improvement as a result of assuring cyclic sustainable cooperation of model factors, it can be argued that:
$a^+ + b^+ + c^+ + a^- + b^- + c^- < Va^+a^- + Vb^+b^- + Vc^+c^-$
Therefore, the following is fair:
$SE = (Va^+a^- + Vb^+b^- + Vc^+c^-) - (a^+ + b^+ + c^+ + a^- + b^- + c^-)$,
where SE – synergy effect of engineering education quality improvement as a result of assuring cyclic sustainable cooperation of model factors determining development paths of modern engineering education with due regard for formation of innovation-driven economy;

Va^+a^- – quality of cyclic cooperation on stage "Trends and needs of economic system" determines "Trends of innovation development and modern engineering" and vice versa;

Vb^+b^- – quality of cyclic cooperation on stage "Trends of innovation development and modern engineering" determines "Trends of engineering education (evolving type of engineering thought)" and vice versa;

Vc^+c^- – quality of cyclic cooperation on stage "Trends of engineering education (evolving type of engineering thought)" determines

"Fundamental competences, knowledge, skills, attitudes of a modern engineer" and vice versa.

At this, quality parameters can differ (can be expressed through various criteria and indicators). It is important to assure uniformity and single direction of such criteria and indicators (they should define cooperation in equal variables, either positively or negatively). The higher the synergy effect of "positive" criteria and indicators, the higher the efficiency of engineering and the quality of provided engineering education for formation of innovation-driven regional economy, the higher the level and quality of fostered competences, and the competitiveness of knowledge, skills and attitudes of a particular engineer.

Similar effect can be seen in the opposite direction of interconnection within the proposed model.

Together with this, such cooperation of factors may have problems; some of them can be expressed as a system of specific restrictions typical not only for each phase of interconnection of the shown stages, but for the whole model as well (Tab. 1)

Based on the materials from Tab. 1, it should be noted that, for instance, macroeconomic factors work both for a whole system and for a particular phase of cooperation quality assurance between stages "Trends and needs of economic system" and "Trends of innovation development and modern engineering", since their negative influence (that lowers the quality of interconnection) shows up in a whole system and, most of all, on a particular stage. It is hard to control such factors even on a national level. They should be taken into account when making decisions on quality assurance of "a^+a^-" factors' interconnection.

Microeconomic factors can be partially compensated through certain economic and other efforts on regional scale; however, not in full.

Regional factors that can be influenced significantly are the most interesting ones in the view of action plan determination for increasing the quality of engineers' education process with due regard for formation of innovation-driven regional economy. It is the compensation of such negative factors restraining engineering education in regions that should be emphasized by all interested parties.

Aiming to minimize and partially compensate negative influence from restrictions typical for the "c^+c^-" interconnection, and based on practices of Volga State Technical University (VSTU), authors propose introduction of the following regional-scale actions on management of technical HEIs, organization of research and educational activities of engineers within educational process, assurance of cross-university cooperation with an aim to develop comprehensive engineering education environment in regions:

1. To develop together with leading technical universities (based on premises of one of them) regional monitoring centers on independent quality assessment of engineering education (anonymous surveys for all key interested parties – enrollees, students, graduates, employers, parents, academic community, professional organizations, etc.). Results of such monitoring and assessment can be a basis for development of employer-sponsored engineering study programs, can be used for conducting self-assessment and for evaluating efficiency, quality of education and, partially, for monitoring of HEIs' efficiency. Also, such independent assessment can become the basis for development of criteria system for creation of new regional and national ratings and rankings of technical HEIs.

It is especially important to use joint advanced developments in assessment and assurance of engineering study programs in real-time mode, when conducting such monitoring. Developments and results of international projects can be used. For instance, the ones of the Tempus EQUASP project ("On-line Quality Assurance of Study Programmes") that joins 12 Russian partners (including VSTU) and 6 international partners [6], or other similar projects.

Software developed and piloted within the identified project, as well as the pilot monitoring of future engineers' quality of education, after all on the final stage of the project will transform into a comprehensive system for monitoring of study programs' quality in partner universities including VSTU (with due regard to monitoring and independent evaluation of quality of education by all interested parties). These materials (questionnaires, software) can be the basis for comprehensive regional quality and efficiency monitoring of study programs, and not just the technical ones.

Table 1. Basic restrictions influencing the quality of modern engineering education with due regard for formation of innovation-driven regional economy.

Phase of interconnection formation	Criteria decrease of interfactor connection quality
"a^+a^-"	Macroeconomic factors. Possible influence on regional level – minimal. Include: - sanctions pressure; - global market, economic, political restrictions; - downsides of market development model for global and national economies, etc.
"b^+b^-"	Microeconomic factors. Possible influence on regional level – midlevel. Include: - limited access to advanced technologies, technical developments; - obsolescence (mainly moral and ecological) of production facilities, loss of engineering knowledge' and skills' topicality; - limited access to investments, assets, etc.
"c^+c^-"	Regional factors. Possible influence on regional level – high. Include: - incompliance of engineering study programs with real demands of employers and regional economy; - lack of free access to best practices on regional scale; - low prestige of engineers, insufficient systems for regional support of talented youth and stimulation (popularization) of engineering, etc.

2. Aiming to develop in regions a competitive education environment for engineers, it is possible to create (based on premises of a technical HEI) regional or international platform for cross-university best practices' exchange, in particular: innovative teaching methods for engineers, complex of means for learning outcomes' evaluation, best practices of technical HEIs' management, etc. Concerning the need to assure commitment to innovations of national and regional economies, cross-university cooperation in young researchers' and students' engineering innovations is also desired.

3. Organization of comprehensive and systematic work with talented

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children (including basic and vocational professional education) and creation of specific conditions for stimulation of their training at regional technical universities aiming to preserve and develop human engineering potential for prioritized sectors of regional economy.

4. Organization of cross-university study courses (also delivered distantly) and internships is essential for development of academic mobility, exploitation of resource potential, development of scientific schools and regional scientific best practices' dissemination. It is also purposeful and essential to organize cross-university management of research and engineering work and projects for Master and PhD levels.

5. It is purposeful to jointly develop comprehensive interdisciplinary cooperation in order to fully foster all the competences relevant to a certain engineering specialty, as well as to foster allied competences, permitting to work successfully in different professional areas (transprofessional engineering education).

6. Due to increasing demands of employers and economy towards engineering graduates, and at the same time taking into account the need to comply with modern requirements towards engineering study programs in terms of formation of students' portfolio, when designing such programs it is important to: develop integrated rules for recognition of all types of prior education that has provided an official diploma, assure possibility to recognize acquired credits and all achievements of a student when designing his university learning path. Consequently, these actions may lead to a simpler implementation and popularization of the continuous education concept.

7. Aiming to improve the quality of education and competitiveness of regional HEIs within the national educational community, it is essential to develop a comprehensive regional program on competency assessment of technical universities' staff. Such programs should encompass not only the requirements for achievement of a certain level of faculty qualification set in line with the professional standards, but also the requirement for further personal and professional development (a list of achievements). Besides, such programs should envisage a certain level of qualification of the support staff and criteria for affirmation of this level (certification, competency assessment). In this case, the program should also include socio-economic disciplines (modules in the context of assuring high competitiveness of regional engineering education and developing regional economy on innovative "engineering" basis).

8. Aiming to preserve and develop human resource and engineering potential of HEI faculty in regions, to overcome a lack of regional human resources, it is necessary to develop (together with technical universities, employers, representatives of regional government) joint regional programs for formation and exploitation of human resource pool.

9. In the framework of technical study programs, it is important to develop a system of tests and competency assessment not just for the curriculum courses, but also the one allowing to evaluate all other (non-professional) competences that are interesting for the employers (a system of communication skills, personal attitudes, application of information and communication technologies, systems thinking, teamwork skills, etc.)

10. Form, on a regional level, an integrated approach to determination of engineers' basic competences (taking into account the opinions of all interested parties); it is essential to provide access to determination of engineers' competences on federal level assuring an opportunity to differentiate the set of competences according to the specifics of regional economy.

Undoubtedly, this set of proposed actions is not fulfilling and can vary according to the core economy focus and innovation potential of particular

regions, the specifics of engineering education environment, the status of core industrial enterprises of a region and its public institutions (main employer, basic institutions, international institutions, etc.) At that, most of actions mentioned above are universal and practice-oriented and can already be recommended for implementation, for instance, in Volgograd region.

Particularly, during his official visit the Governor of the Volgograd region, Bocharov A.I., to Volga State Technical University, has underlined the importance of both engineering education and the need for cooperation between all interested parties for the development of regional economy. Thus, the Governor proposed perspective ideas for founding a nanocenter on the premises of VSTU, productive cooperation between HEIs and schools, development of a flagship university, and others [7]. As noted by RAS correspondent member, rector of VSTU, Lyisak V.I.: "The main aim is to attract [students] to the flagship university, which was the idea for its development, in order to facilitate the role of engineering education, to give it a new impulse…" [8].

Consequently, it should be noted that the pressure of sanctions, the dynamics of economic environment, the technological progress boost, the complication of economic connections, the need to assure economic development based on technological and product innovations in the context of limited financing, and many other aspects will bring up new, more complex and global problems for economists and engineers, will form a new system of restrictions that will allow for higher topicality of scientific and applied research in the framework of optimization of methodological approaches to engineering education management, the management of regional engineering education environment in future for assuring commitment to innovations of the regional economy of certain regions of the country.

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The Level Structure of Creative Class

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The article deals with the description of essential characteristics of creative class developed within technological creativity based on the modern engineering creativity methods – applied dialectics, or the theory of invention problem solution (TIPS). Evaluation criteria of creativity levels are suggested. The ways of increasing students' creativity level in the engineering education are studied.

Key words: creative class, creativity levels, creativity structure, TIPS, applied dialectics, TIPS-pedagogics, knowledge invention, innovative projects, CAI programs.

The term "creative class" was introduced by American economist Richard Florida, the head of "think tank" of "The Richard Florida Creativity Group". His famous book [1] not only reveals the fact of appearance of a new social group having new specific relation to the means of production but also is itself a means of intellectual production in different countries. The book details different social qualities of creative class, its subculture development, aspects of its interaction with the society in general, influence on the society.

R. Florida's investigations are of mostly social-economic, psychological, and philosophical character. In authors' opinion, the most essential idea of the book consists in the necessity of creative class for the modern society as a basis for social and economic advance, the role of creative class as a competitive advantage of those countries and areas where it has been sufficiently developed.

Following R. Florida's book, there was a number of other articles and books to some extent devoted to creative class, for example, [2–4] describing mainly its social-economic aspects. At the same time, though in [1] there is no reference to American philosopher and futurologist Alvin Toffler, the first chapter "Creative epoch" correlates sufficiently with the description of the Third wave in [5].

On the whole, all the mentioned and other works on phenomenon of creative class just state its fact, as the authors are mostly "observers" of its formation and development. A specified and managed character of this process as well as investments to be made is discussed about like a problem to be solved: "…creativity does not appear and exist by itself; it is to be cultivated. If we don't find a reliable technique, someone else will do it" [1, p. 345].

The crucial role of creative class for social-economic development in the modern epoch of global innovative society conditions the importance of its transition process from spontaneous to consciously governing one. In particular, it deals with technological creativity. At the meeting of the Presidential Council for Science and Education of the Russian Federation in Kremlin of 23 June 2014 the rector of Saint-Petersburg State Polytechnic University A.I. Rudskoy noted: «We are to develop engineering training of qualitatively new and complementary types … – so called engineering-technological special forces, I would say, modern, possessing the technologies of international level, … engineers-researchers capable of solving seemingly unsolvable problems and providing innovative breakthroughs in the high-tech industries" [6].

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