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Thought Process of Engineering "Elite Force": Russian Development Technologies

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The paper studies potential of Russian cognitive technologies of creative engineering thinking. The technologies are based on applied dialectics or the Theory of Inventive Problem-Solving (TRIZ) and can be applied in the elite engineering education. The author suggests using tested didactic technologies.

Key words: engineering thinking, convergent technologies, cognitive technologies, TRIZ, applied dialectics, TRIZ-education, knowledge invention, innovative projects, CAI programmes.

The task to create "engineering elite force" was first announced by A.I. Rudskoy, the Rector of Peter the Great St. Petersburg Polytechnic University, at the meeting of the Presidential Council for science and education on June 23 2014[1]. It is a crucial condition to meet prior challenges of scientific and technological development of Russia, to achieve the targets mentioned in [2]. There are a number of papers, including those issued in "Engineering education" journal devoted to this topic [3]. They underline the necessity of "jumping over some steps" to the sixth technological mode, convergent technology acquisition, interdisciplinary approach to education and science development. The authors [3] consider it very important to train specialists who would ensure such rapid progress by means of "new knowledge and cutting-edge technologies, which are currently unknown". Project-based learning and interdisciplinary approach are regarded as the way to keep up with rapidly advancing technologies, which change faster than contents of engineering degree courses.

Any goal to be achieved needs a complex set of tools. The paper reviews the capacity of the tools invented in Russia, though now being more effectively applied in other countries. These tools are of project-oriented, convergent, and interdisciplinary nature, which provides "jump over some steps" both in technology and engineering education.

First of all, it should be noted that the idea of engineering "elite force" complies significantly with the idea of innovative person, which has been often suggested recently [4]. The term "innovative person" was used in the Development strategy for science and education in the Russian Federation applicable till 2015. In particular, it is introduced in the description of approach № 5 "Knowledge-active": "...the aim is to create an "innovative person", who adheres to innovations and new knowledge regardless his/her workplace and activity area – industry, research and science, public administration, and etc.".

Part V of the Strategy project "Innovative Russia – 2020" was devoted to this notion. It says that "innovative skills development is as important as the sum of all the other tasks of the Strategy". The approved Strategy [5], however, does not contain the term "innovative person". The parts of the project related to the development of innovative person are included in Part V "Development of competencies for innovative activity". The creators of the Strategy may have considered that the development of these features will not have resulted in "innovative person" by 2020. It might be the reason for only partial development of tools to get this target.

All mentioned above makes it obvious that it is high time to develop these tools. Considering possible means, it should be noted that the tendency to innovation and new knowledge has at least two aspects. The first one is the wish and readiness to constantly perceive new knowledge and cutting-edge ideas and put them into practice. This aspect refers to "linear" engineers. In [5] it is defined as "the ability and readiness to continuous education, learning, self-development, professional development and occupational mobility, in other words, neophilia". This aspect mostly refers to engineering designers involved in development of standard projects for different technical devices and systems that differ from those designed before only in numerical parameters. The second aspect, which is becoming more and more important in innovative economy, is the wish and stable ability to solve problems in the area of technological development, to generate innovative ideas, "know-how", inventions, that is all these things that are to be perceived and acquired by the "linear" engineers. It is defined in [5] as follows: "critical thinking ability; creativity". It is obvious that an engineer of "elite force" should belong to the innovative group of the second aspect.

While analyzing the existing tools to form the qualities of an innovative person, it proves that it is a complex of tools relating to the first aspect that is now being developed in Russia. These are business accelerators, business incubators, startup incubators, technoparks, etc., including those for students and even for pre-university students. All these facilities are provided to accelerate implementation of the innovative ideas that already exist. It is thought that there are so many innovative ideas in Russia that it is impossible to implement all of them. However, we more often face the lack of constructive ideas, especially in student business incubators [6]. In all the organizations mentioned above, those who generate the innovative ideas are proposed to implement them as well, though the combination of both these activities does not always fit the psychological features of one person.

Thus, "to jump over some steps" it becomes necessary to intensify the generation of innovative ideas. Until now there has been applied only one tool to stimulate the generation of ideas, it is competitions of innovations. It is important to develop and implement instrumental methods for generating innovative ideas and to train future "engineering elite force" to apply these methods.

As it is stated in [7], other countries have the same goals; however, Russia should "jump over some steps to reach the level of these countries. Their experience shows that, first, the methods mentioned above do exist and have been developing since the ancient times. Second, it is in Russia, where the most effective methodology has been developed. It is applied dialectics or Theory of inventive problem solving (TRIZ) [8, 9], that is being more and more actively used by leading international corporations. For example, in Samsung Corporation, it is considered a good practice for an engineer to be certified by International TRIZ Association – MATRIZ [10]. To meet the education demand TRIZ course is provided in leading international universities, including the "TOP-100" universities. The authors of [7] studied the application of this methodology to form a creative class and provided its classification according to creativity level. The engineering "elite force", which definitely belongs to the creative class, take the 3rd or 4th creativity levels. They also described an innovative education system of new generation, TRIZ-pedagogics, which has a competitive advantage and meet the requirements [5] for innovative education programmes. The paper studies the potential of the system in terms of development of engineering thinking and other features of engineering "elite force".

Under present conditions of transition to innovative society and sixth technological mode, it is reasonable to classify engineering thinking in two levels [11]:

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1st level: standard design of constructions similar to the existing constructions.

2nd level: innovative design of fundamentally new constructions. It is the level of engineering "elite force".

In its turn, the second level can be subdivided into the following sub-levels:

1. New ideas are found by the traditional "trial and error" method (TEM), which could be effective with several gifted and talented people. The number of such people is small. The lack of intellectually talented people in conditions of innovative society resulted in such activity as headhunting. Some philosophers and sociologists describe the innovative activity based on headhunting as "the Intellectual Paleolithic age", similar to the Paleolithic age – the age of hunter-gatherers, the difference being that now they are "hunting for heads" and "gathering ideas".

2. New ideas are found by purposeless methods ("divergent thinking" method of focal objects, morphological analysis, "brain storm", etc.). Similar to the previous comparison, this method can be defined as the "Intellectual Mesolithic age".

3. New ideas are found by goal-oriented methods (the combination of divergent and convergent thinking). TRIZ and applied dialectics, which refers to non-anthropogenic systems, contain these methods. This situation then can be defined as the "Intellectual Neolithic age".

The transition from the Paleolithic to the Neolithic age, from hunter-gathering to agriculture and cattle-raising finished about 10 thousand years ago. Alvin Toffler regards this transition as the beginning of the First Wave of the civilization [12]. According to A. Toffler, the present days are the time of the third wave based on intellectual product. However, the transition from "the Intellectual Paleolithic age" to the "Intellectual Neolithic age are so similar to those that took place 10 thousand years ago, that it makes sense to discuss the assumption about the Forth wave. According to A. Toffler, the Fourth wave should start with the outer space exploration. There is no doubt that it will be a new wave, but it may be the fifth one.

When comparing all mentioned above with the widely used term "intellectual thinking" (for example, in [13] it is defined as "thinking aimed at ensuring innovative activity, it is realized at cognitive and instrumental levels and characterized as creative, socially positive, constructive, transforming and practical"), it can be concluded that the second level of engineering thinking is an essential part of the innovative thinking.

At the same time, the thought process based on goal-oriented methods can be regarded as innovative thinking as well. It is explained by two reasons. The first is that this way of thinking is scientific and technical and is based on fundamental dialectical laws of development both of anthropogenic and non-anthropogenic systems. It is based on the principle that any productive idea is the idea of anthropogenic system development according to laws of dialectics and applied dialectics. The second is that a systemic dialectical world concept is a socially positive concept that regards the world as a complex of systems developing in accordance with some laws that can be discovered and applied to create more perfect systems. Such a worldview can be defined as innovative [14].

The engineering "elite force" training based on goal-oriented methods allows developing convergent technologies by integrating sientific achievements from different field of knowledge. "The big Four technologies" are considered to be convergent technologies that include the information and communication technology (ICT), biotechnology, nanotechnology, and cognitive technology. TRIZ itself and TRIZ-pedagogics are cognitive technologies, since they develop thought process and imagination of a person. The engineering "elite force" can apply conceptually new class of CAI programmes that facilitate generation of new innovative ideas based on TRIZ that needs to be implemented in innovative

sphere of Russia. The applied dialectics allows intensifying the interaction between cognitive and bio-technologies. In addition to classical bionics that uses principles of living organisms in technical structures and devices, applied dialectics allows studying natural mechanism of invention by observing the living nature evolution and designing fundamentally new biotechnical systems and biotechnologies. TRIZ has been successfully applied in molecular structure design, which shows promise of TRIZ application in nanotechnologies.

The training is interdisciplinary, since the basic TRIZ principle is its multidisciplinary application in problem-solving and idea generation. To ensure this principle, databases of physical, chemical, geometrical and other effects have been created. Biological, psychological and other databases are being in development stage.

According to the 5-level invention scale by G. Artshuler, the solutions based on interdisciplinary approach refer to the highest levels. Thus, the engineering "elite force" training should be interdisciplinary and project-based, with students of different specialties working together on a project for a company under the supervision of faculty members, which facilitates further employment of the graduates by the company. As a rule, Master's degree programmes are thought to be the most efficient for project-based learning. CDIO (Conceive – Design – Implement – Operate) system introduction allows starting to implement this method in Bachelor's degree programmes. However, the weakest chain of CDIO is the first stage – Conceive. The goal-oriented training together with TRIZ-pedagogics, method of knowledge invention and innovative projects [16, 17], allow creating constructive solutions at the "Conceive" stage, which contributes to the success of further training. Thus, it becomes possible to pass the "Conceive" and "Design" stages and to enter the "Implement" stage at the level of Bachelor's degree programme, while Master's degree programme can be focused on development and perfection of the "Implement" stage, application of virtual settings, Product Life Management (PLM) system, and simulation of the "Operate" stage.

Actually, it means transition from project-based to innovative project learning, which upgrades the model of project-based University [18] to the model of innovative project University.

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Project of Innovative Engineering Education

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The paper provides the analysis of engineering education and proves the necessity to develop an innovative engineering education programme. Basic principles of the innovative education programme as well as qualifications of engineering Bachelor degree programmes are suggested. Education modules of the suggested programme are described.

Key words: innovative education programme, fundamentality, automated systems, mechanics.

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Reform of higher education system is continuing, although reversal of the education itself is absent. The development trends of engineering education remain the same, and, in most cases, the existing transfer from 5-year to 4-year education system reveals the fact that the professional content of most education programmemes remain practically unchanged. To implement the principle of continuing education, to integrate and apply the diversity of education programmemes, and to enhance further qualification of engineer-graduates (receiving a Master degree), a new schematic model of developing innovative education programmes has been proposed comparable to the existing programmes. An overview and brief justification including the basic principles of such programmes are being discussed further.

The market expectations of the engineering workforce within Russia revealed the fact that Russia is lagging behind the leading countries within engineering and technology domain [1]. One can observe such a factor as noncompetitive low-quality and expensive product output governed by low efficiency and weak performance (production rate). In Russia today the existing labor market requires no highly-qualified graduates due to the orientation towards resource economy. At the present moment there is a market flooding of low-demand specialists, including engineers. One of the major drawbacks of this situation is the unbalance between higher engineering education content and modern society economic development goals.

The economic development of any country is directly interlinked with the technological infrastructure and automation of present-day production, application and implementation of innovative and energy-efficient technology At this stage the development trend of global economics is determined by advancing high-quality production, promoting knowledge-intensive industry, updating materials, technology and techniques, and developing conceptually new industry sectors.

The infrastructure of any production involving technology and sophisticated techniques is impossible without qualified engineering and technical HR (human resources). The utmost task of professional education is the personnel training, oriented on the needs and demands of developing production and society. The technological modernization of economy and industry is marked by the demand for new generation engineers. Today's knowledge-intensive production requires such specialists that could develop and implement conceptually new engineering and technological approaches based on the