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Forming Competences for Generating New Ideas – Basis of Complex Engineering Education

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The paper examines the structure of modern knowledge, abilities and skills required for generating new ideas. Based on up-to-date approaches, didactic and information technologies have been proposed.

Key words: *ideas generating, competence, complex preparation, TRIZ, knowledge invention, innovative projects, CAI programs.*

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During the progress of engineering education in many world's leading countries, development of problem-based learning (PBL) and project-based learning, as well as other instructional strategies, attention is being increasingly focused on generating innovative ideas. Training creative engineers capable of generating new concepts is the imperative of our time – time of transition to the strategy of innovative development. The worldwide CDIO initiative (Conceive – Design – Implement – Operate), a new approach in engineering education, originally developed at Massachusetts Institute of Technology and actively supported by many leading universities, starts with the "Conceive" stage.
In the United States, STEM education (Science, Technology, Engineering, and Mathematics) is being currently turning into STEAM education [1]. A new letter "A" stands for "Arts". It is considered that the arts nurture a creative ability of future engineers to identify and view problems from different perspectives. Those universities which are proved to be «progressive» in this view are actively trying to introduce state-of-the-art Theory of Inventive Problem Solving (TRIZ), originally conceived by Russian scientists G.S. Altshuller and further developed by his followers all over the world [2], instead of simple teaching methods such as "brainstorm", morphological analysis, method of focal objects, syntectics and etc., which are aimed only at developing divergent thinking or some of its elements.

The above-mentioned trends are important to consider when modernizing Russian education system because of the following reasons:

- in accordance with the strategy "Innovative Russia – 2020", creativity is included into the list of competences required for innovative activity, which are developed within the education framework through "modern learning methods and techniques aimed at formation and continuous development of creative thinking skills, motivation, abilities to reveal and formulate problems, as well as to create new concepts that can contribute to problem solving";

- the List of Critical Technologies of the Russian Federation embraces cognitive technologies, i.e. information technologies which are specifically designed to develop intellectual abilities of humans;
- TRIZ originally conceived in the USSR is proved to be one of the most effective theories in the world which is aimed at generating innovative ideas. Most Russian people who share the ideas of this theory grew up in modern Russia and deliver idea generation courses at leading foreign universities.

Deficiencies in forming and developing engineering students' creativity and innovation skills directly influence technological capabilities at the country level: Russia owns 0,4% of worldwide patent applications filed for new inventions (USA – 30%, Japan – 20%, Germany – 10%) [3].

When developing creative thinking skills in engineering students, it is essential to consider that innovation skills and high creativity is a combination of creative, transformational and systems thinking activity which should be based on the peculiarities of interdisciplinary knowledge [4].

The ability to create new ideas is highlighted as an essential characteristic of human activity in terms of sustainable innovation development framework when civilization turns to the fifth and sixth innovation waves.

Developing creativity skills in students is determined by a number of factors:

- innate personal characteristics;
- quality of pre-university education;
- the Mission of the University;
- faculty knowledge and experience in teaching creative skills;
- teaching model (individual learning path, learning in project-based teams);
- launching Elite Education Programs;
- curriculum content;
- teaching tools and techniques;
- adequacy of facilities and computing resources, access to domestic and foreign educational and information resources;
- availability of modeling equipment and systems including simulation software CAI;
- integration level of educational, scientific and engineering activities;
- faculty and student motivation;
- need for innovation in industry, business, and education system.

There are many different techniques which help to generate new ideas. They can be divided into two groups:

1. "Purposeless Search" techniques, historically first to appear, are intended to stimulate human divergent thinking activity, i.e. an unusual and unstereotyped way of thinking. They, for example, include morphological analysis, "brainstorming", method of focal objects (MFO), lateral thinking, "Six Thinking Hats" and etc. [2]. Unlike traditional trial-and-error techniques, these techniques significantly increase the speed of idea generation. However, they can hardly increase the number of ideas effective for solving problems.
2. "Target Search" techniques which are aimed at stimulating not only divergent, but also convergent thinking, i.e. generation of productive ideas effective for solving problems. Synectics has some features in common with target-search techniques, while TRIZ, a theory of inventive problem solving, fully coincides with them [2].

The main postulates of TRIZ can be briefly summarized as follows:

1. Any problem solution is a result of the development of a system. (For example, the invention of the automobile triggered the develop-

ment of "transport" system, the invention of radio – "communication" system, and etc.).
2. In terms of dialectics development results from the struggle of opposites.
3. To solve the problem it is necessary to reveal the contradictions within it and overcome them.

The definite tools (principles, rules, methods, standards, algorithms) to eliminate contradictions derived from the problem have been developed based upon the research and analysis of patents.

Essentially, TRIZ is a philosophy which is not accidently termed as «applied dialectics». According to the recent trends, the meaning of «applied dialectics» has been broadened, implying both non-anthropogenic and social systems. It has been proved that typical models to overcome the contradictions derived from the process itself coincide with TRIZ principles, rules, and standards applied to anthropogenic systems [5]. It allows engineering graduates to «learn from the nature» while acquiring knowledge within Basic Sciences study area.

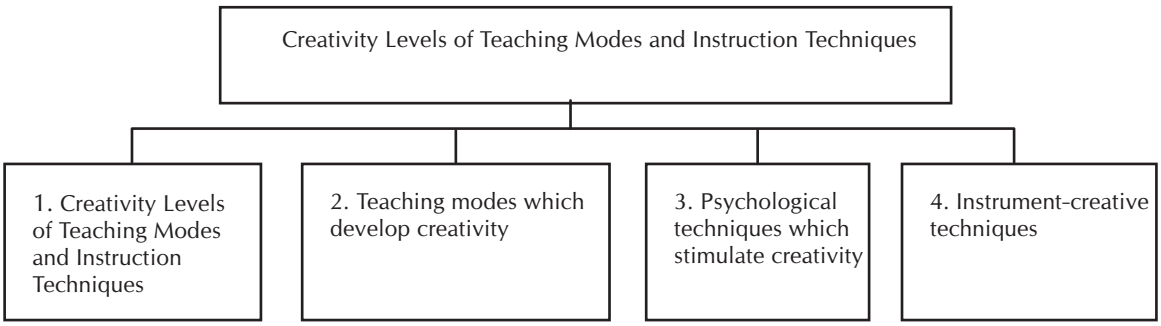
The comparison of different teaching modes and instruction techniques allows us to classify them based on the level of creativity (Fig. 1) [6]. Traditional lecture-seminar teaching mode corresponds to the 1st level, with best examples of innovative teaching being at the 2nd and 3rd levels. Problem-based learning which is being actively introduced at foreign universities can be referred to the 2nd and 3rd levels, as well. "Purposeless Search" techniques can be applied at the first three levels. Innovative education system TRIZ-pedagogics [7] corresponds to the 4th level and allows integrating TRIZ principles into other disciplines, design activity and scientific work. As a part of TRIZ-pedagogics there was a method of creative tasks which could be solved applying not only definite knowledge, but TRIZ principles, as well.

Siberian Federal University is actively involved in the development of innovative education system "TRIZ-pedagogics". It offers such courses as "Principles of Scientific Research", "Fundamentals of Technical Creativity", "Innovation Studies" and etc., which outline the methods that help to be effective at problem-solving, include the exercises aimed at developing creative skills and provide recommendations on filing patent application. The experts from UNESCO Centre "New Materials and Technology" have been working on knowledge invention method and the method of innovative projects since 2000 [8]. Due to their hard work, "TRIZ-pedagogics" is gradually becoming an educational system which can be applied at different stages of education process.

The method of knowledge invention allows incorporating innovative ideas into a body of existing knowledge, which in its turn develops corresponding skills and abilities in class and presents new material in terms of practice and experience. This method fully explains and confirms the idea of many scientists and educators who insist on the necessity of turning from traditional learning to "active knowledge acquisition". Evolution of any system studied within any education program is regarded as a result of solving contradictions in the system-predecessor, which create barriers for further evolution. It is this result that is "reinvented" by students by using TRIZ methodology, principles and standards.

The method of innovative projects is a combination of problem-based learning and project-based learning with TRIZ methodology. Problem-based learning stimulates student's interest in curricular subject matter, deepens their understanding of the material. However, students being only psychologically motivated to take charge of problem solving are not provided with the corresponding cognitive "instruments". Therefore, educators often have to give their students ready solutions. For the

Fig. 1. Teaching Mode Classification Based on Creativity Levels



same reason, the projects which are created within project-based learning are not often innovative. TRIZ significantly improves a student's ability to solve problems given by a teacher and contributes to developing the projects which are really aimed at solving serious engineering problems.

Information technologies play a significant role in training creative engineers. It is a world-wide trend to apply product lifecycle management (PLM) to design and production of high technology products based on the information technologies. The main components of PLM are as follows: product data management (PDM), collaborative product development (CPD), computer-assisted design (CAD), computer-aided engineering (CAE), manufacturing process management (MPM). Modern CAD-systems are based on the technologies of parametric design, i.e. optimal choice of numerical parameters of an item without changing its structure and operation mode. Innovations, as a rule, involve the development of a radically new structure. Therefore, it is essential to combine PLM standards with new-class programs – CAI (Computer Aided Invention) – which are becoming increasingly common.

There are CAI programs which are based on the methods of possibility enumeration, for example "Brainstormer" that features brainstorming process. "Invention Machine", the first CAI program, was developed by a group of specialists from different republics of the Soviet Union in accordance with the TRIZ principles. During the period of socio-economic restructuring («perestroika»), when there was a significant decline in demand for any type of inventions, most of these specialists went abroad, specifically to the United States and established Invention Machine Corporation Company. The company produced new English versions of Invention Machine with the significant financial support of such companies as Motorola, Intel and etc. Other companies which were also established by soviet specialists designed such programs as "Tri-Solver" and "Innovation Work Bench". Today, Invention Machine Corporation offers "Tech Optimizer" and "Goldfire Innovator", an optimal decision engine. These programs are in great demand among transnational corporations and universities which train specialists for such corporations. It is obvious that knowledge of PLM standards and CAI software is essential for student future professional career.

The algorithm of forming the structure of modern knowledge and abilities required to develop corresponding skills for generating and implementing new ideas is presented in Fig. 2. All three types of thinking (Fig. 2) comprise innovative thinking.

However, all above-mentioned components can be affective at developing creative thinking skills only in a case of interconnection between them. Even fundamental courses which are delivered during the first years of education should be based on the method of knowledge invention and principles of applied dialectics. To make this process even more effective, it is better to apply these methods for pre-university education. Besides, it is important not only to reveal the existing demand for inventions, but also to influence the demand itself. Practical skills are developed in class alongside the acquisition of corresponding information technologies when the existing body of knowledge is «reinvented» for further application in scientific work and project activity.

An engineer capable of generating and implementing new ideas is a key figure of innovation-driven economy. Russian system of engineering education has an important competitive advantage over corresponding foreign systems as it has significant resource for further improvement – refining the methodology for developing idea-generation skills. The serious task to solve is to apply this resource effectively.

Fig. 2. Algorithm of Competence Formation Required for New Idea Generation and Implementation

REFERENCES

1. Frolov, A.V. Reform of US Innovative System. The Turn from STEM to STEAM-education [Electronic resource] // Alma Mater—Vestnik Vysshey Shkoly (High School Herald): offic. site. – M., 2008–2013. – URL: http://www.almavest.ru/ru/favorite/2013/05/14/384, free. – Tit. from the screen (usage date 19.12.2013).
2. Altshuller, G.S. To Find and Idea: Introduction to the Theory of Inventive Problem / G.S. Altshuller. – 3rd edition. – Petrozavodsk, 2003. – 240 p.
3. Chuchalin, A.I. Economy Modernization and Engineering Education Quality Improvement // Alma Mater—Vestnik Vysshey Shkoly (High School Herald). – 2011. – № 11. – P. 12–18.
4. Agranovich, B.A. Challenges and Solutions: Master's Student Training for Post-Industrial Economy// Engineering Education. – 2011. – № 8. – P. 56–61.
5. Pogrebnaya, T.V. TRIZ and Applied Dialectics / T.V. Pogrebnaya, A.V. Kozlov, O.V. Sidorkina [Electronic resource] // Methodologist: site. 2003–2013. – URL: http://www.metodolog.ru/01108/01108.html, free (usage date: 19.12.2013).
6. «Education for Innovative Societies in XXI Century» and TRIZ-pedagogic / S.A. Podlesniy, Y.P. Salamatov, A.V. Kozlov, T.V. Pogrebnaya, O.V. Sidorkina // 5th Int. Conf. "GLOBELICS-RUSSIA-2007", Saratov, Sept., 20–23, 2007. – Saratov, 2007. – Vol. 2. – P. 219 – 222.
7. Vikentiev, I.L. TRIZ-pedagogics / I.L. Vikentiev, A.A. Gin, A.V. Kozlov // Modestov, S.Y. P The Problen Book on Biology, Ecology and HSE. – Saint-Petersburg, 1998. – P. 162–165.
8. Pogrebnaya, T.V. Methods of Knowledge and Innovative Project Invention based on TRIZ / T.V. Pogrebnaya, A.V. Kozlov, O.V. Sidorkina. – Krasnoyarsk, 2010. – 180 p.