Innovative thinking development in engineers

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Abstract. Innovative thinking may be considered as a certain type of thinking both “serving” engineering and ensuring its success. Innovative thinking is to become a basic resource of experts in engineering. The article defines main components of innovative thinking (technical thinking, creative thinking and critical thinking). The authors study the problems of training experts in engineering in Russian universities. The recommendations on developing critical thinking in experts in engineering have been worked out.

1. Introduction
Nowadays, 70 – 85% of the GDP growth is accounted for new knowledge being implemented through technologies, equipment and production organization in the industrialized countries. The global market share of innovative products is equal to $2.3 trln. [1]. «Globalization, rising international competition and dramatic development of technologies make constantly growing demands for better labour quality. According to experts, about 80% of the modern technologies will become outdated in the next ten years and there will be 80% employees who got their education more than ten years ago» [2].

In these circumstances higher education is considered as the strategic resource providing successful innovative development of the country. Thus, institutions of higher education must solve the essential strategic task of training managerial personnel, which results in the competitive ability of both: graduates in the labour market and the country in the international arena. Training personnel for innovation activities, innovators, experts in engineering is an urgent national problem that must be tackled to ensure all social spheres being developed in a new knowledge-based economy.

Today students of Russian universities specializing in systems engineering are trained in a very narrow way with fundamental and classical engineering subjects being focused on. Traditional views on preparing students for professional life can’t solve the problems of innovation economy giving priority to generating new ideas being implemented in technical and technological innovations.

Innovation capacity of people is a decisive factor of functioning and developing a science-driven economy, which is determined by the national system and level of education. Prospects, level of performance and effectiveness of the national programs in science and technology are determined by the system of training engineering personnel.

2. Results and discussion
According to the United Nations Economic Commission for Europe «engineering is a special activity related to building and operating enterprises and infrastructure facilities or, in other words, complex of
project and practical service related to the engineering and technical field and necessary for building and operating facilities» [3].

Engineering is based on the development, modification (for the purpose of being improved) and control of technological, organizational and financial and economic models of technical systems (facilities) being implemented in accordance with the goals being set. Engineering is the chain between science and production that creates technological (and technical) base of the production process.

High level of training in the sphere of systems engineering is characteristic of leading technical universities of Austria, Germany, France and Switzerland. Curriculum materials of leading technical universities are based on the professional standards and national certification system. Thus, training for systems engineering and its most essential component (Requirements Engineering) is based on the international certification system (Certified Professional for Requirements Engineering – CPRE) [4].

International practices could be useful for organizing education in the field of systems engineering as their research shows that high priority should be given to [5]:

- merging professional and academic communities being interested in overcoming the crisis of engineering education in our country;
- identifying pilot majors for testing curriculum materials being developed;
- boosting the development of benchmark curriculum materials for systems engineering.

Experts in engineering are managers possessing qualities and functions of the innovator characterized by profound knowledge, creativity, abilities and skills in the field of engineering.

Aspirations for being innovative must be developed in students specializing in systems engineering. These skills are essential for making new products, service, developing science and technology. The capacity of national enterprises must be increased, that is why special methods of teaching aimed at developing innovative thinking are necessary for students specializing in systems engineering.

Thinking is an intellectual process during which a person (an expert) resorts to conceptual images of technical and technological and organizational and economic objects and systems, which is based on his professional knowledge and understanding values of the spheres of social life [6].

Stimulating thinking processes of students is both criterion and important condition of the effective educational process. Thinking processes are based on: students implementing different mental operations (analysis, synthesis, comparison, generalization, classification, abstraction etc.); a variety of kinds and forms of mental, cognitive processes; combining individual and group work; using productive pedagogical technologies; creativity of all participants of the educational process; reflection.

Innovative thinking is aimed at seeking, discovering, creating something new. It must be and needs to be developed on purpose. The earlier innovative thinking is started to be developed, the more successful and demanded a student will be in the future. He will both possess innovative ideas and, what is more important, know how to implement them. An expert in engineering thinking in an innovative way will make fewer mistakes in his professional life: he will take the most right decision in any situation. Nowadays most educators do not teach innovative thinking, which results in students not being able to think out-of-the-box and using given patterns to make decisions.

Innovative thinking is based on technical thinking, creative thinking and critical thinking.

Students specializing in systems engineering must know the achievements of science and technology, be able to create new scientific values, make technical and technological and organizational and economic decisions, be active and possess skills of participating in innovative projects, contests, grants, creating and operating small innovative enterprises. Developing technical thinking is a condition of evolving the ability of experts to be creative in the field of science and technology.
Creative thinking is the ability to look at monotonous, routine work in a new way. In all spheres employers need employees being able to think creatively and develop new prospects [7].

Creative people have the ability to develop new ways of solving tasks and problems. They contribute new, sometimes unorthodox, prospects to their work. Such thinking may help companies to enhance their development, that is why employees possessing creative thinking are of the highest value for the company. In fact, the history of science and technology is full of projects which didn’t work not due to technical or methodological errors but people being stuck in their suppositions and old habits.

Critical thinking is a system of judgements which is used to analyse things and events with the conclusions being justified and allows to give reasonable marks, interpretations as well as implement the results in different situations and for solving various problems in a proper way [8].

Critical thinking has a number of characteristics:

- Critical thinking is independent. Nobody can think critically instead of us, we do it only for ourselves.
- Information is the starting, not final point of critical thinking. A great number of facts, ideas, texts, theories, data, concepts must be processed to generate a sophisticated thought.
- Critical thinking starts with raising questions and understanding problems to be solved. At any stage a genuine cognitive process is characterized by the desire of a person to solve the problems and answer the questions arising from his own interests and needs.
- Critical thinking seeks for persuasive arguments. A person who thinks critically is able to find his own solution of the problem and supports it with reasonable and rational arguments.
- Critical thinking is social. Any thought is tested and enhanced while being shared with other people. Thus, effective exchange of opinions based on tolerance, the ability to listen to other people, responsibility for the person’s own point of view should take place while developing creative thinking.

Critical thinking is seeking for common sense: how to make objective judgements and act logically in accordance with both the person’s own point of view and opinions of other people; the ability to refuse from own prejudices.

Innovative thinking may be developed in students under the following conditions:

- Theory classes. All information must be new and relevant, showing the current situation and both national and global events.
- Learning materials must be presented in two forms: digital and game. Digital materials include presentations, online conferences with third parties being involved; scientific films, lectures of famous scientists and experts, educational videos being demonstrated. Playing business games students obtain practical skills which will be required in the future. They appear in learning situations in which they can perform different roles, show their abilities and skills in practice.
- Practice lessons. Practice lessons for future experts in engineering must be applied ones, that is students must learn to create innovations, improve existing products and develop new, nonstandard ways to solve the problems being set.
- Internship. This problem is of high importance for students as they are interested in getting practical experience. Practical skills are especially essential for students specializing in applied engineering as theory and practice classes are not enough to get appropriate vision of the objects being studied. Direct involvement in the production process is necessary to obtain deep understanding of the material.
- Participation of students in scientific research (conferences). It enables students to get new knowledge, appear in the scientific environment, communicate with students from other universities, meet their potential employers and learn from their experience.
• Building trust with students and professors and tutors being open for new ideas in the sphere of teaching methods. They should take into account interests and preferences of their students. It is obvious that basic knowledge must be given in the appropriate amount but the time being left must be devoted to the things students are interested in.

Current circumstances strongly require a transition from the concept and practice of education for the whole life to the strategy of lifelong learning and training a new generation of qualified experts of the international level being able to ensure high competitiveness, innovative breakthroughs and investment attractiveness of both particular regions and the whole country.

3. Conclusion
Experts in engineering having obtained skills of innovative thinking at university possess: 1) the ability of continuous upgrade of theoretical knowledge and skills to use it in practice in their professional life; 2) the ability to look at the problem in a new way, to identify ideas being prospective for further development, to persuade others of the value of the idea; 3) the ability to professionally guide themselves in economic policy, understand the mechanism of implementing the achievements of technical innovations into real economy and work effectively on practical development of new technological products; 4) the ability to question the sustainability and success of the traditional conceptions and approaches, notice and use new trends; 5) the skill to implement creative methods of generating new ideas and imagination to create products being competitive on the global market.

Developing thinking which is relevant to a new type of socio-economic relations in experts in engineering implies deep understanding of existing completely new things in the society, critical comprehending of the past experiences, profound generalizing of modern Russian and foreign practices, overcoming many existing stereotypes of thinking. The problem of developing modern innovative thinking is one of the highest importance and priority.

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