PARADIGMS OF POLYTECHNIC EDUCATION IN THE EVOLVING TECHNOCENIC WORLD

RUDSKOY, A.; IPATOV, O. & SERGEEV, S.

Abstract: The paper looks into the relation between the contents and technologies of engineering and professional education with technological paradigms and types of scientific rationality dominating in the society. It is shown that it is possible to point out the paradigms of education corresponding to classical, neoclassical and post non-classical rationality. The technical-technological, scientific-methodological and psychological-pedagogical basis of the pointed out types of engineering and professional education is studied. The paper considers the weaknesses and strengths of the institutional forms of such engineering and professional education paradigms. A concept of symbiotic education, reflecting the concepts of post non-classical scientific rationality, is proposed

Key words: types of education, scientific rationality, classical and non-classical education, symbiotic education

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1. Introduction

The specific feature of today's stage of human civilization development is an intensive growth of the global man-made environment, its transformation into a highly integrated entity, which unites and governs all types of activities, and human and society life. The growth of scientific and technological power of the humankind is extremely accelerated. It allows us to speak about a non-linear nature of the human civilization's opportunities, and it's approaching the point of technology singularity (Vernor Vinge, 1993; Raymond Kurzweil, 2005). In the context of the 5th and 6th technology paradigms which are developing now, new types of engineering activities appear. The latter are related with NBICS processes – convergences, cloud and distributed information technology, global methods for accessing, storing and processing information. New technologies for integrating man with the services of the global man-made environment are actively formed. New complex machines and mechanisms appear to come into various non-trivial forms of interaction with operators who control or use those (Akaev & Rudskoy, 2017; Takakuwa, 2013). The processes connected to creation of equipment and machinery having diverse forms of artificial intelligence is becoming more and more common. Some forms of hybrid combination of natural and artificial intelligence emerge. The phase of forming a technobiotic - a single self-organizing planetary entity, uniting man and technology - has started (Sergeev, 2013a).

The new world of the organized and organizing man-made environment calls for a change in the technical education paradigm, since the classical forms of education do not allow training specialists ready to operate in the conditions of the forever sophisticating, evolving techno-social environment, which requires continuous learning of the new and trans-disciplinary vision of the world.

Today we witness a transition from classical engineering education to the non-classical and post non-classical models, which consider the realities of the network-based, self-organizing and evolving man-made and technobiotic world. The development of science, its transformation into techno-science, which reflects a symbiosis of science and technology, creates conditions for the emergence of new objects of engineering activity constituting integrated network unities, which work within new technology paradigms. They include the Internet of Things (Grgurevic et al., 2015), Industry 4.0, TechNet, cyber-physical systems, quantum systems, smart production industry, "smart media", distributed registers, digital economy, etc. It all leads to the emergence of new professional competences and calls for the relevant changes in the forms and methods of engineering education. According to V.S. Stepin "today the cognitive and technological assimilation of complex self-developing systems is determining the strategy of the front-edge of science and technological development" (Stepin, 2009).

The purpose of the present research is to analyze links between types of the polytechnic education, based on dominant forms of scientific rationality, and methodological educational concepts. Discussion of models of the environment-oriented approach to education.
2. The types of polytechnic education in the models of the technogenic world

It can be supposed that the operating system of polytechnic education reflects the needs for human resources, ensuring the existence and evolution of the current development stage of the man-made environment. It should be noted that the content of the scientific and technological system of society’s engineering activities is a heterogeneous socio-cultural process, which reflects the forms of engineering, technology, technoscience, technology paradigm, and the type of scientific rationality dominating in society. Their interaction results in a changing engineering and technological system, makes the implementation of new system engineering objects possible. Given the above, it is possible to single out the following types and features of the existing and future models of polytechnic education:

– classical engineering education: the primacy of natural science education, a clear focus towards creating and applying technologies for changing the physical world, training on local, model objects of the emerging techno-environment;

– non-classical polytechnic engineering education – the primacy of classical science and its convergent associations, interdisciplinary synthesis, growth of new forms of organized interaction between science and technology, humanization of education, transition to fundamental education, learning based on local fragments of the evolving man-made environment interacting with man, symbiotic forms of integration, techno-integration of man with intellectual environment;

– post non-classical technical education – the primacy of technology, technology-oriented learning, transition to the environment-oriented forms of technical education, work with the man-made environment organizing man and society, technical modification of man in the environment, the problems of harmonization of man and technology.

Consider the features and technologies of polytechnic education within the limits of the pointed out models and technologies of the evolving man-made environment and man included in it.

3. Classical engineering education

It is predetermined by the needs of the first technology paradigm, associated with the development of industrial society (Krasic, 2013). Reflects the classical mechanical picture of the world where the views of classical scientific rationality predominate. Its main features are associated with the belief that absolute truth exists, which is the thing determining the objectives of education. The basic concepts are knowledge, abilities, skills that can be transferred, formed and obtained as a result of training. In accordance with them, a special active role of teachers is postulated. They are considered in the pedagogical system as a carrier of advanced knowledge, and the standard a student should try to reach.

Classical engineering education is focused on the development of applying fundamental natural sciences, in particular, physics and mathematics. The top of the classical engineering education can be considered as the “physico-technical approach” developed in 1916 at St. Petersburg Polytechnic Institute (Ioffe A.F., Timoshenko
S. P.). It combined solution to engineering and technical problems by using the methods of applied mathematics and physics with a wide application of engineering methods to run scientific experiments. The connection between practice, science and education is the major feature of classical engineering education. An engineer must be both a scientist and a technical specialist, and an organizer of production operations (Saprykin, 2012).

The drawbacks of classical education include its inflexibility in the conditions of intensively developing and changing technologies, and the need for fundamental training in physics and mathematics, which limits the possibility of mass engineering training. A high overall professional level of teachers is required, as well as communication with research units specializing in applied science, which implies high costs for training a specialist.

4. Non-classical engineering education

Developing technologies have resulted in the complex environment of human activity. The possibilities of logical and structured processing of information have come to a physiological barrier. The forms of clipping thinking have appeared to ensure the forms of user behavior. The connection between education and technology is a distinctive feature of non-classical education. Computer technology is intensively introduced and used in the educational process (Fenollera & Goicoechea, 2011; Pardanjas, Eleven & Kaurovic, 2014; Konecki, 2014; Fomin, 2015). The emergence of complex training systems, which involve interaction between learners and the artificial intelligence of the learning environment (intelligence symbiosis), is a trend of the last decade (Sergeev, 2013c). Education in the form of a graduate’s targeted specialization for specific technological, industrial and scientific environment by gradual integration of the student into the environment at all stages of professional training.

The main concept of non-classical education is the environment-oriented approach (Sergeev, 1995, 2009; Rebrin & Sholina, 2014). The basic idea of this concept is the “learning environment”. It is believed to be a structured subject-content part of the educational material, reflecting the professional content in which the subject of learning is involved. The number of options for acting in the environment is so great that it cannot be accurately calculated. So the learner, when implementing the trajectory of education, forms their own experience independently or completes the tasks set by teachers.

The concept of "educational environment" includes the entire diversity of relationships, forms and contents that arise when a person learns and gets educated. It is a systemic pedagogical object. It transforms the totality of the external conditions for educating and training a collective and a personality into the qualities of the sociocultural environment, which allows improving the quality of life and developing an individual into a personality, and a community into a society. When simple types of engineering activities are taught and technological skills are developed, this method is fairly popular. However, it does not allow us to train high-level professionals who operated in non-standard situations.
The non-classical understanding of the environment is associated with the constructivist methodology and philosophical ideas of radical and epistemological constructivism.

According to them, man is an operationally closed self-organizing system (Tsokolov, 2000; Maturana & Varela, 2001; Knyazeva, 2006; Arshinov & Budanov, 2015).

<table>
<thead>
<tr>
<th>Components of Educational Systems and Environments</th>
<th>Role in Educational Systems and Educational Environments</th>
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<tbody>
<tr>
<td>Learner</td>
<td>Classical approach</td>
</tr>
<tr>
<td>Learner</td>
<td>Passive, an object of pedagogical impact. Doer of an instruction</td>
</tr>
<tr>
<td>Instructor</td>
<td>Directly affects learners, forms their behavior, provides them with educational information</td>
</tr>
<tr>
<td>The role of teaching means and educational environment simulation</td>
<td>Simulate the contents and conditions of real activities with the best possible degree of resemblance</td>
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<tr>
<td>The content of education</td>
<td>Formation of a personality by a template. Completion of learning tasks</td>
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<tr>
<td>Communications in the system</td>
<td>Information transfer from the instructor to the learner</td>
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<tr>
<td>Assessment systems</td>
<td>Objective control of performance indicators. Quantitative indicators</td>
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<tr>
<td>The role of assessments</td>
<td>Objective evidence of the formed level of professional qualities</td>
</tr>
<tr>
<td>The purpose of the educational system</td>
<td>To form the knowledge, abilities, skills, and personality of an engineer</td>
</tr>
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<td>Organizing a training system</td>
<td>Rigidly determined</td>
</tr>
<tr>
<td>Principles for organizing a training system</td>
<td>Fixed structure, rigidly defining the functions of the system Descriptions are unambiguous</td>
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</tbody>
</table>

Tab.1. Distinctions of the key components of classical and non-classical environment-oriented polytechnic education.
The key differences between classical and non-classical understanding of the educational environment (table 1) is accepted by the system views. In the classic version is a hierarchical system, and in non-classical autopoietic system.

“An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which:

(i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and

(ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network” (Maturana, Varela, 1980, p. 87).

By autopoietic organization, Maturana and Varela meant the processes interlaced in the specific form of a network of productions of components which realizing the network that produced them constitutes it as a unity.

Because of this, the environment is a designed part of physical reality. It is presented to a subject in the form of reality, resulting from continuous recursive interactions of human perceptual-analytic systems with physical reality. The environment is connected with man’s life experience and mediated by him.

In a narrower sense, the environment is reality connected with the external world. The external world is understood in a broader sense and encompasses a wide class of interactions of the subject, including their material and social aspects. In the post non-classical environment-oriented approach, special importance is attached to the properties of learning communication which forms the discourse of the educational environment (Sergeev & Sergeeva, 2012). Communication in the non-classical engineering education is also seen as a self-organizing autopoietic system (Luhmann, 2005-2007).

5. Post-non-classical engineering education

Post non-classical engineering education represents synergy between practice, research, technology and education. Work with historical systems. Instead of individual educational technologies, based on methods of educational testing, it is advisable to use “personal learning environments”, which are forms to organize the educational environment by changing its content according to stages of the syllabus selected by a student (Sergeev, 2012). This approach allows for motivational factors and educational preferences of a student and triggers associative learning mechanisms.

The paper considers development of open network framework that contains academic material of courses and requirements to master it (Sergeev, 2013b). Individualization of learning environment comprises the stage of selecting courses by students and discussing the educational process with a professor. Assessment of the course is based on lecture attendance, participation in seminars, written papers, research and engineering activity. After each course a student is interviewed or asked to fill in a questionnaire in order to collect information about causes of educational obstacles with further correction of courses (enhancing their integration features). Afterwards the student moves on to the next individual educational step.
Post non-classical models of engineering education imply nurturing labor teams for particular trends in research technology and engineering activity, and dealing with the problem of scientific schools. The modern Russian science is focused on developing scientific schools, which requires a regular inflow of young researchers, optimization of research staff. Leading countries see the increase in scientists involved in a number of research fields. Russia has a different situation. A number of academic associates is decreasing dramatically, which is explained by the purpose to improve the quality of scientific organization staff and concentration of funds on prospective areas. However, actually, such downsizing is impossible without analyzing activities of the existing scientific schools and directions.

It is worth noting a key difference of post non-classical models of education from non-classical education. The former refers to creating collective unions, providing their history and evolution with high specialization of team members. Here self-development of the organization is the main goal of education, which leads to tasks of having a target for the created organizations. Yet non-classical education is focused on training universal specialists, who become part of industrial and research teams in the process of marketing self-organization.

6. Models of post non-classical engineering education in Peter the Great St. Petersburg Polytechnic University

Implementation of the TechNet Program within the National Technology Initiative, adopted on February 14, 2017, at the Presidium of the Presidential Council, dedicated to economic modernization and innovative development of Russia, requires launching new forms of engineering education. This is related to the fact that the task to design the digital economy cannot be resolved by the methods of classical education, due to complexity and fast evolution of the target object and socio-technical type of the designing process.

The TechNet Program in brief. Within this program the Computer Engineering Center (director – prof. A.I. Borovkov) implemented such educational concepts as STS approach (Science, Technology, Society), STEM-education ideas (integration of science, technology, engineering and Mathematics), its next stage – STEAM-education (supplemented by “Art” component). These are targeted at forming conceptual understanding, operational freedom, strategic and logical thinking, and developing productive consciousness (Rudskoy et al., 2017). Activities within these paradigms have been conducted since 2010 (A.I. Borovkov), which allowed SPbPU to create the research team of complex technology, who mastered CAE (Computed-Aided Engineering Technologies). Besides, the generated chain of CAD/CAM/CAE technologies, supplemented by Computer-Aided Manufacturing, resulted into the «Simulation-Based Design» paradigm with production of innovative goods. For the recent decade this approach has been continuously and intensively developed, and today it is used by hundreds of thousands of engineers, leading to formation of the new production ideology – ideology of Digital Manufacturing (Borovkov & Boldyrev, 2014).
We assume further development of digital economy technologies based on integration of cross-platforms which implement digital design, simulation, and prototyping with technologies of supercomputing and distributed artificial intelligence.

7. Conclusion

The presented theoretical research has resulted into determining three types of the polytechnic education that reflect dominant types of scientific rationality: classical, non-classical and post non-classical education. Each of them has its own forms and methods of education. The authors assume that the universal approach in the classical and non-classical education is an environment-oriented approach. We analyzed its peculiarities related to various systemic bases of classical and non-classical education. Emergence of new objects of technoscience leads to the development of technogenic environment as a complex technobiotic self-organizing system, which restricts opportunities of the classical polytechnic education. In order to train engineers, evolution and complication of the technogenic world would require application of new methodological schemes that reflect classical and non-classical views about implementation of educational systems.

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