Engineering Education Educology: Basic Postulates of Systems Engineering

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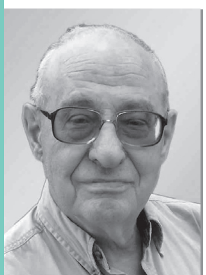
At the beginning of the 21st century, the novelty of the situation in the global system of engineering education (EE) is determined by the legislative introduction of the international EE Standards. These regulations should become a universal tool in the intensifying attack on the well-known phenomenon – Education Gap. To achieve the target- EE modernization, it is necessary to develop a general theory- EE educology. The basic postulates of this theory are discussed in the following article.

Key words: *systems engineering, adequacy, homoeostasis, feedback.*



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Problem situation. At the beginning of the 21st century, the global Engineering Education (i.e. EE) system began to operate within a principally new situation. International Standards of EE were legislatively implemented. These Standards were grouped into three clusters [1],[2],[3],[4] for different global regions. The basic principle – competence approach incorporates all these three clusters. Competence approach is an explicit primacy requirement of any employer to the quality of EE "product" and every individual "item"-EE graduate. These requirements are included in the parameters of "professional competence (PC) of an EE graduate" and relevant professional competence package (PCP).

Within the Fours "PC, knowledge, abilities, skills" (PCKAS), characterizing the EE results, the last three factors are inferior to the PC parameter, being exclusively intermediate registering indicators.

The adoption of a consensus on the basic principle of IC EE was a concluding solution to the long-term conflict of interests between "employer: producer – engineer" to overcome the EG-Education Gap. This phenomenon is typical for most EE structures, systems and elements and shows the developmental EE lagging from today's reality and yesterday's innovations, such as hi-tech, infor-tech, and science-tech in the technosphere. Thus, the novelty of the situation in EE involves the fact that the universal tool IS EE is developed and imposed to activate an attack on such a well-known phenomenon EG.

The existing EG is the real continuous long-term state of EE. However, there is no objective and principal justification of this existing EG and it is only the cause and effect of a well-known triad postulate: new technology and knowledge, abilities and skills in the technosphere should be accompanied by simultaneous and alternative updating technology- hardware, software, strategies and didactics in EE. Today, the consequences of the scientific-engineering revolution are the phenomenal

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increase of complex objects, elements and segments in the technosphere; thus, executing the triad requirement is a consuming and non-trival problem. However, the triad postulate has been cancelled, and today, enough experience has been accumulated to solve this problem, which in its turn, is discussed in many publications about engineering education [5].

Nevertheless, it should be highlighted that EG has deeply penetrated into the EE universities, where EG "stagnations" are permanent and never-ending ones. Important factors of this "stagnation" are such university establishment fetish as campus freedom, pluralism in understanding the EE targets and others. Under such conditions the execution of new IS EE requirements is often farmed out by the professorship that are not really ready to modernize the interminable university "life" structure.

EE top-staff personnel cannot counteract the professorship "opposition" theoretical-based viewpoint, because there is no existing EE theory. Numerous theoretical publications concerning particular EE issues and areas have still not been merged into one basic theory- EE educology. The implementation of the IS EE strikingly shadowed out the necessity to close this gap up, as the absence of EE educology theory encourages the top-staff personnel to only the administration application of the EE strategies and tactics as a voluntary policy, which in its turn, hinders the possible target solution- EE optimization.

EE systems engineering It is obvious that the problem of EE modernization is intrinsically imperative. If the basic EE structure model is considered as a graduate department model –structure, then it should be emphasized that the above-mentioned problem is multi-dimensional and significantly depends on a number of internal and external factors. In other words, it is a complex problem which could be considered as a complex system. Systems Engineering is the design of a complex interrelation of many elements (a system) to maximize an agreed-upon measure of system performance.

EE Systems Engineering includes the following modules:

- general theoretical methodology and tool aspects, optimal for system targets, i. e. system model, defining and characterizing such systems, modeling, simulation, optimization, decision making;
- technological methodology of the major system process - acquisition, education, assignment of knowledge, abilities and skills and their transmission into professional competence; i.e. planning and designing Curricula and Syllabi, sub-systems, assessment indicators, and other factors;
- engineering i. e. education engineering;
- organization of engineer's activities, i.e. social psychology, planning, management.

Selected EE structure model is termed as academic-organization system (AOS). AOS components include human resources, technology, process engineering, methodology, information, finances, which should develop an effective functional system. This is rather a complex task under the conditions of increasing sophistication of all the components in the outer world. Nevertheless, this task is feasible. An excellent example can be the leaders in university and department rating in the development of EE. Hence, the problem of process technification, occurring within the domain of these EE leaders, emerges (excluding the supposition that all these processes are exclusively heuristic and can be neither analyzed nor reproduced). Technification is the first stage in transferring the performance from the heuristic to the operational plane. The following stages include: formalization and algorithmization for analysis, problem-solving optimization, simulation. The tool, in this case, is systems engineering.

Up to the present day, many EE top-managers are convinced that it is sufficient enough to only design the AOS as a concise operating mechanism, and then all stated problems will be solved. However, the complexity and dynamics of the 21st – century world, in particular, enforces on AOS a high-level capability to adaptation, execution ability of its functions in a wide range of changing internal and external conditions, and, even within the framework of a conflict. Accordingly, the transformation from a mechanism to an organism or from a machine to a system is necessary for AOS with a rather high degree of adaptation potential.

Leading systemologists, for example, John van Gigch [6], consider the education system to be a soft system (SS). Such systems depending on the environmental constraints, especially, given super-system commands, could produce various types of results under one and the same initial conditions. Assessment of activity results of the education system is very difficult due to a number of reasons [6].

Different (including negative) AOS activity result effects on the ecosphere, inform-sphere, techno-sphere, socio-sphere should be taken into consideration at the performance and development stage of EE AOS. Designers and administrators of today's AOS should "keep abreast" of their structure-designs and receive all necessary evaluation from employer-consumers and graduates. This information is an important feedback during the updating of the input and inner AOS processes.

Feedback outline is technically included in the AOS design. However, at the AOS performance and development stages, there are a number of objective and subjective factors that reduce the significance of this feedback; or it is used only as watered information, completely losing its correcting functions.

For example, campus freedom is the "shield and buckler" playing the negative role in this collision. It may result in possible dualism when adopting management decisions within the AOS. Frequently, in these cases, monitoring and feedback in the AOS is pushed back into the marginal position or even, sometimes, this obtained information is completely annulled. There is an obvious reason for this- monitoring (feedback) is always an external intervention for AOS factors, i.e. employers, administrators, their experts, etc. In this case, the professorship considers that this intervention, spoken or unspoken, is an invasion of campus freedom. Thus, quite often the real results of AOS activities significantly differ from those in the stated AOS target of the project. Many employers, experts and auditors characterize this situation as EE crisis.

This statement is based on evident standards – the target of the state EE system should meet the country's demand in professionals. However, all this evidence proves the fact that this target has not been included in the priorities of the current module performance and EE system structure. As objective and subjective factors have dramatically corroded and deformed the essence of this target, the above-mentioned problem- demand in professionals- is not even considered as a specific target of the EE system. It is regarded as the problem of the labour market, but not of the EE system.

Above-mentioned indicates that the role of the feedback is extremely minimized because the feedback outline is practically annulled. Nevertheless, one basic axiom of systems engineering states: soft systems with any feedback are inclined to deform the targets and "outputs" of this system and with further inevitable degradation. Such a scenario can be cured by on-time treatment of the "diseased" system.

Feedback is not the only stimulation tool in the AOS. All EE system modules-people, or organizations- are open systems which cannot be controlled exclusively by feedback as in the case of inanimate systems. According to the monitoring results, a self-control component should be included, i.e. simulators and motivation elements, triggering an infallible performance of the system target. It is unacceptable to be indifferent to the fact that enormous resource expenses are used without results.

Management concept in complex systems is based on the solution of two associated problems: providing a stable performance of the system and increasing an effective introduction of

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innovation. It is obvious that these two problems are in close confrontation. The aim of this optimal management retains these two system features- stability and variability- in a dialectic unity.

The principle of divergence is involved in any complex system, i.e. the target of individual system elements is more progressive than the major target of the system itself. This is characteristic of complex systems with human resources; its "elements" pretend to assume an advantageous or convenient position for itself and frequently at neighbor's or resource's expense, which in its turn, are intended for the achievement of system performance target. This situation is termed as "travellers in a boat", where besides personal aims all of them have one common aim "not to sink the boat".

The term homeostasis can be technically applied to these systems. Let's consider x-space as y1.....yn, where yi- input of every system "element" in achieving the common target. The homeostasis boundary area within this space is termed as surface F (y1...yn) = F0, designating the area of all existing individuals, i.e. area of stability, homeostasis of this system.

To preserve its existence within H surface, the system includes the following possibilities:

1) to change its position relevant to the surface H;

2) to change its internal characteristics to some degree which affects the contour of surface H (threshold property);

3) to temporary change the environment parameters temporary.

To implement these possibilities, the system should have two potentials: non-response and resistance to external disturbance; and tracing internal disturbances caused by the parameter disharmony within the system.

The general system theory is a warning indication against the trivial understanding of H due to the unjustified comparison of it to well-known categories from natural sciences. For example, in biology, H is defined in a simple way; however, such simplicity is not typical for complex systems connected with people. There is also a formal description of H, identifying it with its stability in simple systems, while, in the case of complex systems, it is impossible to find a clear-cut connection between complexity and stability [7].

Homeostatis as a development trend resulted in the generation of self-controlling systems aimed to confine its parameters within definite boundaries.

Homeostats operate within system-like communities, invoking an information exchange between them. AOS can be termed as an artificial homeostat with a certain level of self-control to achieve a given target and self-programming when the target of the system changes. The term AOS involves such an important non-trivial property as an organismic one. Organism is a system having one's own aims, resources to achieve these aims and task-oriented performance (behavior). The super-target of the organism is H post-storage. In the organisms with people (communities), there is a distinctive complication- a response to any innovation is not reflexive (syntactic), but semantic, involving an indirect complex behavior.

Homeostatis is basically relevant to such a phenomenon as "progress", i.e. the efficiency growth of performance through the implementation of innovations. However, the behavior of this organism (organization) suffocates this tendency in order to exploit other development strategies. Frequently, the hypertrophy of H results in stagnation and negative professional and social results. This is the result of stagnation, long-term application of worn-out, but "reliable" technologies and performance methodology, blockage of the innovations within the system, etc.

Such tactics results in relatively significant system stability against the system relevance prior to super-system, downstream management system and actual environment. In other words, one H category is insufficient to effectively manage AOS as H only characterizes one side of the system stability. Variability and stability in the system is in a complex dialectic collision with unity; and there is no doubt that both of these categories should be included in the system management concept. The growth of complexity and the dynamics of modern systems produced such a new system analysis category as adequacy (A) - the ability of the system to accept and implement innovations, adequate outward and super-system influences, remaining, at the same time, an effective performance to achieve the given system target.

Because of various reasons, not only the objective but also the subjective ones, AOS is often shielded from direct outward influences and operates in an artificial favorable performance area. However, environmental dynamics constantly increases, and, consequently, furthers the interruption of AOS development in these conditions signifying the following facts: the regression of this system, dramatic abruption, and violation of the AOS adequacy principle through sophisticated innovations in the techno-sphere and inform-sphere- i.e. Educational Gap (EG).

Thus, there are two performance strategies for EE model:

(1) model-machine: stated final target, algorithm and resources to achieve all objectives. After this, AOS begins to work according to a rigid scheme, whatever the external conditions are;

(2) model-system: stated final target and a number of operation trends to achieve this target. After this, AOS begins to work tending to achieve this final target and, at the same time, preserving the given trend under changing external conditions.

This organization is often formed in a hierarchic structure. The delegation of authority and resources downward reduces these subsystems into independent organisms with individual aims and further results in the collision between the authority center and downstream subsystems. This collision is often based on the fact that H overemphasizes itself and becomes the super-target of the organism. Within such hierarchic EE systems A is quite often sacrificed for H, therefore, AOS management strategies should be directed towards the preservation of category A at a required level.

Major target of AOS Discussed EE model structure-AOS is designed and developed when there is a problem-solving situation, i.e. collision between new society demands and the low EE performance efficiency in satisfying these requirements. What are the challenges of the 21st century? A very simple and decisive answer: the every-day growing sophistication of such spheres as techno-, inform-, and socio- .The tool to grasp all this is high professionalism "heavily armed" with a contemporary system approach in the spheres of technology and inform-knowledge, where the role of empirical knowledge and heuristic, creative and conceptual problem-solving solutions drastically redouble. The traditional problem-solving approach, based on natural science, physicalism, model-designing and analytics "takes second billing".

The problem-solving situation models the AOS target. Based on the above-mentioned, the major target of AOS is formed as following: the relevant development tendency of the civilization and a specific society, in particular, the growth of professional competence dimension and quality of a defined student community, which in its turn, is achieved by constant monitoring of mentioned trends and, at the same time, the reconstruction of the structure, element behavior and the system itself.

This statement reflects such items as the final products of AOS and the ideal management object situation in accordance with how AOS should operate. The quality-quantity combination of an effective process is a compulsory integrated brand of today's successful AOS. Both of these features should not be in a cause-effect relationship, as each of them characterizes an important independent aspect of AOS performance.

The alignment space is generally 4-dimensional: AOS co-operates with managing system (super-systems), managed systems and present-day environment. Besides, AOS, itself, forms targets for its own stable operation. Therefore, four sub-targets should be determined at the second decomposition stage, in accordance to the 4-dimensional alignment space.

AOS model performance is based on A and H criteria. The following stages are included in designing this model:

1. selection of input and output model parameters;
2. selection of criteria to conform the input and output model parameters; these parameters can be calculated or assigned in respect to H and A;
3. selection of major criterion for AOS operation;
4. technical determination of AOS performance result, i.e. output parameters through input ones, through the AOS operation function;
5. definition of the optimization target due to the major criterion for AOS operation, limitations and interrelation between input and output AOS parameters.

The operation function defines the operation systems, which includes the basic performance process for the designed system. In the monograph "Education Gap: engineering education on the threshold of the XXI century" [5] the authors suggested the Cobb-Douglas production function in designing the AOS operation function, as it is a classical solution for similar problems in economic cybernetics [8].

The processing technique of AOS operation function as well as the definition of the optimization target for AOS and the algorithms to solve specific suboptimization problems are discussed in the monograph "Education Gap: engineering education on the threshold of the XXI century" [5].

REFERENCES (ALL TITLES IN RUSSIAN)

1. International Engineering Alliance [Electronic resource]: the official site. – URL: http://www.washingtonaccord.org.
2. ABET [Electronic resource] : the official site. – Baltimore: ABET, Inc., 1998–2010.– URL: http:www.abet.org (usage date: 14.05.2011).
3. ENAEE EUR-ACE European Accreditation Engineering programmes [Electronic resource]: the official site. – Brussels: ENAEE, Inc., 1998–2010. – URL: http://www.enaee.eu/the-eur-ace-system/eur-ace-framework-standards/ (usage date: 14.05.2011).
4. The APEC Engineer Manual: the identification of substantial equivalence [Electronic resource] / Asia-Pacific Economic Cooperation, Human resources development working group, [2009]. – 48 p. – URL: http://www.washingtonaccord.org/APEC/Documents/APECEngineerManual.pdf (usage date: 14.05.2011).
5. Beljaev A., Livschits V. Educational Gap: Engineering education on the threshold of the XXI century – Tomsk: STT, 2003. – 503 p.
6. Gigch John P. van. Metadecision: Rehabilitating Epistemology (Contemporary Systems Thinking). – New York: Springer Publ., 2003. – 363 p.
7. Moiseev N.N. Mathematical Problems of System Analysis M.: Nauka, 1981. – 488 p.
8. Economic Kybernetics - Manual for universities, ed. Kobrinskiy N. E., Maiminas E.Z., Smirnov A.D. M.: Economics, 1982 – 408 p.