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Peculiarities of Engineering Education Within the Innovation-Based Economy

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Abstract
In today's fast-changing market, the link between the decisions made in different fields is of significant importance. This peculiarity should be reflected in engineering education. The theory of technological modes serves as a methodological basis for the current research. It has been revealed that engineering-economic environment is shaped as a combination of technological modes, within which the problems of harmonized development of technologies are solved. The models to shape engineering knowledge under modern conditions are proposed.

Key words: innovation, engineering, models, multidisciplinary, technological mode, economy.

Introduction

An ongoing shift in global economic activity [6, p. 391; 12] (development of innovation-based economy) stipulates the changes in education [7, p. 245; 20]. It is required to consider the link between the changes in engineering knowledge and innovation market.

The thing is that in the modern highly-integrated market technical objects definitely perform their applied (technical) functions. However, they increasingly perform so-called systemic functions, i.e. the functions that affect constructive processes of economic environment.

In practice it means the following. A new integrated circuit is designed. Its introduction into the market stipulates rapid changes. As a result, new conditions for advancing the integrated circuit emerge: new consumers' requirements, technological capabilities, use options. All this advances the integrated circuit and contributes to further change in the market conditions. In this context, the changes of the integrated circuit should not cause the discrepancies in the constructive processes of economic environment. Otherwise, an ongoing advancement of the integrated circuit will cease. Therefore, the integrated circuit should possess systemic characteristics that manage the concurrence of market changes (concurrence of constructive processes).

It is essential to secure the required technical and systemic properties of an engineering object. While designing an education programme, it is reasonable to find the answer to the following question: how a complex of engineering objects ensuing concurrence of changes in technical and economic environment is formed?

For this purpose, it is necessary to examine the processes of modern engineering knowledge acquisition, develop the models of knowledge acquisition and design the corresponding curricula. These issues have been addressed in research literature [1, p. 57; 2, 5, 17]. Precisely, they are examined in the works dedicated to “Knowledge Management” [14, p. 37; 15, p. 46]. However, the fundamental processes of an innovation-based economy have not been considered. To be more precise, the peculiarities of technical and economic knowledge interaction in the innovative development of systems have not been examined.

The peculiar feature of the current study is the use of the innovation-based economy development models. The essence of the applied models is as follows: modern economy is based on the numerous production modes [6, p. 391] developed by mass technologies of different origin (industrial, informative, social, etc.) and forming the corresponding technological modes (S.Yu. Glaz'ev [6, p. 391; 7, p. 245; 8, p. 256]). The technological modes are comprised of highly-integrated complexes of consumers, manufactures, products, etc. (microelectronics, information systems, the internet, mass information systems, mass consumer technologies, etc.). Each mass technology is enhanced alongside the corresponding technological mode. Therefore, a technological mode is often an object of engineering research.

The article examines the processes of knowledge accumulation in technological modes of the innovation-based economy. The design peculiarities of the corresponding curricula are presented. This fact of a great interest as the theory of technological modes serves as a basis for one of the well-known options of the Development Program of the Russian Federation [7, p. 245]. The results of such experiment are not found in research literature.

The article describes the proposed models of engineering knowledge development. They can be applied for design curriculum in microelectronics. The analysis of the course content has revealed that the following tasks are fulfilled: harmonization of mathematical modeling and expert methods, "resonance" of knowledge during the course material delivery, simplification of some course parts, etc.

It is proved that engineering education should incorporate such courses as "Systemic analysis in innovation-based economy" and "Fundamentals of innovation-based economy". The obtained results can be applied in design of courses for the experts in technology development management in the innovation-based economy.

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1. Materials and methods.

1.1 Methodological problem of modern engineering development

Ensuring harmonization of numerous changes stipulated by the constructive processes of different nature is one of the overriding tasks in the modern economy (innovation-based economy). It is required to harmonize all the development processes within the knowledge system [18, p. 28-31]. Therefore, to study engineering industry in the innovation-based economy, it is necessary to define its role in solving this problem.

Harmonized development of technological and economic environments is secured by two types of methods to shape the future [3, p. 75; 4, p. 73]. The first method implies description of knowledge via the formal models (theoretical, logical) followed by the modeling. This method can be primarily applied in natural science. The main property of the formal models is that the so-called "packed" knowledge stipulates properly harmonized constructive processes of different nature. The formal models of Euclidean geometry are the best examples. They created "resonance" in development of numerous sciences and caused fundamental transformation of Ancient Greece thinking. The mechanics of Newton and Leibniz played even a more significant role in integration of sciences. Thus, development of knowledge within the natural science area could not be separated from creative processes originated both in social and economic environments [9, p. 6-10]. This link should not be disconnected in education that is tied to rapidly changing market.

However, in the course of economic-technological environment development (quantitative changes) many formal models lose their adequacy regarding practice. Correspondingly, there is a loss of the link between the models and creative (constructive) processes. The knowledge system loses the link with the economic environment. As a result, there is a falling interest in acquiring formal knowledge (primarily, Mathematics).

The second method to harmonize the development of systems is rooted in the systemic methods [1, p. 57; 3, p. 75; 4, p. 73; 21, p. 352]. The conditions for harmonizing constructive (creative) processes which have been deduced from the gained experience are registered. The relation patterns that secure harmonization of the taken decisions are developed [11, pp. 13-25; 14, p. 1159; 21, p. 352]; concepts; unified values; indicators. They define the conditions at which the forming constructive processes might be harmonized. This increases the validity of the experts' opinions. Such approach is peculiar to the humanitarian sciences. The problem is that the impact of various decision making patterns can be rather controversial, insufficient and unstable. This impedes innovative development that requires high harmonization.

The two above-mentioned methods are closely interconnected. Each method performs its function in harmonizing the development elements and each of them has its own limitations. It is essential to ensure harmonization of the results obtained due to the use of these methods.

In the field of engineering, two methods are applied: formal methods of Physics and engineering, as well as systemic concepts and patterns. In this respect, it is regarded both as a natural science discipline and economic one. Therefore, for engineering development (as well as to design a comprehensive education programme), it is required to ensure continuous harmonization of the results obtained due to application of formal-logical and systemic methods in designing systems. To enhance the efficiency, the methods should complement each other.

Obviously, it is impossible to solve this problem via analytical tricks. The solution could be achieved only by means of new properties of technological and economic environments. It is required to indicate the specific processes that stipulate these properties in the innovation-based economy. Their models would become the bases for mastering engineering disciplines and designing engineering programmes.

The notion "engineering" is primarily referred to the mechanisms of knowledge generation, but not to discipline-related properties.

1.2 The model to shape engineering knowledge that stipulates innovative development

As noted in the introduction, the modern economy is rooted in mass technologies that shape their own technological modes. In the technological modes, the problem of integration and harmonization of development processes is naturally solved.

The harmonized physical, economic and other knowledge advances as the result of the constructive processes of the corresponding technological modes. Therefore, to design adequate education programmes, it is essential to develop the models aimed at enhancing engineering knowledge within the technological modes. They are determined by the peculiarities of modern mass technology development including corresponding technological modes.

The complex mass technology or a tool could be hardly improved as a whole since its changes are secured by a combination of numerous harmonized constructive processes of different origin. Therefore, modern mass technology (including its technological mode), as a rule, advances as a combination of options (table 1) of its industrial units [19, p. 49]. It means that it is required to study simultaneously all the available options.

Each described option (represented by a certain industrial unit) is focused on

Table 1. The elemental cluster

	Segment A	Segment B	Segment C
Industry type	Mass production	Manufacture on the basis of new stable technologies	Innovative production
Consumer type	Traditional	Continuously developing	New
Dominating properties	Harmonization of numerous technological processes, product requirements	Enhancement of the most popular technological options and products	Improved properties within certain new trends
The role in technological mode development	The link with the constructive processes of the "previous" technological stage	Enhancement within the stable trends	Solutions for shaping future technological mode
Dominating methods	Expert methods	Combined	Formal-logical

the enhancement of a set of parameters (table). Precisely, some plants are aimed at increasing the production yield of non-defective products. At the other similar plants, parameters of radiation stability are improved. Obviously, the plants are interconnected as they enhance the same mass technology. It is essential to ensure the unity of the constructive processes stipulated by the changes in the technological units. It can be achieved due to the fact that each of them corresponds to a certain stage of technology enhancement [19, p. 50-59] (table). For example, technological unit A supports the constructive processes tied to the economic environment of the past. Technological unit C contributes to enhancing new generation of technical equipment and machinery. The corresponding plants are characterized by different operation criteria, consumers' properties, and research pattern, etc. (table). Improvement of mass technology as a whole stipulates further enhancement of all technological units (that support different stages of the discussed technology improvement).

This means that to ensure the "resonance" of knowledge associated with these different technological units (physics, engineering, etc.), it is required to study the corresponding subjects as a whole simultaneously and coherently. This actually defines the teaching mode. In addition, it is necessary to ensure harmonization in knowledge development. For this purpose, properties (parameters) of technological units should be also well-balanced and meet some relations. This would determine the disciplines to be included in the education programme.

To define the properties and relations, it is required to elaborate the unified model of innovative development mechanism shaped within the technological mode due to the act of increasing number of mass technologies. It should determine the conditions for solving the problem of harmonization of systemic and formal-logical approaches within the innovation-based economy.

The essence of the model is as follows: to ensure rapid development, there are certain objects in the market whose systemic properties are primarily connected with the

constructive processes of the past; there are also objects whose systemic properties are aimed at stipulating the constructive processes of the present and future (fig.1).

In the innovation-based economy, all constructive processes should constitute one harmonized constructive process, preserve the unity of the past, present and future processes [4, p. 73-75; 10, 11, p. 13-41].

Harmonization should be achieved by emergence of a broad-scale mass technology (fig.1). Definitely, a broad-scale technology affects the constructive processes linked to all objects and, at the same time, removes the barriers that impede enhancement of the constructive processes. The constructive processes that are continuation of the past processes and part of the present and future ones emerge (fig.1). In addition, they are integrated by mass-technology and, therefore, constitute the required unified cross-cutting constructive process of all generations.

In this case, the formal-logical and systemic approaches or methods are properly-harmonized. Obviously, the constructive processes of different generations are connected with a certain formal-logical or expert methods (this will be covered in the next section). The integrating effect of technologies ensures harmonization of their application results.

Therefore, the study aimed at investigating knowledge (course content) that emerges as the result of technology development (fig.1) is of particular interest. It is urgent to address the issue of designing education programme content that would be adequate to market conditions and the system of engineering solutions. For this purpose, it is required to determine the optimal criterion for mechanism operation (fig.1).

A more detailed analysis of this criterion is beyond the scope of the current research. Simply speaking, the essence of the criterion is as follows: in a case of a great number of new solutions, a mistake is likely to occur; in a case of a great number of out-of-date solutions, the development strategy mistake arises; therefore, the amounts of funds of different generations should be balanced [19, p. 49; 21, p. 352]. This actually stipulates the balance of the constructive processes. The balance is defined by the consistency between the fund amounts of different generations [13, 21, p. 352].

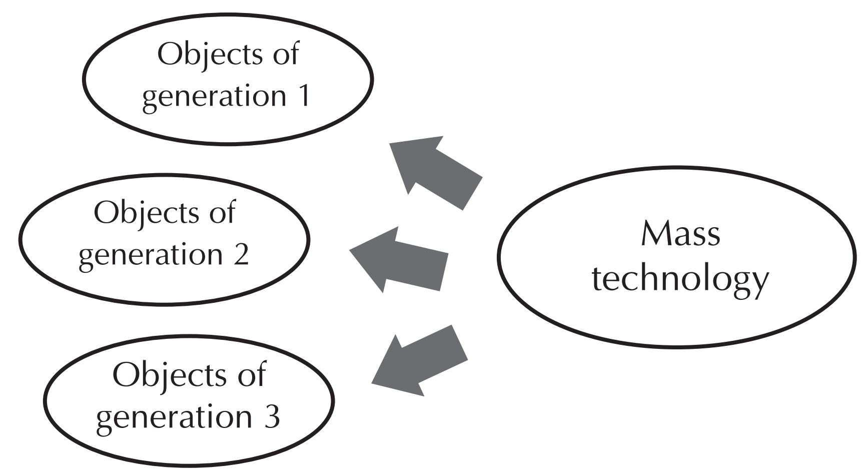
It appears from the foregoing that education programmes should deliver engineering knowledge shaped within the technical and economical environments that correspond to the systemic criterion and the model presented in fig. 1.

2. Results

The content of engineering course

Let us examine the simplified example of course design, which is aimed at studying

Fig. 1. Model of innovation development origin



the integrated circuits of signal processors (integrated knowledge of physics, circuit engineering, architecture, manufacture management, applications).

Formation of technological environment is represented in fig. 2. To adequately solve well-known consumers' tasks on the basis of the optimized mass technologies, the integrated circuits of the purpose-designed processors are developed (segment A, fig.2). They actually reflect the peculiarities of processing algorithms and opportunities to apply the options of mass production (in fig.2, segment A represents the "past" generation). Here, numerous well-harmonized physical effects, engineering solutions, special algorithms and etc. that stipulate "resonance" effect in physics, circuit engineering, and applications are used. The harmonized standards for decision making are defined. The systemic approaches are efficient. This allows using exports' opinions during course delivery, which defines the peculiarities of teaching modes.

However, it becomes even impossible to generalize knowledge interpreted by experts with the increase in difficulty in segment A. Therefore, the course should familiarize students with the mechanism to manage harmonized development of knowledge. In addition, it is necessary to consider the model of future development.

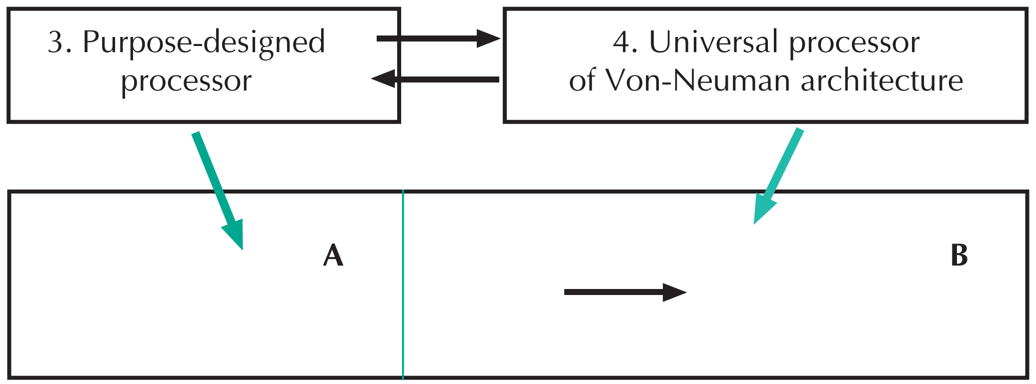
The number of tasks increases (additional segment B appears, fig.2). In this context, the environment of segment A, which is focused on solving early examined problems, could hardly be involved in solving the tasks of segment B. The system may stop developing as it is difficult to build an integrated circuit of additional purpose-designed processor within sufficient experience in solving problems of segment B. Due to this reason, the system should include the integrated circuit of a universal processor which is able to solve the problems of segment B (even for a long time period). As a simplified option, it could be a universal processor of Von-Neuman architecture performing in sequence simple operations and is based on a simple physical structure. This allows designing algorithms for resolving new tasks which do not require absolutely new physico-technical solutions and knowledge of circuit engineering. This fact gives the opportunity to carry out experiments in physics and circuit engineering on the basis of well-examined problems, thus, increasing the system quality. Therefore, segment B is a study of "the future" stage in development of technical and economic environment.

The main peculiarity of this segment is that similar technical solutions, operations and algorithms are united. Therefore, segment B represents the area of formal-logical modeling. This defines the specific ways to master the knowledge related to this segment.

3. Discussion

Thus, a set of processors includes segment B which serves as a tool to study the "future". There is also segment A that shapes the harmonized knowledge (incorporates "the past" into the system development). Segment A mostly applies systemic methods and approaches. The Formal-logical methods are peculiar to segment B.

Fig. 2. Model of harmonized expansion of signal processor technological mode



Therefore, the proposed course explains physics, engineering, and mathematics regarding two separated, but interconnected market segments of integrated circuits. It means that two harmonized sets of knowledge that create required conditions for each other are studied. This allows studying different segments via different methods, apply different criteria for learning material selection. For example, to evaluate the quality of segment A, it is possible to apply experts' estimates, while segment B requires using Moore's law [16, p. 384]. As a result, the problem of studying knowledge related to different areas becomes less difficult.

However, it is always required to secure harmonization of the studied segment properties. To solve the problem of on-going integration, it is essential to apply systemic analysis.

It is worth noting that the main task of the systemic analysis is to ensure harmonization of numerous solutions (constructive processes and objects). Within the innovation-based economy, this task is naturally resolved. It means that the instrumental environment of this type of economy becomes the basic object of the systemic analysis.

The systemic analysis is a part of both natural science and economics since it considers physical properties of an object in conjunction with the constructive processes (cognitive processes). This actually posed the challenges in its development. The innovation-based economy eliminates these challenges. The systemic analysis becomes a well-organized discipline as formal-logical and systemic approaches are harmonized (simplified). It allows solving the problem of optimizing the process of shaping instrumental environment and engineering knowledge. Therefore, an engineering course should be always supplemented by the discipline "Systemic analysis in the innovation-based economy". In addition, it is also useful to introduce the discipline "Fundamentals of the innovation-based economy" that examines the certain examples of new engineering impact on transformation of economic, social, and other relations.

Conclusion

The transition to a new global technological mode changes the model of economy enhancement. It is the most important innovation and resource. As a result, engineering knowledge that includes both systemic (economic) and technical aspects appears. Such knowledge is shaped at technical and economic organizations that function in accordance with the peculiar models of the innovation-based economy.

The development of the innovation-based economy stipulates "revolution" in the systemic analysis. As a result, there arises the basis for analytical management of engineering knowledge development. It should be included in education programmes.

Master's degree programmes offered by universities should provide students with that knowledge that is interconnected by the models of enhancing technological modes of various fields. As a result, the teaching process becomes simpler. In addition, it becomes easier to harmonize and revise the elements of education programmes, which, in its turn, assists in connecting theoretical engineering knowledge and applied tasks and problems offered by a new economy market.

The obtained results have revealed the peculiarities of engineering education intended for high-tech business within the innovation-based economy.

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