ISSN 0798 1015

REVISTA ESPACIOS

HOME | Revista ESPACIOS | ÍNDICES | A LOS AUTORES

EDUCACIÓN • EDUCAÇÃO • EDUCATION

Vol. 38 (Nº 40) Año 2017. Pág. 13

Engineering Education in Innovation Economics

Ingeniería Educación en Innovación Economía

Yuri Petrovich FIRSTOV 1; , Olga Alexandrovna MOISEEVA 2; , Dmitry Sergeevich AKULOV 3; , Ivan Stanislavovich TIMOFEEV 4; Pavel Leonidovich FEDOROV 5

Received: 25/07/2017 • Approved: 02/08/2017

Content

ABSTRACT:

Today's rapidly evolving market necessitates a close link between the decisions made in numerous academic fields such as physics, industrial engineering, economics. This connection should find its reflection in modern engineering education. Underlying methodological basis for this work is the theory of technological modes, which rapidly gains popularity in Russia today. It is shown that engineering and economic environment is formed as a set of technological modes, which resolve the issues of coordinated development of technologies, integration of formal and systems methods, at alia. In the course of research, there have been developed models of dynamic technological modes which define the solution conditions for the stated issues. As a result, the article presents a number of models which form modern engineering knowledge along with an example of an academic course, its structure and analysis. It further illustrates the solution to the coordination issues and offers proper recommendations.
Keywords: innovation, engineering, model, multidisciplinary, technological structure, economics, economy.

RESUMEN:

El mercado de hoy, siempre en rápida evolución, requiere un estrecho vínculo entre las decisiones tomadas en numerosos campos académicos tales como la física, la ingeniería industrial y la economía. Esta conexión debe encontrar su reflejo en la educación moderna de la ingeniería. La base metodológica subyacente para este trabajo es la teoría de los modos tecnológicos, que rápidamente cobra popularidad en Rusia hoy en día. Se demuestra que la ingeniería y el entorno económico se forma como un conjunto de modos tecnológicos, que resuelven las cuestiones de desarrollo coordinado de las tecnologías, la integración de los métodos formales y de sistemas, en particular. En el curso de la investigación, se han desarrollado modelos de modos tecnológicos dinámicos que definen las condiciones de solución para las cuestiones planteadas. Como resultado, el artículo presenta una serie de modelos que forman conocimientos de ingeniería moderna, junto con un ejemplo de un curso académico, su estructura y análisis. Además ilustra la solución a los problemas de coordinación y ofrece recomendaciones adecuadas. Palabras clave: innovación, ingeniería, modelo, multidisciplinar, estructura tecnológica, economía, economía.

1. Introduction

Continuous rapid change in the global economic system (Glazyev 1993; Laslo 2004) (emergence of Innovation economics) brings about the need for adjustments in the form of education process and structure (Volkov and Livanov. 2012; Chubais 2016). In particular, it is necessary to take into account the relationship between the processes of engineering knowledge formation and innovative market development. Today, the technical facilities begin to play systematic functions, thus, influencing the creative processes of economic environment.

For the sake of illustration, let us consider the following example: a new integrated circuit (IC) is created. Its appearance on the market causes rapid changes in the latter. As a result, new conditions for IC optimization such as new properties of a consumer, technological advances and new applications will appear. IC design undergoes further improvements and the market changes in response to them. Nonetheless, IC changes should not cause inconsistency in the business environment processes. Otherwise, the continuous improvement of IC design will stop. Hence, an integrated circuit must also have systems properties that control the consistency of market changes (coordination of the creative processes in the market).

Both, technical and systems properties of an engineering object must be coordinated. In the process, another issue surfaces: how to form a set of engineering objects, which would ensure the consistency of techno-economic environmental changes. The answer requires the examining of processes which form modern engineering knowledge, developing their models and applying them to the contents of academic courses.

These issues were already previously raised in the academic literature (Bobykina A.I., 2010; CDIO Standards 2.0, 2010; Volkov and Livanov. 2012; Theory and Practice of Knowledge-Based Economics and Sociology. Science Council under the Fundamental Research Program, 2007). They are also studied in the field of “Knowledge Management” (Marinko 2004; Nonaka and Takeuchi 2003). However, these studies neither adequately reflect the fundamental features of the development processes of Innovation economics, nor do they take into account the particularities of interaction processes of technical and economic knowledge in innovative systems development.

This article analyses the use of organization models of Innovation economics. Modern economics is based on a variety of production methods (Glazyev 1993), created by mass technologies of various nature (industrial, informational, social, etc.), that form technological modes of their own (S.J. Glazyev (Glazyev 1993; Glazyev and Kharitonov 2009). Technological modes consist of highly integrated consumer, industry and product systems (micro-electronics, information systems, internet, mass media, mass consumer technologies, etc.). Each mass technology advances alongside its technological mode, which consequently, becomes the object of engineering studies. The market contains many mass-technological modes of different scales, associated with different mass technologies and tools, which intersect and interact. Rapid and coordinated development of technological and economic environments transpires within them; emerges new knowledge, coordinated by the processes of mode perfection.

This article examines the processes of knowledge creation in technological modes of Innovation economics. It poses an interest as the technological mode theory lies at the basis of one of two variants for Russian Federation development program (Stolypin club, (Glazev 2017)). The corresponding models of engineering knowledge development were designed and are presented further in the article. They were used to create a course in microelectronics. The examination of course contents has shown that a number of important properties were provided: consistent application of mathematical modelling and expert methods applications, availability of knowledge “resonance” throughout the duration of the course, facilitation of simultaneous changes in different parts of a course, and others.

This article substantiates the importance of introducing the subjects of “System Analysis in the Innovation Economics” and “Principles of Innovation Economics” into the engineering education.

The obtained results can be used for the development of academic courses for training specialists in management of technology development in Innovation economics.

The authors are grateful to Academician S.J.Glazyev, Professor G.N.Azoev, Professor I.A. Lazarev, Professor V.V. Kharitonov et al. for helpful discussions about control over the formation of new technological paradigms in collaboration with the National Research Nuclear University "MEPhI".

---

2. Methods and Materials

2.1. Methodological Problem of Modern Engineering Development

In modern economics (Innovation economics), the dominant task is to ensure the consistency of changes, established simultaneously through the creative processes of various nature. The processes of developing the entire system of knowledge require synchronization (coordination (Thagard 2007)). In order to study the engineering in Innovation economics, the primary goal is to define its role in this task.

Coordinated development of technological and economic environment is created via two types of methods for forming the future (Bussey 2014; Bussey 2013). The first method is the description of knowledge using formal models (theoretical, logical) and the execution of modeling. Such approach is typical for the natural sciences. The main feature of formal models is that the knowledge “packed” in them, creates highly coordinated cognitive processes in different developmental directions of real economics and technological environments. Examples include formal models of Euclidean geometry. They have created a “resonance” in the development of many areas of knowledge and caused a fundamental transformation of thinking and reasoning in Ancient Greece. The mechanics of Newton-Leibniz were even more important for the creation of integration. Thus, the formation of scientificfic knowledge cannot be separated from the creative processes, which they generate in the entire technical and economic environment (Dobryakova and Kotelnikova 2015). This connection must not be interrupted in an educational process in rapidly changing market.

Nonetheless, in the process of the development of technical and economic environments (qualitative changes) many formal models lose their value and usefulness. Accordingly, there occurs the loss of coordination among the cognitive processes. The system of knowledge and economic reality are no longer in tune. Currently, there is a decline of interest in the study of formal knowledge (especially mathematics).

The second method of coordinated systems development is associated with the use of systems methods (Bussey 2014; Bussey 2013; Firstov, Akulov, Timofeev and Fedorov 2017; Sharov and Schreider 1985). Certain conditions of creative processes coordination are fixed, which leads to the generation of relations templates that support the consistency of decision-making (Bussey 2013; Inayatullah 2008; Sharov and Schreider 1985), conceptions, common parameters and indicators. These templates determine the conditions under which the creative processes are coordinated. This process enhances the reliability of the resulting expert opinions and is inherent in Humanities studies. Still, in reality, the influence of various templates of decision-making processes may prove to be contradictory, insufficient and unstable; which, in turn creates difficulties in the innovative development, where high consistency is required.

Two approaches discussed above are interconnected – each has its own functions and limitations in the process of coordinated development creation. It is important to ensure the consistency of their application. However, there is no guarantee that the patterns of decision-making will ever be able to generate enough of volume in creative processes (i.e. ensure the reliability of an expert opinion) for sufficient correction of elements and rules of formal models of a new reality. And, one can never be sure that a new set of rules and elements will exhort a sufficient effect on the creative processes, which will allow for the creation of accurate system models and templates.

Engineering science applies both of methods considered above – the formal models of physics and technology and systems approach with templates. In this respect, engineering is scientific, natural and economic discipline. Consequently, the development of engineering as a comprehensive field of study needs to be continuously and consistently coordinated within the application of formal models and systems methods in course of creation of the studied systems. The outcome of joint application of two methods should increase the effectiveness of their use.

Obviously, the solution to this problem is not based on any analytical tricks; instead, it can only be achieved due to new traits within technological and economic frameworks. It is necessary to identify the processes of the Innovative economics, which establish these traits. Their essence will form the fundamentals for the shaping of engineering knowledge and academic training.

Henceforth, the modern engineering knowledge will be examined as a knowledge system of various subjects (Physics, Economics, technology, etc.), which are coordinated by the previously discussed methods. Generally, the concept of engineering is associated with the mechanisms of knowledge generation, and not with the substantive features.

2.2. The Model of Engineering Knowledge Supporting the Innovative Development

As stated in the article introduction, modern economics is founded on mass technologies and their particular modes; and the issue of integration and coordination of the development processes is solved within these technological modes.

Coordinated knowledge (in Physics, Economics, etc.) emerges and develops within the creative processes of technological modes; that is why, in order to develop adequate academic courses, it is necessary to create models of knowledge improvement within these technological modes. The trick is that a complex mass technology is difficult to perfect as a whole, as its changes are the result of many different concerted and cognitive processes. Therefore, the modern mass technology (and its mode) is perfected as a set of production unit options (cluster, see Table 1) (Firstov, Akulov, Timofeev and Fedorov 2017).

Table 1. Basic Cluster Example

	Production Unit A	Production Unit B	Production Unit C
Production Type	Large Mass Production	Production Based On Sustainable New Technologies	Innovative Production
Consumer Type	Traditional	Steadily Developing	New

In each column some of the parameters are being perfected. For example, one plant perfects the options needed to increase the yield rate; another plant, with the same technology, perfects the options for radiation resistance. Of course, all these plants are interconnected – they cultivate the integral mass technology. The unity of perfection processes (the unity of creative processes in a production unit modification) must be ensured. This is achieved through the clusters, formed by the production units (see Table 1), where each unit is “responsible” for a certain stage of the perfection process (Firstov, Akulov, Timofeev and Fedorov 2017).

Example. Technological unit A favors the creative processes associated with past stages of economic development. Technological unit C favors the perfection of new generation technology. The two plants have different work, consumer and research standards. The improvement of mass technology as a whole allows for continuing mutual improvements of all the technological units, which support various phases of the innovation process.

As a result of mass technology impact on the Innovation economics, a curious pattern is observed – in order to ensure rapid development in the market, there are objects with systems properties of the past; and, there are also objects with systems properties which greatly support the creative processes of the present and the future (see Figure 1).

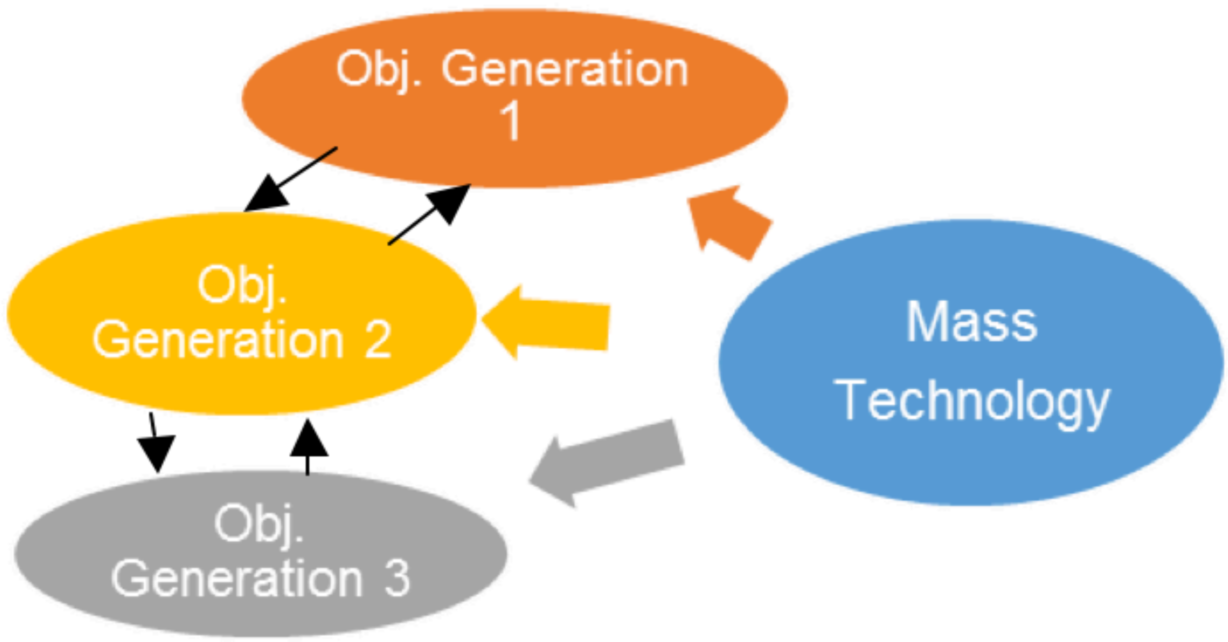

Figure 1. The Model of the Emergence of Innovation Development

In Innovation economics, it is important that all cognitive processes make up a single cognitive process without any collisions, and maintain unity of present, past and future approaches (Bussey 2013; Inayatullah 2004; Inayatullah 2008).

The coordination must occur due to the emergence of large-scale mass technology (see Figure 1), which reflects the particularity of Innovation economics. Indeed, large-scale mass technology simultaneously affects the cognitive processes associated with all the objects and removes the barriers which prevent its perfection. As a result, the cognitive processes of present, past and future are merged into one unique creative process of all generations.

Consequently, the results of using the formal and systems methods become naturally coordinated. The creative processes of different generations are associated primarily with the use of different methods. The integrating effect of technology supports the consistency of the results of their use. Therefore, the issue of coordinating the expert and formal methods use is solved due to the peculiarities of the Innovation economics.

Now, as a result of the model, presented in Figure 1, the study of knowledge (academic course content) poses an interest. The question is the organization of market content and the engineering solutions system within the framework of a course. To answer this question, it is necessary to determine the standard for the optimal effectiveness of the mechanism in Figure 1.

Detailed evaluation of such standard lies beyond the scope of this article. The essence of this standard can be described as follows: the more new solutions are considered – the more mistakes are accumulated; and, too many old solutions cause a mistake in development strategy. Hence, the methods of different generations need to be balanced ((Firstov, Akulov, Timofeev and Fedorov 2017; Sharov and Schreider 1985), as it facilitates the balance in the creative processes. The balance is defined by the number of objects from different generations which falls within the Zipfian distribution (Malevergne, Saichev & Sornette 2013; Sharov and Schreider 1985).

Consequently, it follows that academic training courses should address engineering science within the framework of techno-economic environment and pursuant to the respective models in Figure 1 and the systems criteria.

3. Results. The Structure of an Engineering Course

Let us consider a simplified version of an academic course structure where the only covered topic is the integrated circuit processors of signal processing (i.e. integrated knowledge of physics, circuit design, architecture, production organization and their practical applications).

Fig. 2 shows the composition of a technological environment, which, according to the simplified model in Figure 1, develops in the following way: on the basis of optimized mass technologies, the integrated circuit special processors are created for the optimal solution of well researched consumer needs (Figure 2, segment A). Such integrated circuit processors quite adequately reflect the characteristics of processing algorithms and application options of mass production (Figure 2, segment A represents the "past" generation). An array of well-coordinated physical effects, engineering solutions, specific algorithms, etc., which create "resonances" in knowledge development are applied, and coordinated standards for decision-making are ascertained. Systematic approaches prove to be effective – they allow for the use of expert opinions and common examples as means for the justification of new knowledge. This demonstrates the particularity of knowledge presentation methods.

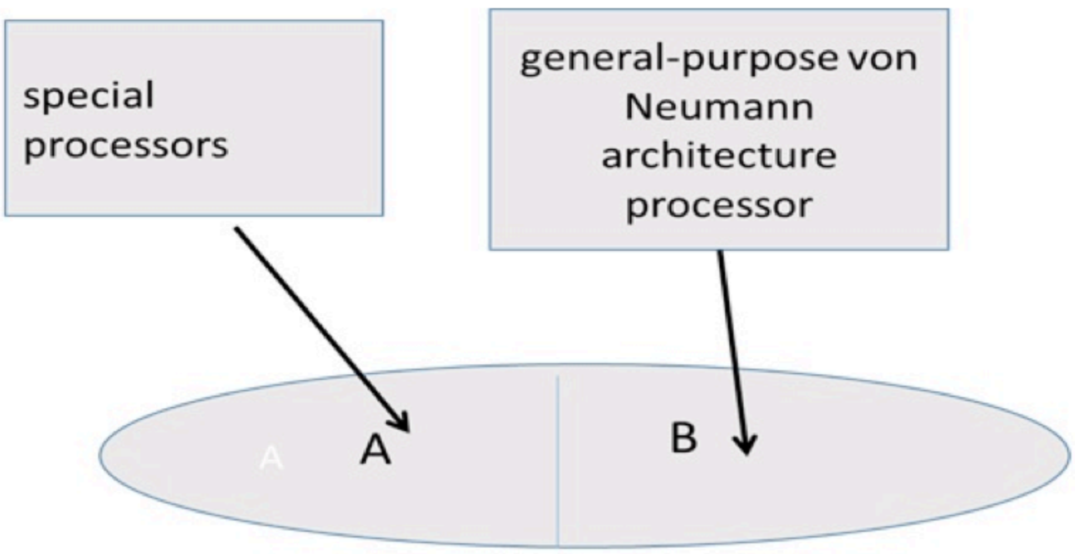

Figure 2. The Model Of Coordinated Expansion Of Technological Mode For The Methods Of Signal Processing

Still, as the complexity of segment A grows, it becomes harder and harder to keep the body of knowledge intact; that is why, it is important to demonstrate the mechanism, which controls its coordinated development. In order to achieve this, the model of further development needs to be considered.

The pool of tasks now expands (Figure 2, segment B); the environment of segment A, focused on the solutions of previously researched tasks, will likely not be able to solve new tasks from the segment B. Systems development can come to a halt, as it is difficult to create an integrated circuit of an additional specialized processor without sufficient experience in solving problems from segment B. For this reason, a universal integrated circuit, which is able to solve segment B tasks, should be introduced into the system. In can be a simple general-purpose von Neumann architecture processor, which consistently performs same-type minor tasks. Consequently, a set of algorithms can be designed, which will not require any new technical solutions for its implementation and simplify the study of new tasks. This presents an opportunity to experiment with physics and circuit design applying well-studied tasks and improving the quality of the system. Thus, segment B represents the area of the "future" research in course of technical and economic development.

The main feature of segment B is that it is designed as a combination of same-type instrumental solutions, operations and sets of algorithms, that is why it represents the area of formal (mathematical) modeling; and, this determines the characteristics of its study. Accordingly, within the system of processors, there is a segment B, which is a research tool of the “future;” and, there is a segment A, which operates with already existing knowledge and brings the “past” into the process of systems development. Segment A represents the performance effectiveness of systems methods; segment B represents the area of effective application of formal methods.

4. Discussion

For these reasons, the academic course covers physical, technical and mathematical topics with respect to two different but related segments of integrated circuit market. What actually is being taught are two coordinated streams of knowledge, which complement each other in their development. This allows for the study of different segments with the use various methods, and the selection of specific criteria in the choice of study materials. For example, in order to assess the quality of segment A development - expert evaluations can be used; and, for the assessment of segment B - Moore’s law should be applied (Sneed 2015). As a result, coordinated study of various types of knowledge is simplified.

However, it is necessary to constantly ensure the coordination of studied segments. It can be achieved by implementing the system criterion stated above (see Section 2, paragraph 2). This assures the preservation of coordination and the “resonance” of knowledge, studied with different methods. In order to resolve the problem of preserving the continuous integration of creative processes, and, hence, the coordination of segment properties, the systems analysis must be used.

It should be noted that the main aim of systems analysis is to assure the coordination of a multitude of solutions, creative processes and objects. In Innovation economics this aim is achieved naturally as the mechanism of instrumental (engineering) environment sets in (Figure 2). So, the instrumental environment of the Innovation economics becomes the fundamental object of systems analysis research.

Systems analysis is both, a scientific and an economics discipline as it examines the forming of physical properties of an object in combination with creative (cognitive) processes. This produced some difficulties in its development. In the Innovation economics, systems analysis is becoming a strong discipline due to resolving the coordination problem between formal and systems approaches. This opens the possibilities of studying the questions of optimization process for the formation of the instrumental environment. For this reason, in addition to a course in engineering, there should be a course in “Innovation economics: Systems Analysis.” Besides, it is useful to add a course “The Principles of the Innovation economics” which discusses specific cases of the effects of instrumental environment of the Innovation economics on the reorganization of economic, social and other relations.

5. Conclusion

The transition to new global technological and economic way of life changes the processes of perfecting the economy. This is the most important innovation and a key resource. As a result, emerges the type of engineering knowledge, which jointly studies economic and technical features of an object. This knowledge is formed within economic and technical framework, which satisfies the specific models of Innovation economics.

The development of the Innovation economics brings about the revolution of systems analysis. As a result, emerges the foundation for the analytical administration of an engineering knowledge development. This should find a reflection in the content of education.

Academic courses in graduate schools should provide knowledge filled with models of innovative improvement of technological structures in the fields of a students’ research. It would simplify the processes of delivering and understanding the knowledge and increase the possibility of fast and coherent improvement of the course content. Also, it allows to connect the theory of engineering studies with the practical tasks, which are formed in a developing market of a new economy.

The obtained results show the particularities of an educational process of future engineers in high-tech business of the Innovation economics.

References

Bobykina, A.I. (2010). Innovative Strategy of the Development of Higher Education. *Contemporary higher school: innovative aspect,* 1: 57-67.

Bussey, M. (2014). Conceptual Frameworks of Foresight and Their Effects: Typology and Applications . *Foresight Russia,* 8 (1): 75-78 .

Bussey, M. (2013). Causal Layered Analysis: Towards a Theory of the Multiple. *Foresight Russia*, 7(3): 73-75.

Chubais, A.B. (2016). *Technological Entrepreneurship and Global Technology Trends.* Open Lectures at eNANO. Data View 17.04.2017 http://edunano.ru/doc/6276378079627921512/

CDIO Standards 2.0. (2010). Data View 17.04.2017 http://www.cdio.org/implementing-cdio/standards/12-cdio-standards

Dobryakova, M. and Kotelnikova, Z. (2015). Social Embeddedness of Technology: Prospective Research Areas. *Foresight Russia,* 9 (1): 6–19.

Firstov, Y.P., Akulov, D.S., Timofeev, D.S. and Fedorov, P.L. (2017). The specificity of solution selections for long-term projects in Innovation Economics. *Economic systems management,* 3: 10-15.

Glazyev, S.Y. (1993). *Theory of Long-term Economic Development*. Moscow. VlaDar, pp. 391

Glazev, S.Y. (2017). *Strategy for russian growth in the context of the global economic crisis.* Moscow: Economy, pp: 245 .

Glazyev, S.Y. and Kharitonov, V.V. (2009). *Nanotechnologies as a Key Factor of a New Technological Mode in Economics.* Moscow: Trovant, pp. 256. .

Inayatullah, S. (ed.) (2004). *The Causal Layered Analysis (CLA) Reader: Theory and Case Studies of an Integrative and Transformative Methodology.* Tamsui, Taiwan: Tamkang University Press, pp. 247

Inayatullah, S. (2008). *Mapping Educational Futures: Six Foundational Concepts and the Six Pillars Approach Alternative Educational Futures: Pedagogies for Emerging Worlds.* In M. Bussey, S. Inayatullah, I. Milojevic (Eds.). Rotterdam. Sense Publishers, pp. 13–41.

Laslo, E. (2004). *MacRosdwig (Sustainability of the World Through Changes).* Moscow: Tidex Co, pp. 301.

Malevergne, Y., Saichev, A. and Sornette, D. (2013). Zipf's law and maximum sustainable growth. *Journal of Economic Dynamics and Control,* 37: 1195-1212.

Marinko, G.I. (2004). Contemporary Models and Schools in Knowledge Management. "*Vestnik of Moscow State University", Upravlenie (State and Society)*, 21 (2): 45-65.

Nonaka, I. and Takeuchi, X. (2003). The Knowledge – creating Company: How Japanese Companies Create the Dynamics of Innovation. Moscow: "Olymp-Business", pp. 384.

Sharov, A.A. and Schreider, Y.A. (1985). *Systems and Models*. Moscow: Sovradio, pp. 356.

Sneed, A. (2015). Moore's Law Keeps Going, Defying Expectations. Data View 17.04.2017 http://www.scientificamerican.com/article/moore-s-law-keeps-going-defying-expectations/.

Thagard, P. (2007). Coherence, Truth, and the Development of Scientific Knowledge. *Philosophy of Science*, 74: 28–47.

Theory and Practice of Knowledge-Based Economics and Sociology. Science Council under the Fundamental Research Program, Presidium of the Russian Academy of Sciences "Economics and Sociology of Knowledge". (2007). Moscow: Science.

Volkov, A. and Livanov, D. (2012). *Bet on the new content*. Data View 17.04.2017 http://www.vedomosti.ru/opinion/news/3499241/stavka_na_novoe_soderzhanie?full#cut

---

1. National Research Nuclear University "Moscow Engineering Physics institute", 115409, Russia, Moscow, Kashirskoye shosse, 31. E-mail: firstov_y@mail.ru

2. National Research Nuclear University "Moscow Engineering Physics institute", 115409, Russia, Moscow, Kashirskoye shosse, 31. E-mail: oam0703@gmail.com

3. National Research Nuclear University "Moscow Engineering Physics institute", 115409, Russia, Moscow, Kashirskoye shosse, 31. E-mail: akulovds@mail.ru

4. National Research Nuclear University "Moscow Engineering Physics institute", 115409, Russia, Moscow, Kashirskoye shosse, 31. E-mail: tis12693@gmail.com

5. National Research Nuclear University "Moscow Engineering Physics institute", 115409, Russia, Moscow, Kashirskoye shosse, 31.

Revista ESPACIOS. ISSN 0798 1015
Vol. 38 (Nº 40) Año 2017