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Research Article

TEACHING PHYSICS AT A MANAGEMENT FACULTY OF PHYSICS AND ENGINEERING UNIVERSITY

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ABSTRACT

In today's increasingly integrated technological market, the focus of study at a Physics and Engineering University expands to encompass the industry in its entirety and diversity. Apart from scientists and engineers, the University now prepares managers, economists and experts in business and computer science. These specialists need to have sufficient knowledge of physics and science in order to work with engineers and manage the development of technologically oriented economic systems.

This requires specific organization of academic and course curricula in physics and science. They should address matters, relevant for managers and directors – e.g. what facilitates scientific development; the modes, in which scientific research promotes knowledge development, and other essential issues of innovative development.

This article discusses the challenges and methods which help to conform the delivery of scientific subjects to future manages and economists. Further, it offers suggestions and recommendations.

INTRODUCTION

In today's increasingly integrated technological market, the focus of study at a Physics and Engineering University expands to encompass the industry in its entirety and diversity (Firstov, *et al.*, 2017a). Apart from scientists and engineers, the University now prepares managers, economists and experts in business and computer science. At the National Research Nuclear University MEPhI, the education of engineers and physicists has long been perfected. Presently, the pressing question is the training of managers-engineers-physicists. This demands the reorganization of educational process at the Economics and Management Faculty.

New subjects of study now are technologically economic systems, i.e. economic systems which stem from the technological sphere and are perfected in coherence with technological development.

Work experience at the Management Faculty at MEPhI (the Institute of Economic Analysis) reveals that quality management in modern field of technology requires solid knowledge of physics and engineering. But, management education has its own methodology and objectives. The challenge is to develop courses that adequately present scientific subjects in a way which is compatible with economics education. Due to continuously growing integration (coherence (Thagard, 2007) of technologically economic systems, students demonstrate an increasing desire to learn physics and engineering in the context of management and economics knowledge. This demands a conceptual

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connection between the subjects, which simplifies their understanding from the point of management science. As Innovation economics (Tonn, 2004) develops and management and economics education is changing, this connection becomes especially important (CDIO Standards 2.0, 2010; Volkov and Livanov, 2012; Dobryakova and Kotelnikova, 2015).

For instance, let us take a course in general physics. Its outline follows natural and logical processes of scientific explorations of an inquisitive mind and, therefore, entirely fits into the methodology of a scientific education. On the other hand, managers and economists require essentially different approach. They should understand physics (science) as means for answering such questions as what facilitates the scientific development, how scientific knowledge is managed, how engineering decisions are made, and other essential queries of innovative development.

Effective teaching requires us to remove the differences in scientific and humanities education methodologies. It does not entail the application of scientific models in economics (econophysics (Kharitonov and Yezhov, 2007; Bouchaud, 2008), nor does it involve the commingling of physics (and engineering) education with economics and business organization tasks (Chubais, n.d.). The unity of scientific and humanities knowledge must occur on a much deeper level.

The importance of interdisciplinary unity becomes particularly evident in Innovation economics. Its study requires the coordination of multiple simultaneous and coherent changes, which occur in different spheres. We can expect that the unity can be reached due to mechanisms of the emerging economy. That is why, scientific education should include the study of knowledge development models of Innovation economics.

The objective of this article is to analyze the characteristics of scientific education for managers, specializing in innovative development of technological industry. We will study the models of ideal Innovation economics for the purpose of establishing the connections between physics and management knowledge and use the theory of technological modes, currently popular in Russia (Glazyev, 1993; Glazev, 2017; Glazyev and Kharitonov, 2009). Further, we will identify important aspects of scientific studies, which should be used in management, economics and computer science education. The findings of this article may be used in development of educational processes.

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MATERIALS AND METHODS

The comparison of science and humanities knowledge and education

At the very introduction of scientific subjects to management students, we need to make clear the nature and importance of unity between science and humanities. The best way to address this is by posing the following questions: what integrates technological and economic systems?; and, what coordinates and steers the cognitive processes of these systems? (Firstov, *et al*., 2017a; Firstov and Khusniyarov, 2014) It is also important to determine the role, each subject plays in the process of integration, which will subsequently define physical properties that make it into one united whole. Let us consider the example below.

Initially, the integration of complex economic systems was implemented through humanities methods (humanities mechanisms). For the sake of illustration, let us name such mechanism a “Tsar.” Life of a “peasant” was defined by the world of “Tsar’s” creation. With time, however, the definitions of “Tsar’s” world became insufficient. As technological innovations emerged, “peasant’s” life could no longer be defined as before; the integration of technology and life demanded a new approach.

A new approach had to be an integration method, which coordinates cognitive (creative) perceptions without “control from the top.” Its essence must lie within the material world (the scientific integration mechanism (Firstov and Khusniyarov, 2014). Indeed, once we are introduced to the laws of physics or Euclidian geometry, our actions become coordinated. Science and humanities are the integration tools; they interact and that is the essence of their unity (Firstov, *et al*., 2017a; Firstov and Khusniyarov, 2014). Just like the Euclidian geometry, they create a school of thought which unites the development of knowledge in many different spheres.

Another example would be Newton’s Laws – they have united the world of mechanics, which sparked the interest in nature and its phenomena. As a consequence, emerged the philosophy of Diderot, the school of European medicine (equating human body to a mechanism); the mentality of a European man was formed. The combined knowledge of science and nature thus, integrates the development of many cognitive processes.

For a manager it is important to optimize the process of physics development, in order to optimize the integration. The course in natural science must demonstrate how such subjects as physics and mathematics affect the coherence in different fields of knowledge and vice versa.

Euclidean geometry would make a good example. New technologies emerged in the process of a cognitive effort. These technologies removed the necessity of straight beams, point fixings, exact measurements of angles and joints etc. A new thought was developing as a set of points, segments, straight lines etc. Geometrical proof now became the requirement for a technological solution. Such an integrated world made possible the creation of mass technologies and provided opportunities of rapid development for the technologically economic system as one united whole (Firstov, *et al*., 2017a; Dobryakova and Kotelnikova, 2015; Firstov and Khusniyarov, 2014); the development, which comprehensively contributes to the development of physics research.

A management student must see the relationship among management, economics and scientific knowledge. We should note that economics is the study of motivation and coordination (coherence) of cognitive processes (Firstov and Khusniyarov, 2014). Profit is merely an indicator of this coherence. Physical qualities of an object determine its ability to generate cognitive processes. It is helpful to demonstrate how a physics discovery incorporates the development mechanisms of technologically economic environment. This defines the development of a science course for engineers-managers as well as certain aspects, which require further closer examination.

The presentation of scientific knowledge within the framework of management models of innovation economics. the unity of physics and systems qualities

Knowledge integration in modern economics defines the characteristics of a physical object analysis. It is illustrated in the example below.

A new integrated circuit (IC) is created. Its presence causes rapid changes on the market – the emergence of new consumer trends, technological potential etc., which, in turn, creates the conditions for IC improvement. New physical phenomena are now studied, IC is improved and market is altered. It should be noted that the IC change must not bring any inconsistency into the business processes of economic environment; otherwise, the continuous improvement of IC will halt. Hence, the integrated circuits now have two functions – the primary applied technological function and the market change coordination control function. Consequently, the ICs must possess the systems qualities. The stronger the integration of technological and economic environment of a market, the more accurate and profound is the knowledge of the physical world.

It is necessary to ensure the coherence of both, technical and systems properties of an engineering object. The question is how to form the complex of engineering and physics objects (knowledge) preserving the coherence (Thagard, 2007) of changes in technological and economic environment (Firstov, *et al*., 2017a).

This poses the challenge of continuous identification of multiple directions in physics development - the directions which facilitate the greatest effect in the optimization of physics development, which rises a few interesting points.

At first, let us look at physics and economics as an environment for the research of coherent changes. For example, in gravitational field, the changes of all objects (coordinates, velocity etc.) represent a united whole. The same happens in Innovations economics, though here we speak of technological modes (Glazyev, 2017; Glazyev and Kharitonov, 2009). Modern products and mass technologies possess an extensive integrating influence on the development processes of consumers, suppliers et al. For instance, technologies and products in microelectronics exert an integrating effect on the development of many industries (Firstov, *et al*., 2017a; Glazyev and Kharitonov, 2009). Thus, emerge technologically economic modes and integrated cognitive processes, which are coordinated through physical knowledge – the field of technological mode. The integration of these fields and their interrelation becomes important in Innovation economics.

The need for simultaneous analysis of physics and systems properties raises the question of unity of formal (mathematical) and systems approaches – the unity of formal and expert research methods (Firstov, *et al*., 2017a; Bussey, 2013; Inayatullah, 2004). The question is crucial for the future managers. Regrettably, in science courses, the questions of hypothesis origination, proof of their validity etc. are rarely raised. Science majors treat the use of expert methods as manifestation of inability to reach a formal result. Managers should not take this position. In science course for managers, the unity of formal and systems methods is inseparable; and, Innovation economics facilitates the coordination of these two methods (Firstov, *et al*., 2017a; Inayatullah, 2004).

It is necessary to clearly demonstrate the strengths, limitations and unity of the two methods in a scientific development. New knowledge, formed via formal (logical, theoretical) models has its limitations. As technological environment develops, many formal models become impractical and lose their coherence with corresponding cognitive and creative processes (Firstov, *et al*., 2017a; Bussey, 2014; Bussey, 2013).

Systems approach secures conditions for the coherence of cognitive processes, derived from the experience of scientific development. It establishes certain templates, which support the coherence of decision-making processes (Firstov, *et al*., 2017a; Bussey, 2014; Bussey, 2013). In fact, many physical models are the result of accumulated research processes. For example, an abstract liquid drop model of nucleus is the result of compilation of multiple research results. Systems approach does not focus on an internal structure of an object; it merely provides a convenient tool for further research and improves the consistency of expert opinions. However, the effect of different concepts (templates) can often be contradictory and insufficient.

The two approaches discussed above are interrelated. Each has its function in the process of coherent development. The issue is to ensure the coordination of their joint application. The use of one approach should remove the limitations of another; their implementation needs to complement each other.

A natural science course for management majors should address joint coherent application of the two methods. Article 1 discusses the conditions, which Innovation economics creates for the development of technological environments and fostering the coordination of the two methods; and, its increasing importance for the scientific development in today's highly integrated market.

RESULTS

The unity of formal and expert analysis in physics (Science)

The understanding of unity of formal (mathematical) and expert analysis is becoming crucial for managers. The issue of coordinated application of formal models and expert research should be studied within the framework of scientific development. Partly, it has been discussed in articles 1, and 16.

Coordinated perfection of knowledge transpires within each technological mode, where conditions for the coherent application of formal and expert methods are formed. It is pertinent to study the features of physical processes, which maintain the perfection of a technological mode. Physical processes of mass application must form the technological modes. That is why, their models must correlate with the models of the perfect technological modes. This would allow for the determination of common traits in models, supporting the unity of development in scientific and economic environments. Let us briefly look at the model for the formation of a simple technological mode in an ideal Innovation economics.

The dynamics of a scientific object in the field of economics: The model of a simple technological mode

A simple technological mode (see Pic. 1) is formed by a scientific object of mass application – a production unit, technical or an organizational tool etc. (Firstov, *et al*., 2017b) - henceforth, a mass instrument. It is perfected in course of an ongoing process of scientific research, production, workforce experience and others.

The perfection of a complex mass instrument is a complicated process. It is researched and perfected in a variety of ways (special instruments sI), each of which focuses on a particular consumer issue (Fig. 1). Each consumer issue has multiple sIs for its resolution. When there are many issues, there is a whole cloud of sIs. In order to perfect all of possibly applicable sIs, a great amount of scientific research must be done in various fields. One way of doing it is using the cloud projection.

The analysis of sIs reveals that some of them have similar organizational structure. This leads to the development of a mass instrument (mI), which encompasses several sIs with comparable organizations – now there is an instrument of mass application. When various sIs are combined into one mI, the technological structures are combined along with cognitive processes of a market, which now begin to operate in coherence with each other.

As a result, the MI outperforms all the sIs that it consists of, as it permits to attract large amounts of resources and financial investments for its perfection. With proper support an mI and its production technologies may be perfected, which includes a change of consumer objectives for more convenient application of an mI and further development of cognitive processes for the perfection of sIs.

Accordingly, in an ideal Innovation economics, the perfection of some physical object and its technological mode proceeds in a continuous cycle, that includes the variations of consumer objectives,

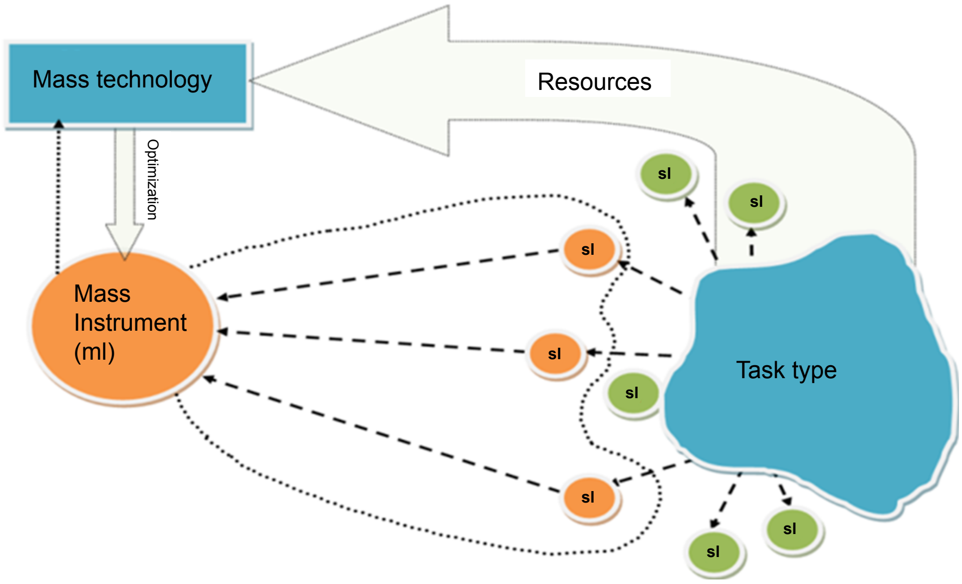

Fig. 1 The model of technological mode perfection (mI – Mass instrument; sI – Special instrument.

instruments, production technologies and physical knowledge; and, scientific development occurs within this continuous cycle. This brings up the key question: what are the optimal conditions for the development of scientific knowledge?

Optimization criteria for the perfection of scientific knowledge: The condition of expert research reliability

In order in achieve the optimal perfection of a mode (and a credible expert opinion), there needs to be a balance of new (future), medium (present) and traditional (past) tasks. When there are too many new tasks, mistakes will accumulate; when there are too many traditional tasks, wrong benchmarks will be set. The number of tasks in each generation must be balanced, which ideally should follow the Zipfian distribution (Sneed, 2015; Sharov and Schreider, 1985). The same balancing condition must apply to the instruments and technologies.

Next, we will discuss the establishment of conceptual connections between this (economics) and physics models in a scientific academic course for management majors.

It should be noted that the economics model considered above also covers the question of expert research reliability. Expert knowledge is considered reliable when all the cognitive processes in a mode are coherent. Consequently, expert knowledge is reliable when the number of elements in each generation follows the Zipfian distribution. Note that the allotment of tasks, instruments and technologies per generation can be done by a pool of experts. Yet, such expert pool is generated in the conditions of generation balance (i.e. coherence of cognitive processes). Therefore, the reliability of expert knowledge lies in the continuity of generation balancing as a mode is being perfected.

Thus, in ideal Innovation economics, there is a formal condition for the reliability of an expert research in the process of object perfection (either scientific, or economic).

A natural science academic course for managers should touch on such topics as the conditions for the optimal process of scientific development in light of technological modes and the conformity of physical process models and their technological modes. It is important to convey the semantic connections which govern the coherence of a learning process.

DISCUSSION. MODEL INTERPRETATIONS

Let us consider some examples of semantic connections, valuable to future managers. An example from nuclear physics may help establishing an analogy with technological modes. An electron can be fixed in an atom only at certain levels – just as a mass instrument (MI) is fixed as "valuable" for the economy only on the level of technological mode.

Based on a common model of a technological mode (see above), "the field" is a space, where the elements of mass application are continuously formed and updated. In physics, such elements would be electrons, atoms, stable compounds etc.

The condition for coherence in change processes is the simultaneous presence of an object in past, present and future while steadily maintaining the balance. The continuous balance of all objects indicates that they are in a common field.

Another analogy can be drawn with Newton's laws. A physical body has properties, associated with its state in the past (inertia), the present (power and speed) and the future (acceleration). The body is simultaneously in different time segments. All states are integrated and belong to one field (e.g. gravitational field). Newton's laws demonstrate the condition that past, present and future states of an object are in coherent balance. Newton's laws establish the condition for the reliability of an expert research.

Another point of interest is the connection between the models of physical changes and dynamics of technological modes. The model considered above suggests that the motion is a continuous and simultaneous state of an object, associated with past, present and future.

Let us consider the motion of an electric current. There are inductors, capacitors and resistors in an electric circuit. In an inductor, the current changes slowly as the ongoing processes are mostly associated with the past state of a signal. The capacitor produces high-frequency components, which are future-oriented. The current in a resistor reflects the present state. The current flow occurs on the condition of balance among capacitance, inductance and resistance.

Another example is the mass output (production) of electronic elements, there is always a difference in certain parameters of each sample. A sample with better parameters indicates the potential for improvement in production technologies. Samples with lower quality parameters reflect the influence of the past and deficiency of the perfection process. The optimization of perfection process requires it to be balanced. It should include the technological capacities of the past (ensuring the sustainability of already existing mass production) and the future (mildly incoherent modernized production options). The yield of samples with different parameters creates the balance.

Physical examples illustrate clear conceptual connections, which can be used in such academic courses as systems analysis, innovation economics management and many others.

CONCLUSION

Modern economics demands the optimization of physics development processes and purposeful reestablishment of technological sector into a state, adequate for the ideal Innovation economics. This requires special training of future managers of technologies. The study of physics and natural science are important, but the study of physics knowledge-generating processes is crucial. These processes should be studied in cohesion with economics and business knowledge. Here, the models of Innovation economics and technological mode theories should be used as they define the conditions for coherence in knowledge formation while technological modes focus on the integrational issues.

Effective training of future managers demands presentation and clarification of unity in physics and systems features of an object, formal and systems methods, mathematical and expert research. These matters are better taught using the principles of general physics on the basis of Innovation economics. Natural simplicity of physics and definiteness of common models in Innovations economics form the ideal academic basis of a natural science course for management students. It could also be useful to employ the conceptual connectors, which would help the creation of a conceptual framework for the study of systems analysis, technological management and other subjects.

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