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Development of Methodical Materials for Teaching of Modern Physics

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Abstract: In the paper, the results of a study into a problem of cognitive barriers (difficulties) related to the third component of a pedagogical triad "how to teach what to teach to how to be learned study" are reported. At the first stage, methodical approaches to academic performance rating for students learning mathematical and natural-science disciplines were proposed. At the following stage, the cognitive barriers of students arising in the course of studying the specified disciplines were established. The results, obtained during realization of the above two stages were used as a basis for the development of methodology for teaching the discipline "Concept of modern natural sciences", which is intended for the students of humanitarian and economic profiles. The core of the methodology for teaching the mentioned discipline is a theoretical course, guided by the fundamental ideas of physics, which have been formulated conceptually. Also, the content of a special course entitled "Physical foundations of new composite materials" is disclosed. The special course is intended for senior students of the technical universities studying in the directions training technical officers of industrial productions. The purpose of this course is to give to students the basic knowledge on the physical phenomena of material world of nano - and microscales, which are used for design of the advanced materials.

Keywords: C*ognitive barriers; Modern physics; Physics course*

Introduction

A crucial moment in the development of modern science is ever-increasing body of information. Having arisen in the ancient world in connection with requirements of public practice, the science has turned into the productive force and the major social institution exerting considerable impact on all spheres of society and culture. Since seventeenth century, when thanks to works, first of all, of the outstanding Italian scientist Galileo Galilei the foundation of natural sciences has been laid, the amount of scientific activity doubles approximately each 10 – 15 years (growth of discoveries, scientific information, and number of researchers) (Voronov, & Podoplelov, 2005). Already by the middle of the twentieth century, huge scientific material has been accumulated. Since ninetieth years of the twentieth century, a rapid development of nanoscience is triggered, which now we witness. In this regard, application scope of the scientific achievements in various spheres of human activity significantly extends. This circumstance necessitates the training of the corresponding technical personnel, experts for other enterprises and the organizations.

A consequence of rapid growth of the information amount is ever-increasing gap between the level of knowledge reached by science and contents of teaching disciplines in educational institutions of different level (schools, average special educational

institutions, universities). Therefore, introduction of new scientific achievements in training process of the universities (especially of technical and natural-science profile) represents a challenge. Indeed, these universities should teach high-skilled personnel at the level of chief specialists (engineers, technologists, and economists), heads of various profiles of the enterprises and organizations.

All the above has prompted (about twenty years ago) a group of scientific and pedagogical employees of the Irkutsk National Research Technical University (Irkutsk), the International Tomographic Center, Siberian Branch, Russian Academy of Science (Novosibirsk) and Bratsk State University (Bratsk) to prepare of the study materials for universities that would cover the advancements of physics for approximately fifty – sixty years, since the middle of the twentieth century. The specified period is characterized by emergence of numerous new fields of knowledge, in particular, nonlinear optics, physics of open systems, quantum information, as well as fields related to study of molecular structure and dynamics. Impressive results have also been achieved in the field of astrophysics. When this group (the head – V.K. Voronov) started to work, there was rather extensive scientific literature on new sections of knowledge, e.g. original papers and reviews published in specialized periodicals. However, this literature was intended mainly for experts. As for the study materials, they were almost lacking. Earlier, the results of the studies devoted to specific research topics have been published by us in a number of papers. In the present review, we have summarized the previous results on preparation of the study and methodical materials.

Here, it is pertinent to note that three participants of group (V. K. Voronov, A. V. Podoplelov, and R. Z. Sagdeev) were awarded in 2015 the Prize of the Government of the Russian Federation in the field of education for the work "Preparation of the study materials "Modern Physics" for technical and natural-science specialties of universities".

Methodology of Research

At a moment, a huge number of methodical papers of pedagogical orientation has been prepared and published. Obviously, the number of promoted theses on this topic is not less. However, as we know, the problems in education do not decrease. At the same time, quality of training of university students (and not only) becomes worse. This was repeatedly stated not only by the Russian public, heads of the enterprises and organizations employing university graduates but also by the top officials of our state. There is a question: "What are the reasons of such situation?" Search for the answer to this and other questions has led researchers to a thought that the problem consists not only in the one who teaches, but also in the one who learns. From the point of view of pedagogics, it is extremely important not only what and how to teach, but how to be learned. Thus, the pedagogical triad how to teach, what to teach and how to be learned has been formulated.

This triad in its present version exists for about twenty years. However, the researches in this direction were conducted much earlier. In particular, it is assumed that landmark was a complementarity principle introduced to pedagogics in 1993 (similar to the Bohr complementarity principle in physics). At last, in 1997, the cognitive barriers caused just by the third component of the above triad have been formulated. Actually, thanks to the researches carried out, first of all, by A.A. Pinsky, A.I. Pilipenko, G.G. Granatov,

V.A. Popkov, A.V. Korzhuyev, E.V. Shevchenko, the new scientific direction in pedagogics has been outlined (Korzhuyev, & Shevchenko, 2000; Popkov, & Korzhuyev, 2004). Authors of this work consider this direction as extremely promising from the point of view of carrying out the demanded scientific researches, at least, in particular those devoted to the problem of university students teaching. In fact, it became obvious, that there are not only regularities of understanding of the training material, but also regularity of its misunderstanding. Therefore, in the course of the organization (planning) of training process it is necessary to consider those distorted views and representations, which can arise and surely arise at students owing to manifestation of cognitive barriers inherent in them. The above mentioned scientific direction is mainly focused on a problem of the cognitive difficulties connected with the third component of a pedagogical triad "how to teach, what to teach and how to be learned ". The demand for the researches related to a problem of cognitive barriers in training of the university students is connected, first of all, with active process of commercialization of educational process in Russia. Other reason of such demand is a consequence of the actual destruction of the Soviet education system including the obligatory system of selection through which high school graduates have passed.

Cognitive Barriers in Teaching, Their Identification and Overcoming

In the course of training, the information can be perceived, or, for some reason, not to be perceived. Besides, it can be incorrectly interpreted or simply misunderstood during its processing. Consequently, the corresponding negative phenomena in cognitive activity of a student are formed. It is proposed to designate these phenomena as the cognitive barriers, i.e. as a set of the phenomena, which negatively influence the subjective and cognitive opportunities of the student. In reality, an indicator of such barriers manifestation is a degree of intellectual readiness of the student for understanding of training materials. Having revealed the specified readiness, it is possible then to elucidate manifestation of different cognitive barriers, which the students face during the training process.

There are four levels of the problem connected with the third component of the above-mentioned pedagogical triad. The first level is types of the barriers per se; the second one includes signs of their manifestation; the third level (we suggest to name this technological level) relates to the methods for identification of the cognitive barriers. If the first two levels can be considered as comprehensively studied, the third level is in this regard still open for research. And, at last, the fourth level, at which the first three ones focus, reflects manifestation of the barriers in real training process. A need for such researches is dictated by relevance of a problem of the cognitive barriers at the technological level.

One can state that by the end of the ninetieth years of the twentieth century, the investigations into a problem of the cognitive difficulties have reached a stage, when a need for direct employment the actions, directed to overcoming the mentioned barriers, in the organization (planning) of training process became obvious. It is clear that for this purpose it is necessary to have the corresponding approaches, which by the beginning of our researches (Gerashchenko, Voronov, & Chang, 2003; Gerashchenko, Voronov, &

Petrovsky, 2004; Gerashchenko, Voronov, & Chang, 2009), have not been developed yet.

Our approach to identification of the cognitive barriers of students includes three stages: 1) collection of the primary information; 2) the statistical report and processing of the obtained primary information; 3) analysis of the statistical information. The first stage of a research was carried out by a poll method on the basis of the test tasks including ten questions (Gerashchenko, Voronov, & Chang, 2003). The poll is an irreplaceable method for obtaining information on the world of people, their addictions, motives of activity, opinions. In some ways, it is universal method: it can be used for obtaining any information. However, at the same time, it should to take into account that the information obtained via poll contains subjective opinions and estimates, which are subject to hesitations. It depends on of conditions of the poll performance and other circumstances. Therefore, at the second stage of the research, the collected information was statistically processed, i.e. systematization and arraying according to the main signs of similarity. At the third stage of the research, statistical information was analyzed using descriptive and mathematical methods. 1417 students (1191 full-time students and 226 off-site students) participated in the experiment.

According to the existing ideas, successful application of the statistical methods for the analysis of experimental results very often depends on combination of two conditions. The first of them is the usage of whenever possible small amount of parameters (criteria), on the basis of which the database for processing is collected. The second condition is that the chosen criteria should reflect most fully the information, which is supposed to be received in the course of the statistical processing. The analysis of the answers to our questionnaire received during a three-year cycle has allowed us to select such criteria of integrated character: 1) school level of knowledge of the interviewed students at school; 2) desire to study; 3) disposition to studying of natural-science and (or) humanitarian disciplines; 4) interest in a subject. From the point of view of the cognitive barrier theory, our experimental data and their analysis have allowed to reveal the cognitive barriers in students, which are caused by technological style of thinking, i.e. “prescription thinking”. The latter appears to hinder the development of deeper productive thinking. In this case, even well-absorbed system of knowledge and skills is perceived by a student as a game in the correct answers to the correct questions. However, before the "correct" question formulated in an unusual form, the student is down and out. The analysis of the collected databank permits us to also reveal existence of the cognitive barriers of historical type in university graduates. From the methodical point of view these results give a reason to use the historical aspect of science development for optimization of the training process. Our researches have allowed us to eventually reveal the cognitive barriers (difficulties) formed in students during studying a cycle of mathematical and natural-science disciplines including disciplines of "Concept of Modern Natural Sciences", which is usually intended for the first-year students (Voronov, & Gerashchenko, 2013; Voronov, Grechneva, & Gerashchenko, 2013; Voronov Grechneva, Podoplelov, & Sagdeev, 2016).

Training Program of a Special Course "Physical Bases of New Composite Materials"

Another result of our scientific and methodical activities for introduction of new scientific achievements to training process in universities is the compilation of a special course entitled "Physical Bases of New Composite Materials". The purpose of this course is to give to the students the information on the physical phenomena of a material world of nano- and microscales, which constitute the basis for design of new advanced materials. In particular, the course is aimed at a study of 1) fundamental laws, phenomena and processes belonging to physics of micro- and nanoworld of material bodies; 2) structure and properties of the nanostructures, which are a part of the macro samples including those localized at a surface of solids; 3) physical nature of relationship "physical properties of material – production technology of products". The special course is intended for senior students of the universities studying in the directions training technical officers of industrial productions. It can be used also for training other specialties of the natural-science and technical directions in those universities where the courses related to the physical phenomena of a material world of nano - and microscales are given. It can be also useful to teachers who conduct classes in the corresponding disciplines. It is supposed that studying of this course will take up to hundred academic hours (lectures, seminars, independent work of students) (Voronov, & Podoplelov, 2008; Voronov, Podoplelov, & Sagdeev, 2011).

1. Introduction. The main peculiarities of the state-of-the-art of physical ideas of a material world at the level of micro- and nanoscales.

2. Physical properties of carbon nanotubes and materials on their basis. Fullerenes; Euler formula; Endohedral compounds; Structure of single-layer nanotubes, chirality indices; Manufacture of nanotubes; Materials from nanotubes, polymers and composites on their basis; Technological applications of carbon nanotubes.

3. Peculiarities of electronic structure of metal nanoclusters. Clusters, their classification and methods of preparation; Energy shells of nanoclusters, sizes of clusters, Knight rule, magic clusters, their energy spectra; Metal nanoclusters as building blocks for design of materials with specific crystalline structure.

4. Structure and properties of nanocomposite coatings. Technological manifestation of dimensional effects, concept of nanocrystalline composites formation; Structural phases of nanocomposite coatings, their physical properties; Nanocomposite coatings for new generation of materials; The major factors determining the increased strength of nanocomposite coatings, the critical sizes of nanocrystallites; Prospects of nanocomposite coating application.

5. Metamaterials. Fundamental difference of the term "metamaterials" from traditional "natural" materials; Artificial media with non-potential nature of electromagnetic interactions; Optical metamaterials; Wave masking of bodies; Method of wave flow; Maxwell equations, their invariant character in transforming coordinates; Fermat's principle; Scaling method; A hyper lens as the device allowing to overcome a diffraction limit; Light-absorbing devices; Concentrators-collectors of light energy; Acoustic

metamaterials as the composite media created from acoustically resonant ordered structural element; Model description of magneto acoustic metamaterials.

6. New magnetic materials. New magnetic states in crystals, exchange interactions of Heizenberg type, the induced magnetic order, a critical point of transition between structures of different orderliness; Giant magneto electric effect in the multiferroics; The phase transition induced by magnetic field, materials on the basis of bismuth ferrite; Physical properties of manganites; Ferromagnetics with shape memory; Control of material properties by mechanical tension, electric and magnetic fields; Heusler alloy, elastic and magnetic subsystems; Mechanism of magneto deformations.

7. New analytical methods for research of the condensed state. Thermovision as a new type of information technologies; Application scope of thermovision; Portable optical biosensors for determination of biologically active and toxic compounds; Biosensors on the basis of liquid crystals of DNA molecules; Laser isotope separation on the basis of infrared multiphoton dissociation of molecules; Laser separation of carbon isotopes; Multimode acoustic sensors and systems; Acoustic analyzer of liquids and thermal processes; Nonlinear acoustic diagnostics.

Conclusions

1. The researches, conducted in the nineties of the twentieth century, have shown that there are not only regularities of understanding of a training material, but also regularity of its misunderstanding (Bohr complementarity principle in pedagogics). Consequently, the corresponding negative phenomena in cognitive activity of a student are formed. It is proposed to designate these phenomena as the cognitive barriers.

2. Specific methodical materials for the discipline "The concept of modern natural sciences" with students of economic and humanitarian specialties of universities have been developed. The developed approach to teaching of the mentioned discipline is based on the theoretical course which is guided by the fundamental ideas of physics formulated conceptually.

3. Methodical materials for a special course "Physical Bases of New Composite Materials" are compiled. The course is aimed at acquaintance with the physical phenomena of material world of nano- and microscales, which are used for design of new materials. Among subjects of this course are physical properties and structure of fullerenes and carbon nanotubes, peculiarities of electronic structure of metal nanoclusters, optical metamaterials, new magnetic materials, which properties depend upon exchange interaction of Heizenberg type, materials with shape memory. A separate section is devoted to the analytical methods developed for the last about fifteen – twenty years to study the condensed state. The program has provided subjects of papers and sections for independent work of students.

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