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METHODOLOGICAL BACKGROUND TO THE NATURAL SCIENCE EDUCATION CONTENT INTEGRATION IN MODERN SCHOOL

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Abstract

The paper describes the methodological background to the content integration, the hierarchy of natural systems (as exemplified by physics and chemical systems, bio systems, geo systems). The authors substantiate and develop the methods of integration for the science education content (physics, chemistry, biology, geography) in the primary and secondary school educational programmes. The methodological background to the content integration is identified as having philosophical, methodological ideas; environmental-oriented content and content-integrated relations. The introduction of a propaedeutic course "Natural sciences for 5 – 6 grades" allows exposing the diversity of types of relations in the environment. The natural science course containing information about the methods of nature perception, such as modelling, observation, measurement, experiment, and interrelation of the above allows school students to identify observable phenomena in the environment with scientific concepts, laws, and theories. Further establishing relations helps in explanation of the known natural phenomena and in cognition of the unknown phenomena.

Keywords: Integration, scientific method of enquiry, methodology, natural science education.

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1. Introduction

Education, science and culture are the most important development areas of each state. Modern scientific trends include convergence and consolidation of a wide range of trends in scientific perception of nature as well as interaction of different methods and ideas (integration processes). Within the educational system in terms of natural sciences (physics, chemistry, biology, geography) it is appropriate to resort to content integration connections: conceptual framework, categories, principles, doctrines, the nature and content of core ideas, their evolution, the limits of applicability of notions and laws; the understanding of structure of matter and its most important features, of the forms of its existence and laws of development of scientific knowledge. Integration connections are resolved differently at different age periods (Choi et al., 2013; Christopher, Prescott, 2013; *Education for Sustainable Development in Action,* 2010; Education Bureau, 2017; Finnish National Board of Education, 2012; *Innovation on Science Curriculum in China*, 2006; Fong, Kwan, Lam, Lee, Lim).

2. Research Questions

Based on the main trends of education development and the main approaches to the integration of education, highlighted the methodological basis of integration of content in natural science education in contemporary school. The article considers the system of school science education from 5 to 11 class: in the framework of the introductory course in "natural Science, 5 – 6", systematic courses of physics, chemistry, biology, geography in primary and secondary school.

3. Purpose of the Study

The purpose of this research is theoretical substantiation and development of methods for the integration of the content of science education at the stages of primary and secondary education.

4. Research Methods

The authors use theoretical and experimental methods. The analysis of the literature, the pedagogical experiment, the approaches to the creation of the model of the laboratory of natural science for grades 5-6 are considered.

5. Findings

The authors have identified the main methodological background to the content integration in natural science education in modern school:

- Philosophic, psycho-pedagogical scientific grounds, political and regulatory documents in the field of education.
- Content integration connections.
- Methodological ideas of a modern *scientific world image* (SWI), interaction of SWI – NSWI (*natural science world image*) – PWI (*physical world image*) – CWI (*chemical world image*) – BWI (*biological world image*) – GWI (*geographical world image*) (Broun et al., 2009; Choi et

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al., 2013; Christopher, Prescott, 2013; *Education for Sustainable Development in Action,* 2010; . Education Bureau, 2017; Efimenko, 1976; Fadeeva, 2017; Fadeeva, 2014).

- Environmental-oriented content; factors determining the environmental sustainability of the Earth.

Here we will briefly cover the methodological background to the integration of natural science knowledge. *The scientific world image* (SWI) deals with the reflection of consecutive stages, levels of cognition by a human being of a material world and its patterns. One of the main methodological functions of a SWI is the basis for the analysis of philosophical categories (main and opposing), perception principles, laws of the dialectic. *The natural science world image* (NSWI) is a part of the scientific world image. It is based on the system of fundamental notions of the natural science, laws, and modern scientific theories. The NSWI is dominated by the *physical world image* (PWI), *chemical world image* (CWI), *biological world image* (BWI), and *geographical world image* (GWI). In the course of science development, these world images are constantly changing. For instance, the PWI gives the most comprehensive systemized knowledge about the physical essence of natural phenomena. The understanding of the structure of matter and its most important features, of the forms of its existence and the laws of development of scientific knowledge finds a concrete natural science expression in the PWI (Fadeeva, 2014; Vernadsky, 1997). Due to a particular position of the geography at the interface between natural and social sciences, the *geographical world image* (GWI) is a constituent part not only of the natural science world image, but also of the social science world image (Kasimov, Chalov, Panin, 2013).

One of the most important scientific concept formed by the means of georgaphy is the category of "space". Studying the face of our planet as the result of long-term processes shapes the understanding of the fact that the events on the Earth are evolving over the time and space. The view of interactions in geographical space makes it possible for schoolchildren to form a special perception of a territorial unity, teaches them to oriente themselves and act with reason in the environment where lives and works the human society; to forecast the trends of changes and development of the environment ; to identify and explain the causes of the events; to hypotesize, make assumptions; to draw conclusions.

The interaction between SWI – NSWI – PWI – CWI – BWI – GWI may be used in secondary school. *The secondary school focuses on the main categories: the matter (substance and field), movement, interaction, space and time.*

The term and the notion of "environment" is fundamental in modern natural science and reflects subjective and objective relations. The notion of "environment" acquires a certain meaning depending on the central subject of the system. With respect to a living creature (or their community), the environment means an aggregate of bodies and substances surrounding this subject (a living creature or a community). The "environment" in its most comprehensive sense means natural forces and phenomena, its substance and space, as well as any human activity beyond the human body or any other living creature. In the "Natural sciences for 5 – 6 grades" course, the main terms are "organism – environment", i.e. the interrelation between a man and its habitat (Petrova, Solovieva, 2014; Razumovsky, Mayer, Varaksina, 2014; The Education department, Hong Kong, 1998; *Science Education,* 2002; Ministry of Education, Singapore, 2013; Ministry of Education, Science and Technology, Korea; Teo-Gwan, Sao-Ee, Luan, Dr

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Hwa; *The main results of an international study PISA,* 2015; Vernadsky, 1997; Yano, 2012; Choi, Dobbs, Suh, 2013).

The most important methodological ideas of a modern SWI provide the basis for the integration of training materials in a comprehensive school. These ideas include: the world's unity and materiality; universal connection, dependence of all structural levels of the latter and different fields of a material world (nano-, micro-, macro-, megaworld); universal character of movement and interaction of the matter; correlation of space and time, dependence of the space-time properties of bodies and phenomena on the structure, state, movement of the matter being one of the ways of expressing the universal connection of natural phenomena, underlying the matter at all the levels (from elementary particles to star systems); the applicability of laws of conservation; overall causation of phenomena taking place in real world (Broun et al., 2009; Hawking, 2010; *The main results of an international study PISA,* 2015).

A new Federal State Educational Standard has marked a huge leap in terms of increasing quality requirements for secondary education, it has been noted that such an improvement has to be reached in the near future. Schoolchildren have to familiarize themselves with scientific methods of studying natural phenomena, methods of perception and understanding of the world of nature, machinery and technologies.

The strategic direction in the education development, which allows resolving the problem of discontinuity in natural science education, as well as that of improving the scientific level of education, is the creation of a propaedeutic course "Natural sciences for 5 – 6 grades". The knowledge and skills formed by this school subject are not complete. Nevertheless, they serve as the foundation for shaping a scientific world perception and provide a basis for further studies, upbringing and development of schoolchildren in the course of studying distinct natural science subjects (biology, physics, chemistry, astronomy, geography).

The propaedeutic course "Natural sciences for 5 – 6 grades" will allow resolving the following problems:

- it closes a significant gap in natural science education;
- it promotes the development of a comprehensive view of nature, will allow exploring natural phenomena and processes (physical, chemical, biological and geographical) in their interrelation;
- will give an opportunity to practice a systematic approach in education, since schoolchildren will get acquainted with certain organic and non-organic systems;
- will help implementing the idea of humanization of education: the central issue of the course is the human being as a natural body and a social being. In its turn, it will allow considering all bodies, phenomena and processes on the Earth as characteristics of a biosphere, i.e. the environment where the life and the man appeared, as well as to describe the role of a man in the process of perception, transformation and use of nature;
- will earlier give knowledge on a human body: it will cover the particularities of its composition, functions, will give information on its birth and development; it will describe the main hygiene requirements for staying healthy, will emphasize the necessity to maintain personal hygiene, to comply with work and rest regime; will highlight the benefit of doing

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physical activities and sports; will allow drawing attention to the harmful effects of smoking, drinking alcohol and using other narcotic substances;

- will allow discussing global and regional ecological problems.

6. Discussion

Natural sciences study those laws that underlie the functioning of the biosphere as a human environment, allow us to understand that the characteristics of the biosphere shall not be violated within those narrow limits where the life and *Homo sapiens* as a species may exist. It reveals the diversity of pedagogical functions of natural sciences in basic general education: the formation of a scientific understanding of the limits of biosphere sustainability, which contributes to cultivating a deep respect and reverence for the truth; to stimulating sophisticated forms of intellectual activity of a person; to forming a scientific worldview and commitments to recognize environmental problems as a terrible reality of the twenty-first century, as well as to searching for the ways to solve them (*Education for Sustainable Development in Action,* 2010; Petrova, (2016).

In the course of education, the perception of nature as a real comprehensive environment requires its conscious division into components and objects. *Bodies of living and non-living nature as well as substances* will be considered as natural objects. Bodies of living nature, i.e. organisms, are considered as being divided into four kingdoms: bacteria and blue-green algae, animals, fungi and plants. Bodies of non-living nature are divided into terrestrial and space bodies (the sun, stars, planets and their satellites, asteroids, comets, meteorites). The course will include the following classification of substances: inorganic and organic, simple (metals and non-metals) and complex (oxides, bases, acids, salts, fats, carbohydrates, proteins) substances. Such an approach will enable to naturally fit a man into the system of natural bodies. The knowledge about a man as a natural organism and a social creature will allow, on the one hand, considering bodies, substances and processes, occurring on the Earth, to be the human environment, and on the other hand, to characterize the role of a man in understanding and transforming the nature in the course of its study and use.

The natural science course will contain information on some of the methods forming the complex of modern methods of nature perception, such as *modelling, observation, measurement, experiment, and interrelation of the above*. The training material will reflect the interrelation of these methods and give information on the instruments and tools that people use in their practical activity.

While performing a propaedeutic function, the natural science course should contain not fragmentary, but systematic knowledge. Within this course significant attention will be paid to successive connections between the classes, integration of knowledge around the leading ideas that define the course structure and encourage the formation of a holistic world view (Efimenko, 1976).

The natural science course will give an initial picture of such scientific concepts as a *discrete substance structure, mass, interrelation, force, energy*, as well as will cover the logic of forming a system of knowledge on substances and their transformations. The information on substances and their transformations obtained by students may serve as the initial basis necessary to gradually realize the idea that the matter and the forms of its existence are always interrelated, that the natural objects form holistic systems, which are relatively stable, but at the same time are dynamic due to the interaction of structural

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particles of substances. And since in nature these processes are balanced, then its violation leads to undesirable consequences. It is important to perceive this idea in order to understand environmental issues. Besides, students may be lead to the conclusion that the origin of living systems is the result of complicated transformations of simpler particles, as well as the result of various interactions between substances.

A systematic and activity approach to teaching is used while selecting the content for the "Natural sciences for 5 – 6 grades" course. A systematic approach implies that the teaching process focuses on the identification of different types of relationships in the environment. Students learn about inorganic systems (from the atom to the planet, from the countryside to the geographical environment), and organic systems (from the living organism to the ecosystem). Each row of the system can be visualised in the form of stair steps, where each step up represents the system of a higher rank, comprising the elements of a lower system (Figure 01).

The introduction to natural bodies takes place through their descriptions, comparisons, and classifications. The authors of the "Natural sciences for 5 – 6 grades" course should decide in what order natural bodies will be considered. The main issue is to choose a preferable direction for the movement of thought: from part to whole or from whole to part? The answer may be found while using the principle of a *systematic analysis* of nature (Razumovsky, Mayer, Varaksina, 2014).

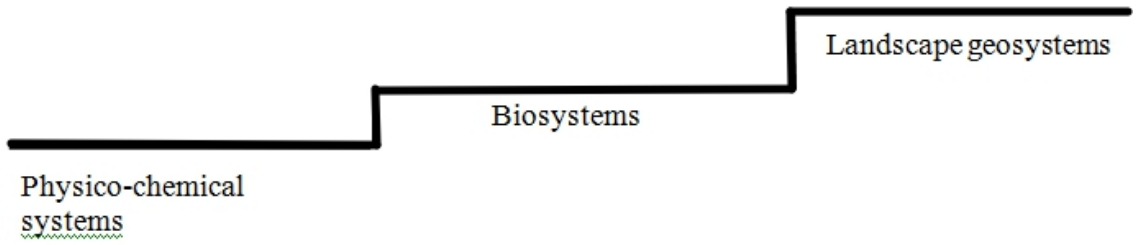

Figure 01. Hierarchy of natural systems

In its turn, each of these natural systems includes its own special components. For instance, physico-chemical systems may include the following elements: atoms of chemical elements – molecules and crystals of substances – macromolecules of bioorganic compounds – disperse systems, in particular, solutions, suspensions, air, smoke (Figure 02). The elements of biosystems are genes – cells – organs – organisms – populations – communities. All these elements of the system may also be displayed in a scheme format (Figure 03). In case the scheme shown in Figure 03 will be expanded upwards, it will end up with landscape systems, and if downwards, it will end up with physics and chemical systems.

Geography deals with a hierarchy of geo systems at a local, regional and global levels. The geographic environment is composed of natural geo systems of different spatial and temporal scales: from the largest and most long-lived formations, such as oceans and continents, to small and very volatile ones, like sand banks on the beach or scree debris at the foot of a mountain slope. They make up a multi-stage system of taxons called a hierarchy of natural geo systems (Figure 04) (Kasimov, Chalov, Panin, 2013).

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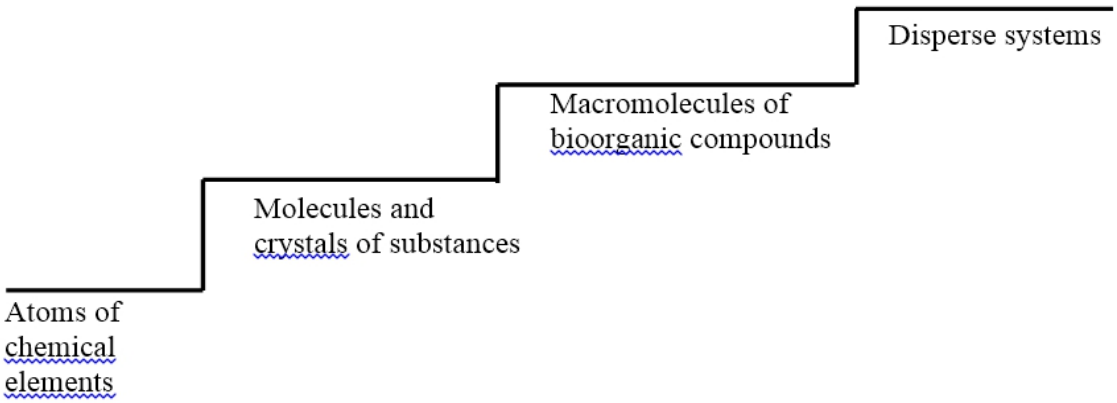

Figure 02. Hierarchy of natural systems as evidenced by physics and chemical systems

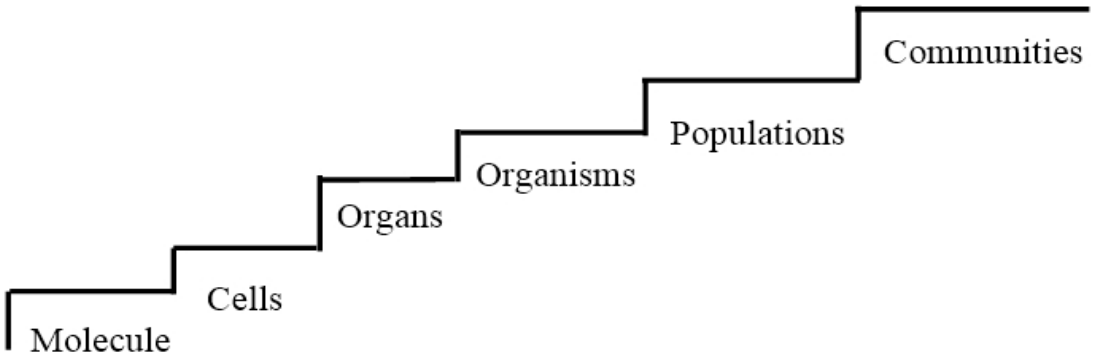

Figure 03. Hierarchy of natural systems as evidenced by bio systems

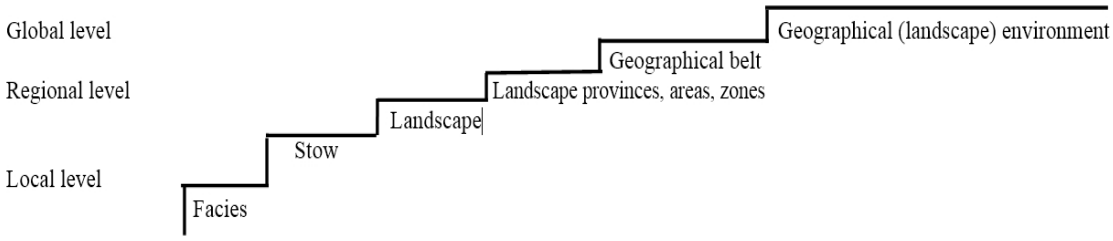

Figure 04. Hierarchy of natural geo systems

A systematic approach provides for two possible sequences in the subject content: the first sequence goes from the lowest level of the system to the its highest level, while the second sequence envisages the opposite option – from the highest level of the system to its lowest level. An exemplary program developed by the authors do not completely implement the idea of a systematical structure, however it reflects two kinds of a sequence. The first sequence implies moving from a high-rank system to a low-rank system, whereas the second moves vice versa. We believe that the shift from one hierarchical level to the other one allows schoolchildren to perceive systems of different scales, and gives them an opportunity to form a broad world view (Mullis et al., 2012; The Education department. Hong

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Kong,1998; Science Education, 2002; Ministry of Education, Singapore, 2013; Teo-Gwan, Sao-Ee, Luan, Dr Hwa; Teo-Gwan, Sao-Ee, Luan, Dr Hwa).

A systematic approach helps students to reveal the effect of the functional integration principle, meaning that the properties of a superior system are not confined to the properties of a lower system, as well as to imagine the correlation of physical, chemical, biological, and geographical properties of terrestrial bodies, their spatial location and interaction.

The course covers biological bodies, i.e. living organisms and their communities, from the ecosystem perspective. On the one hand, ecosystems are so-called "quanta" of the biosphere as a global system, but on the other hand, they are a natural habitat for a man. Experts forecast an end of modern civilization if the mankind does not realize the importance of an "ecosystem" world view. The research of a "natural habitat" covers the study of all organisms living in such a habitat as well as all the processes which make this habitat livable. Thus it helps to shape a conviction that preserving civilization depends on our knowledge of nature and reasonable actions aimed at preserving and improving the environment through well-balanced rather than destructive interference.

The concept of the "Natural sciences for 5 – 6 grades" course was developed in 2016. The priority areas of integration of natural science knowledge in the "Natural sciences for 5 – 6 grades" course are as follows:

- *scientific literacy* – the level of understanding of science and technology, which is necessary in a modern society: knowledge of basic and key scientific concepts, understanding the essence of the scientific method of enquiry and the ability to distinguish between scientific knowledge and unverified information;
- the ability to *conduct experiments* aimed at investigating different phenomena and to define the task / objective of the training experiment; to assemble installations from the proposed set of equipment; to carry out experiments and to draw conclusions; to take direct and indirect measurements;
- the ability to *analyze practice-oriented situations*, to recognize studied phenomena, patterns and laws in such situations as well as to apply the obtained knowledge to explain them;
- the ability to *conduct research* and prepare project works, present the results of such works.

The "Natural sciences for 5 – 6 grades" course pays much attention to the knowledge integration around the key ideas defining the structure of the course and encouraging the formation of a holistic view of nature. The core idea of the course is the interrelation between "Earth – Universe – Human". The integration of scientific knowledge is ensured through identification of central ideas for each grade as well as through systematization of factual information around such ideas.

The central ideas of the course are the following:

- Earth and its geological environments.
- Interrelation of natural objects (bodies, substances, living organisms) and their properties.
- Phenomena as a core for synthesis and integration (interrelation of physical, chemical, geographical and biological phenomena).

The concept of the "Natural sciences for 5 – 6 grades" course proposed by its authors has allowed to develop the structure and content of an exemplary program. The explanatory note contains general information about the subject, indicates the main goals and objectives of the course, as well as determines

the place of the subject in a school curriculum. It also describes personal, metasubject and common subject results of learning the subject. The content of the subject gives a list of sections, provides for an approximate thematic planning which defines main types of students' learning activities, contains a guidance on teaching methods and material support of the educational process, enumerates the expected outcomes of the study of the subject.

The main sections of the course are as follows:

5 grade – "Methods of studying the nature", "Earth as a planet of the solar system", "Environment", "Diversity of substances. Discrete substance structure";

6 grade – "Natural phenomena", "Relationship in nature", "Structure and evolution of the Universe".

Each section contains its key ideas, a list of demonstration materials, experimental assignments, experiments, and project topics. At the end of the course there is a laboratory practicum to be carried out in the field as well as a general refresher section.

In future we plan to create a new generation of teaching materials for Teens: textbooks, manuals for teachers, tutorials for learners.

7. Conclusion

Courses of natural science, physics, chemistry, biology, geography for the primary and secondary (full) schools should contain the main idea: the value of scientific knowledge lies in their relationship, reflecting the natural interdependence of natural phenomena. The result of understanding these linkages formed the ability to identify observable phenomena in the environment with scientific concepts, laws, theories and, conversely, the ability to see in the studied concepts, laws, theories, manifestations of specific observed phenomena. Knowing this relationship, an educated person can explain the known phenomena of nature, to put the objectives of the study the unknown phenomena and to use scientific knowledge to create new technology and the development of appropriate technology.

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