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IMPLEMENTATION OF THE SCIENTIFIC AND METHODOLOGICAL APPROACH IN NATURAL SCIENCE TEACHING METHODS

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Abstract

The authors have defined methodological frameworks for implementing the systematic and activity approach in the content of natural sciences in middle school. The most important methodological features of the new program of the course « Science 5-6» is, on the first hand, its close connection with the learning outcomes of students of the elementary school, and on the second hand, its contribution to the subject content of Geography, Biology, Chemistry, Physics and other subjects. The methods used for teaching natural sciences (physics, astronomy, chemistry, biology, and geography) reasonably combine a conceptual and terminological approach, which is traditional for middle school, with a systematic and activity approach, which the prevalence of the latter. The paper defines scientific and methodological approaches to implementing the systematic and activity approach in the content of physics, astronomy, chemistry, biology and geography courses through studying causal links and relations in the environment, including those relations aimed at explaining various types of interactions between the nature and the society. It also analyzes the organization system of students' activities of school children aimed at reaching both subject and metasubject results of studying. The education technologies define ways and means of achieving a socially expected personal and cognitive growth of students. Thus, it focuses mainly on students' academic achievements.

Keywords: Methods, nature, society, subject, metasubject, results.

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1. Introduction

The implementation of a scientific and methodological approach in natural science teaching methods is aimed at organizing an active learning and cognitive activity of school children through both the content of natural science disciplines (physics, astronomy, chemistry, biology, and geography), and the education technologies defining ways and means of achieving a socially expected personal and cognitive growth of students. Thus, it focuses mainly on students' academic achievements.

2. Problem Statement

The methods used for teaching natural sciences (physics, astronomy, chemistry, biology, and geography) reasonably combine a conceptual and terminological approach, which is traditional for middle school, with a systematic and activity approach, which the prevalence of the latter.

3. Research Questions

3.1. show interrelations and interdependence of natural phenomena on the Earth, and in the Solar system;

3.2. define approaches to studying territorial clusters, geosystems of different levels, from global to local;

3.3. examine functioning features of a combination of processes related to substance and energy transformation and exchange;

3.4. apply a typological approach to learning geosystems of different levels;

3.5. foreground an idea on interrelation between the nature and the society.

4. Purpose of the Study

To substantiate methodological ways of implementing the systematic and activity approach in teaching natural sciences in middle school: physics, astronomy, chemistry, biology and geography.

5. Research Methods

The authors use theoretical and experimental methods. They have studied the literature, conducted a pedagogical experiment, worked out and substantiated the approaches used to prepare education materials and teaching guidelines of the academic and methodological complex in physics, astronomy, chemistry, biology, and geography.

6. Findings

The authors have defined methodological frameworks for implementing the systematic and activity approach in the content of natural sciences in middle school:

• philosophical, psychological, pedagogical, and scientific frameworks, as well as policy and regulatory documents in the field of education;

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• integration linkages in the content of school disciplines;

• methodological ideas of developing a modern scientific world image;

• ecological focus in the content of school disciplines which predetermines sustainable development of the environment.

Here we will briefly review scientific and methodological ways of implementing the systematic and activity approach in teaching natural sciences.

The conceptual and terminological approach is one of the most important ways of presenting education material. It is a way to study the objects of our environment which mainly gives answers to the following questions: "what object is it?", "what properties does it have?", "where is it located?".

In this approach the main types of activities are the class work with concepts and definitions, as well as finding the place of objects on the map.

The systematic and activity approach is a way to study the environmental phenomena and processes, which is primarily based on identifying causal links and relations between the objects and their properties, as well as their comparison, analysis and synthesis. It mainly answers such questions as "why?" and "how?", and also requires explanations. Discovering, giving examples, defining, explaining, comparing, modeling, and tracing the development are main types of learning activity within this approach (The Concept of Development of Geographical Education in R.F., 2016).

It is obvious that the predominance of a conceptual and terminological approach in the education process reduces disciplinary and educational possibilities of natural sciences. At the same time the introduction of a systematic and activity approach into the methodology of teaching natural sciences allows to take full advantage of their integration potential, which implies having such approaches, methods and ways, that ensure learning and explaining space-time interrelations and interactions in the environment, representing a coherent system ("person – nature – economy – environment") (Isachenko, 1986).

Besides, due to the introduction of a new version of the educational standard (Federal State Educational Standard) the students' success in studying will depend directly on how much their rational ways of practical and intellectual work with various sources of information are developed. This will enable them to study the structure, properties, functioning, dynamics of phenomena and processes evolution in the environment at local, regional and global levels as well as to meet the main results-based education target in practice (Federal State Educational Standard of basic general education, 2017).

The integration of natural science knowledge based on the systematic and activity approach is ensured through:

• highlighting key ideas for each class and systemizing factual information around such ideas;

• showing the interaction between objects of nature (natural bodies, substances, living organisms) and their properties;

• showing the interrelation of natural phenomena (physical, chemical, biological, geographical);

• introducing natural science definitions (discrete substance structure, mass, interrelation, force, energy) (Fadeeva & Petrova, 2017).

Special attention is given to familiarizing students with nature perception methods, such as observation, measurement, experiment, modeling, and interrelation of the above.

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The systematic and activity approach in teaching physics is based on methodological techniques and highlights the elements of knowledge (physical concepts, values, phenomena, laws, etc.) (Fadeeva, 2017; Razumovsky, Mayer & Varaksina, 2014). The key ideas of the physics course, including general astronomy issues, are as follows:

• forming a holistic world image, combining unity and diversity of properties of both organic and non-organic systems, in the students' imagination;

• showing the unity of laws of nature, the applicability of physical laws and theories to various objects (from elementary particles to distant galaxies); discussing the problem of the Solar system origin, and unique physical conditions on the Earth for the life to emerge and develop;

• examining substance cycling and energy transformation in the universe, substance evolution in the universe; examining the birth, development and final stages of evolution of stars and the Sun; evolution of the universe as a whole and its stages;

• examining not only areas of technical application of physics, but also examining ecological problems both on the Earth and in near-Earth space;

• considering the human being as a physical object (it moves, participates in force interactions, and is effected by various physical fields), as a complicated physical system (functioning of its distinct systems, interaction with the environment), as a subject of perception (observation, measurement, experiment, hypothesis, model, and theory are all human inventions which help people to study and explain the environment and their place in this environment);

• showing the influence of environmental parametric pollution (heat, light, noise, electromagnetic, radiation, and vibration pollution) on a living organism; discussing social and economic aspects of environment protection (human interaction with the natural environment, atmosphere and the human body, etc.) (Pentin & Fadeeva, 2017).

Using the systematic and activity approach in the methods of studying geographical processes and phenomena, where everything is interconnected and interdependent, where everything constantly develops and evolves, contributes to the formation of natural scientific views on the environment and the society. It is well known that the terrain, climate, surface and subterranean waters, soils, plants and animals do not form random combinations on a specific territory, on the contrary, they do form regular geosystems of different levels - from global to local. The components of both nature and human or society life may be the elements of the geosystem. Such approach allows to fully imagine the linkages between the human being and its habitat and to take a closer look at the consequences, caused by the human activity changing one element of such system, which gives a clue to explaining a variety of geo-ecological problems of our time (Grigoriev, 1966).

The interchange of substance in geosystems is a permanent process, and there are many such examples:

• water dissolves minerals and rocks;

• water in the hydrosphere is part of living organisms of the biosphere;

• water in the form of steam is constantly found in the lower atmospheric layer of the Earth;

• minerals and rocks of the lithosphere are always present in living organisms, in the atmosphere (dust, sand), and in the water;

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• carbon dioxide from the air is soluble in water;

• organisms of the biosphere absorb carbon dioxide;

• once accumulated on the ocean floor, the remains of organisms of the biosphere form sedimentary rocks of the lithosphere;

• oxygen in the atmosphere and the hydrosphere is the main source of life for organisms of the biosphere.

Thus, the nature is characterized by constant interpenetration and interaction of substances and different natural components.

All processes on the Earth take place due to solar energy and internal energy of the Earth. But it should be noted that in every example we have examined, the interchange of substance also implies the interchange of energy. The energy of plants in the biosphere, once consumed by animals, creates energy of fauna. The eternal ice of the hydrosphere cools the atmosphere and the hydrosphere. These processes allow keeping a certain balance between all natural components in the natural complex. Moreover, they help the nature to have an amazing ability to self-regenerate, self-purify, and self-regulate. If any component in the natural complex changes, the other components change as well, trying to find its initial natural balance. Some natural complexes regenerate faster, while others slower. The ability to self-regeneration is the greatest property of nature. Each natural complex (landscape), regardless of its size, is an integral whole (Petrova & Bazanov, 2014).

At the first stage of studying a general geo-scientific course of geography we prepare a set of thematic tables, which systemize the linkages between separate elements of the landscape using different territories as an example:

• interrelation between the terrain, the structure of the Earth crust and natural resources;

• change of total solar radiation from north to south and existence of a permanent snow cover;

• average annual rainfall in different territories;

• examples of territories located in different natural areas;

• particularities of plants and soils in several natural areas.

Within the second stage, while studying the continents in the hot thermal zone of the Earth, we systemize climate characteristics of various climate types and various natural areas in the form of a table, and study the particularities of the economic activity carried out by the population, for example:

• characteristics of climatic belts and zones;

• annual cycle of air temperature and annual distribution of rainfall in different climatic belts and regions;

• natural areas, soils, vegetation and specialization of agriculture.

At the third stage, while comparing Eurasia and North America continents, we learn that typological features are formed if geographically dispersed natural areas occupy a similar position in relation to radiation and circulation climate factors and if they are located within those Earth crust zones which are similar in structure. At the same time, geographical uniqueness is explained by the fact that the main elements of the geographical environment (namely, the Earth’s crust and the Earth’s atmosphere), despite their close interaction, develop under different laws. Individual characteristics inevitably provide for the

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diversity in sizes and shapes of land plots of similar structure, for a various water to land ratio, for a unique location of orographic elements, etc. (Petrova, 2013).

It is impossible to memorize causality links and relations in the content of natural science courses if they are explained by the teacher. They need to be understood and explained by the student himself based on his own work with various sources of information, such as maps, statistical materials, or by means of observation, laboratory researches, presentations, solution of research problems, preparation of relevant projects, work with geo-information systems (Alexander, Johnson & Kelley, 2012; Hampden-Thompson & Bennett, 2013). This requires the student to master, study, analyze, and identify such causality links and relations. Such activity helps to develop self-sufficiency in students and improves metasubject intellectual capacities and practical skills which will be useful for students both in life and profession. But unfortunately we are also facing some challenges with the above in natural science education (Bybee & McCrae, 2011; Maksakovsky, 2013).

The average score of Russian 15-year-old students on the PISA science literacy scale in 2015 was 487, while the OECD average score equaled to 493. Thus, the Russian Federation took the 30-34th place (OECD, 2016). Regrettably, natural sciences do not form core competences at the level provided for in the Federal State Educational Standard. Most mistakes are made while doing the following metasubject tasks:

1. Use the information contained in the text while solving practical problems;
2. Use sign and symbolic means and models (as well as artistic and graphic tools) while solving practical problems;
3. Create a model of a problem situation by separating main elements of the problem situation from secondary ones;
4. Transform models from one sign system into another (tables, schemes, charts, diagrams, figures, etc.);
5. Analyze the findings of the conducted research and draw the conclusions;
6. Define the research objectives, hypothesize and suggest the ways to test the said hypothesises;
7. Prepare the research plan and interpret its results (Krapp & Prenzel, 2011).

The inability to use the information contained in the text while solving practical problems is, in our opinion, one of the key problems of modern people. In this age of information technologies, the volumes of information are rapidly growing every year, and due to this the first priority of a modern school is to teach how to work with textual material. The absence of a critical approach to analyzing the available information may lead to situations where both schoolchildren and adults get lost in large amounts of information (Holdren, Lander & Varmus, 2010; Martin, 2012).

Most metasubject skills are mainly developed while studying natural sciences, such as physics, geography, astronomy, biology, and chemistry. It is almost impossible to imagine these subjects without schemes, tables, diagrams, performing analysis, drawing conclusions, determining causal links and relations, hypothesizing and researching. The problem here is the lack of systematic approach, which means that there is no link between subject teachers not only in reasoning the study of a certain topic, but also in developing various skills and competences, which are of vital importance for successful learning (Alexander, Johnson & Kelley, 2012; Archer, 2010).

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In view of the above, we suggest using the activity pattern below so that a link between natural science teachers could appear. As an example, Figure 1 shows the scheme for developing metasubject skills during the lessons of geography, physics, chemistry, and biology.

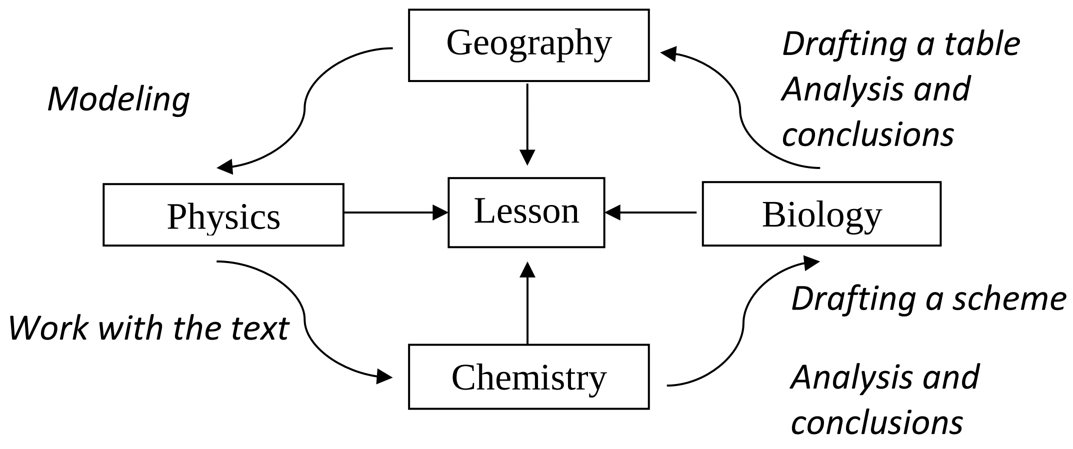

Figure 01. Activity pattern

In the center of the scheme each natural science teacher has a lesson. Each teacher should improve a certain metasubject skill: during chemistry lessons students draft a scheme, during biology lessons they draft a table and then analyze it, during geography lessons they study or create a training model, while during physics lessons students work with the given text (semantic reading). Natural sciences teachers during the next lesson given to the class in question shall work on that metasubject skill which the previous teacher has started training, for example, during chemistry lessons students work with the text (semantic reading), during biology lessons they draft a scheme, during geography lessons they draft a table and then analyze it, while during physics lessons students they create a training model, and so on. It should be noted that a metasubject skill may be chosen based on the particularities of the class, students' age or their academic performance. Here we have presented a rather general model which may include different number of school subjects and skills. This will allow students to perceive and perform various types of activity more easily, and if at first students may have difficulties with drafting schemes, for example, but at the end this task will no longer be a problem to anybody.

7. Conclusion

The systematic and activity approach allows to switch from formal logical structures in studying the course to the methods of searching and treating geo-information used to identify and explain natural science patterns and linkages.

The implementation of the Federal State Educational Standard and the education quality depend directly on all stakeholders involved in the educational process. At the same time, subject teachers are primarily responsible for forming both subject and metasubject competences in future generations, since natural science disciplines are characterized by the fact that students may improve and strengthen relevant capacities and skills while studying almost any topic.

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