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Theory and practice of updating the content of education in chemistry and teaching methods, in view of modern science and technology achievements

Teoría y práctica de la actualización de contenido de la educación en química y métodos de enseñanza, en vista de la ciencia moderna y los logros tecnológicos

Svetlana Aleksandrovna VOLKOVA [1]

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Contents

ABSTRACT:
The main goal of the research is to determine the directions, research the conditions and the mechanism for updating the content of general natural science education and teaching methods, in view of the achievements of modern science and technology. The research is based on the methodology of scientific rationality and reality transformation as a system of foundations and methods of scientific cognition and reality transformation. The most important findings are: 1) methodical resources to update the content of chemistry teaching and teaching methods were defined regarding the world trends in the development of the system of natural science education, 2) a new approach has been suggested for updating the content of school chemistry education involving the widespread use of digital educational resources in combination with full-

RESUMEN:
El objetivo principal de la investigación es determinar las direcciones, investigar las condiciones y el mecanismo para actualizar el contenido de la educación general de Ciencias naturales y métodos de enseñanza, en vista de los logros de la ciencia y la tecnología modernas. La investigación se basa en la metodología de la racionalidad científica y la transformación de la realidad como un sistema de fundamentos y métodos de cognición científica y transformación de la realidad. Los hallazgos más importantes son: 1) recursos metódicos para actualizar el contenido de la química la enseñanza y los métodos de enseñanza se definieron con respecto a las tendencias mundiales en el desarrollo del sistema de educación en Ciencias naturales, 2) se ha sugerido un nuevo enfoque para actualización del contenido de la educación en química escolar que

scale chemical experiments.
Keywords: education in chemistry, digital educational resources, full-scale chemical experiments

implica el uso generalizado de recursos educativos digitales en combinación con experimentos químicos a gran escala.
Palabras clave: educación en química, recursos educativos digitales, experimentos químicos a gran escala

1. Introduction

The issue of updating the educational content and teaching methods as an internal form of self-development of the content (*Shapovalenko 1963)* has always been and still remains one of the most relevant in didactic research. In 1714, Peter I issued a decree on the teaching noble children "numbers and geometry." Learning theories have always tried to find answers to the questions: What to teach? How to teach? Why teach? The transition to a postindustrial information society is accompanied by a continuous increase of the amount of scientific information and its simultaneously rapid aging as well. The worldwide educational systems have been experiencing difficulties related to serious contradictions between the need to include the achievements of modern science and technology in the content of chemistry education and the undeveloped approaches, conditions and mechanism for updating the content of chemistry education. There is yet no answer to the question: how to comply the process of transferring an ever-increasing informational file with the fixed time interval of the subject teaching currently prevailing? Or should this time interval be gradually reduced, exempting a large part of a person's life for constructive activity? The question is what information and in what amount is to be studied. How and in what form should this information be systematized and structured? Which tool should be preferred for its transmitting?

The research hypothesis is that the updating of the content of general natural science education and teaching methods, in view of the achievements of modern science and technology, will be successful if the methodological guidelines, approaches and trends are determined, and the conditions and the mechanism for its implementation are examined. To achieve this goal, it is necessary to substantiate the place and role of modern achievements in science and technology as a factor of updating the content of natural science education; to define trends of inclusion of the information on modern achievements of natural sciences and technologies into the teaching content; to test the results of the research in school practice. Researching the problem of updating the content of general education is related not so much to the level of objective didactics as it has been considered at the state level. Thus, at the State Council meeting (*Meeting of the State Council on improving the general education system, 2015)* the goal "to develop a set of measures aimed at the systematic updating the content of general education ... in view of the the modern achievements of science and technology, changes in students' and social demands, focus on application of knowledge, skills and abilities in real life situations" was set.

2. Methodology

The problem of updating the content and methods of teaching chemistry in modern conditions requires a fundamentally new philosophical interpretation for determining the standpoint of the scientist. It seems important to view the problem as a combination of a subject content with the achievements of modern science - computer science, cybernetics, genetics, synergetics, microelectronics, ecology, and also rapidly developing nanoscale science and supramolecular chemistry. This will allow us to apply a new multilevel methodology of the processes of cognition and learning - the methodology of informational civilization (*Abdeev 1994)* associated with the ideas of scientific rationality and reality modeling as a system of foundations and methods of scientific cognition and reality transformation, applicable to didactic research (Gerus 2003). A systemic approach considered as the systemic influence of modern science on philosophy and civilizational approach, directly related to the ideas of scientific rationality applied as the leading methodological approaches. We bear in mind the statement that postnon-classical rationality takes into account the correlation of knowledge about the object not only with the means, but with the value-oriented structures of activity as well.

In our research, we are guided by the concept of standards of general education, where a fundamentally new methodological position for selecting the content of education, which was called "the fundamental core of the content of general education" was formulated (*The fundamental core of the content of general education, 2011)*. It implies the need to preserve the integrity of the educational space and the continuity of the educational system levels, as well as for general and additional education, to ensure equality and accessibility of education to various starting capabilities, the formation of a common activity basis as universal learning activities that determine a person's ability to learn, cognize, cooperate in learning and transforming of the surrounding world.

According to the concept of the culturological approach to the formation of the educational content (M.N. Skatkin, I.Ya. Lerner, V.V. Kraevsky), the source of formation the content of general secondary education is culture, i.e., the most significant forms of sociocultural experience. In accordance with this concept, the formation of the content of general secondary education is carried out in several stages:

> Stage I (pre-objective) - the formation of general theoretical ideas about the composition and structure of the content of education.
>
> Stage II (subject) - identification of the subjects structure, their specific content and distribution according to study levels.
>
> Stage III - the creation of learning materials.
>
> Stage IV - the organization of the learning process.
>
> Stage V - assignment of the new content by students (*The fundamental core of the content of general education, 2011)*.

The current State standard of general education (The federal state educational standard of general education approved by the order of the Ministry of Education and Science of the Russian Federation dated December 17, 2010 No. 1897), unfortunately, does not define the content of education distinctly; therefore, this gives some freedom to the management of educational institutions. It implies that the content of education is determined by the school itself, and the standard specifies the number of hours to study the subject. In the conditions of a unified educational space, school, director, teacher cannot determine the subject content. Obviously, these are scientists-methodologists who should formulate and write comments on the state standard, highlighting the most important significant blocks of the subject content.

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3. Results

It took rather long time to develop the modern content of the school subject of chemistry. The presentation of the course material hadn’t been systematic up to the middle of the 19th century; the first systematic textbook "Fundamentals of Chemistry", which was written on the basis of the Periodic law by D.I. Mendeleev. Didactic-methodological literature analysis shows that at first there was an "extensive and informational" approach, according to which the content of learning included a large number of "blocks of content", consisting of numerous facts, laws and regularities, for example, the theory of periodicity by D.I. Mendeleyev, the structure of the atom, the structure of molecules, the chemical bond, the theory of solutions, chemical kinetics, chemical thermodynamics, colloid chemistry, the properties of elements and their compounds, qualitative and quantitative analysis, etc. Such a large volume of unrelated topics leads, on the one hand, to the mechanical fragmentation of the material and the violation of integrity of the discipline under study, and, on the other hand, it makes it difficult to find intra-subject connections (*Zaitsev 1999)*, to say nothing of overloading the learners and their impossibility of assimilating this content. At present, this approach is realized in two ways: the first one involves learning the directly observed properties of substances, then their "internal mechanics" (D.I. Mendeleev) and again their properties; the second is a simplified replication of the university chemistry course from the structure of substances to their properties (Zhurin 2016).

In training practice, there is another approach to updating the content and methods of teaching. It is associated with the emergence of an information environment, and, consequently, new didactic means, such as digital educational resources (interactive whiteboards, digital laboratories, Internet resources, new chemistry textbooks) and technologies that some methodologists try to integrate into the old methodical system (*Nazarova 2012)*, which in itself does not need new means, since it is impossible to achieve new educational results with their means.

State Standard focuses on new learning outcomes. Society of the future will need more people with knowledge, flexibility of thought, creative initiative, personal qualities such as adaptability, morals, responsibility, personal self-realization, freedom of choice, creativity, critical thinking, and self-improvement. Education is designed to ensure that each graduate has the opportunity to gain experience in creative activity that opens opportunities for the development of individual abilities of a person and ensures their preparation for life in the context of science and technology progress. The increased intellectual component means personality related outcomes. New educational outcomes entail new activities, which in turn will inevitably lead to the new learning outcomes. And for the new activities it is necessary to develop new educational resources, for example, new chemistry textbooks, chemical experiments combining full-scale and computer experiments. Such educational resources provide for the implementation of new types of activities, such as, for example, educational research and project activities, while developing experimental and intellectual skills to plan, simulate the experiment, predict and interpret its results, build a hypothesis, test it, etc. (Volkova 2016a). In the light of the requirements of the State standard, new forms of lessons - lessons-projects and lessons-research play more important role. This is due to the fact that it is the project and training and research activities that the Standard considers as means of improving universal learning activities, and project activities also as a means of assessing the level of their formation.

A mechanism for updating the content of training and activities, which includes four stages, has been suggested by us (Gerus 2003; Volkova 2016a; Volkova 2016b). The domestic and world experience of school practice, as well as the author's many years of experimental work as a teacher of chemistry (Volkova and Tarakanova 2016) show that the implementation of this mechanism in the informational and educational environment is possible in three directions:

- integration of knowledge about modern research and achievements of science and technology into the content of the traditional school chemistry course (integrated education);
- solving the issues of updating the educational content in view of the achievements of modern science and technology in additional education (facultative education);
- introduction of a special academic subject, for example, supramolecular chemistry (special education) (Lehn 1995).

This experience is realized in some universities.

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4. Discussion

Let us consider the possibilities of integrating knowledge of modern science achievements in the content of school chemistry education. Currently, two approaches to teaching subjects in the natural science cycle, including chemistry, are mainly used. The first "knowledge-oriented" approach is traditionally realized in the secondary general education. The second one, competence-based, has been accepted all over the world, beginning in the 80s of the 20th century in school, university and postgraduate education as the concept of teaching competencies or practical skills. An important problem of the subject methods science is the comparative research of the possibilities of applying "knowledge-oriented" and competence-based approaches in science education.

Comparative analysis shows that, within the framework of the traditional approach, the main content of teaching is the mastery of a topic or a section of the program. Subject teaching is aimed at mastering the subject domain, the boundaries of which are not defined and can change. The result of thematic training is the knowledge of the content of the topic. The competence-based approach to learning contradicts the traditional "knowledge-oriented" thematic training, as it is seen as the concept of teaching competencies or practical skills, i.e. competence is seen as the content of training. Competence acts as a unit of content and activity. The structure and content of competence as units of activity can be represented by a triad: motivation → context → technologies and algorithms. Such a model of training is realized in our country only at the university and postgraduate levels of study. The main content of competence training is the determining the context and the algorithm of actions. The basis of the training technology in terms of competencies is the tasks for mastering and demonstrating the algorithms of actions. Thus, competence as a unit of activity is defined as a motivated sequence of actions in a certain context.

The context is the same for the traditional and competence-based approaches. For example, it is very important to include in the content of natural science education the materials of modern natural sciences research related to the successes, problems and troubles of modern society, the results of advances in the science of technology, as well as new issues, new inter-scientific problems. It is confirmed by the analysis of the contents of the TIMSS and PISA international research missions, which shows that most of them are of an interdisciplinary nature, contain questions of ecology and health, and also have methodological properties, for example, related to the way research is conducted, to a greater extent (2017 is declared as the Year of ecology). At the International Conference "The results of the international studies of TIMSS and PISA 2015 and the factors influencing the changes in the education system" (February 1, 2017, Moscow), it has been stated that Russian students have a poor understanding of scientific knowledge and especially their application. They have meager abilities to observe, explain, generalize, recognize, predict, draw conclusions that are formed through experiment. A graduate of a secondary school should be able to represent ways of solving global problems facing humanity: environmental, energy, raw materials, and the role of chemistry in solving these problems.

Here is an example of one of the PISA–2015 tasks "Fossil fuels". Many power plants burn carbon-based fuel and emit carbon dioxide (CO2). CO2 emitted into the atmosphere has a negative impact on the global climate. Engineers use different strategies to reduce the amount of CO2 emitted into the atmosphere. One of these strategies is the burning of biofuel instead of fossil fuels. While fossil fuels are formed from long-dead organisms, biofuels are formed from plants that have lived and died recently. Another strategy involves capturing part of the CO2 emitted by power plants and storing it deep underground or in the ocean. This strategy is called "carbon capture and storage". The schoolchildren are offered, based on the data given in the table, to explain why someone might use oil instead of ethanol, even if their cost is the same. What are the advantages of using ethanol instead of oil for the environment? Using these graphs, it is necessary to explain how the depth affects the long-term CO2 storage efficiency in the ocean.

Updating the content of natural science education knowledge of "protection" should be taken into account. Possible trends for further research are related to the determining approaches to updating the content of natural science education on the basis of the minimization principle. The next stage can be the development and approbation of the methodology for incorporating modern achievements of natural sciences and technologies into the content of natural science education.

5. Conclusion

The carried out research can be characterized as theoretical-experimental with the distinct practical orientation. The results of the research confirm the hypothesis that it is possible to achieve the goal of updating the content of general natural science education and teaching methods in view of modern science and technology achievements. We determined methodological guidelines, approaches and trends and studied the conditions and mechanism for updating the content of chemical education. It has been established that in order to achieve this goal, the reserves and methodical resources for updating the content of teaching chemistry and methods of teaching must be sought in the subject content itself. The new suggested approach for updating the content of school chemical education in modern informational environment implies a wide application of digital educational resources in combination with full-scale chemical experiment, as well as various chemical tasks as an important component of the content of learning and activity.

It is important to focus on the experimental tasks, which are considered as a tool for the learning process of and the reality cognition. The fulfillment of such tasks is expedient in problem teaching through problem situations modeling.

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1. Federal State Budgetary Scientific Institution "Institute for Strategy of Education Development of the Russian Academy of Education", Russia, 105062, Moscow, Makarenko Street, 5/16; E-mail: inter@instrao.ru

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