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QUESTIONS OF CHEMICAL CONTENT IN THE INTEGRATED COURSES OF NATURAL SCIENCES

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Abstract. In formation of complete knowledge of nature and the person a big role belongs to studying of chemistry as the discussing subject according to its nature is primary integrated and its (her) maintenance (contents) is interconnected with that of physics and biology. Chemistry teaching in average educational institutions now is accomplished by studying obligatory independent rates as well as and by including of questions of chemical maintenance (contents) into the obligatory integrated rates of natural sciences (alongside with independent rates of chemistry by choice of pupils). The maintenance (contents) of a chemical component in the integrated rates of natural sciences taught in Japan, Canada, USA, the Great Britain, Ireland, Italy, France, Spain and Byelorussia is considered in the work. It is indicated that doubtless advantage of the integrated rates of natural sciences in general is the establishment of full interrelation between investigated natural-science subjects, and with reference to chemistry - formation of belief in necessity of chemical knowledge for the decision of many vital problems. Introduction of national standards and aspiration to equivalence of documents on the general education urgently demand definition in the different countries of uniform approaches to natural-science rates in high school, preparation of the scientific and pedagogical staff, to perfection of continuity school and high school natural-science education.
Key words: natural science education, integrated courses, chemical education.

Introduction

It is well known that the total amount of knowledge accumulated by mankind is doubled every 5 years (some researchers are expecting the period in the nearest future will be reduced to 1,5 years). This fact, as well as the one that the bulk of this knowledge is produced within interdisciplinary sciences, is the major reason for the principle of content integration to become one of the basic methodological principles in modern education. However, it must be noted that the phenomenon of integration in education is firmly established in the theory of didactics, being, thus, not a prerogative of the present time. Integration is not limited to the interdisciplinary studies; it has a strong influence on the organization of teaching throughout the entire educational system.

Chemistry plays one of the major roles in the formation of the scientific view on nature and a human being. It is inherently integrative, as the content of chemistry is strongly interrelated with that of physics and biology.

In today's secondary school chemistry is being taught either as a separate course or as a part of a complimentary integrated course in natural sciences, as well as a pure chemistry course to be chosen as an option. These conclusions are supported by the analysis of the structure and content of scientific education in 39 countries, which participated in TIMSS (Third International Mathematics and Science Study) project, launched by IAEEA (International Association for the Evaluation of Educational Achievement). Analysis showed that integrated courses of natural science were taught in 21 of those countries (54%) (Kovaleva & Koroshchenko, 1997).

Education in natural sciences, including chemistry, is one of the most important areas in Belarusian secondary education system, which is currently being reformed. Introducing of national standards and the tendency of establishing the equivalence between the certificates of secondary education in different countries make it necessary to establish common approaches to natural-

science education, as well as to ensure evolutional rather than revolutionary transition from secondary to higher and postgraduate education, namely educational succession.

This indicates **urgency** of our research and defines its **aim** — to reveal the major trends in improving natural-science education in secondary schools worldwide.

The **subject** of the research is chemical content in the integrated courses of natural sciences worldwide. **Methods** of the research are based upon comparative and correlative analysis of various printed materials relevant to the topic.

Results of the research

The framework of pre-college education in Western countries is constituted by three major levels: elementary school (5–6 years), lower secondary school (3–4 years) and higher secondary school (2–3 years) (Bratennikova & Vasilevskaya, 2001). In ***elementary school*** chemistry is taught as a part of integrated courses, same as physics and biology. For example, in **Japan** some foundations of chemistry are taught as a part of the integrated course "Life experience" (grades 1 and 2), which includes natural studies as well as the basics of geography, physics, chemistry, biology and social science. This educational course is aimed at teaching students to make conclusions about the world around them by using theoretical reasoning and experimenting. The educational content can be subdivided into two basic areas (Shimozawa, 1982):

1. Matter, energy, atoms, molecules and ions.

2. Diversity of natural phenomena. The universe. The Earth's crust. Relations between the living and inanimate nature.

In **Great Britain** and the **USA,** the content of the integrated courses of science is defined by national standards and programs, which contain the guidelines on the knowledge and skills which students must acquire at different grade levels. Conformance to these guidelines is controlled by nationwide tests.

The national educational standard in the USA for grades I–IV requires the students to have a notion about the *properties of various objects and materials; position and motion of objects; light, heat, electricity and magnetism*. Integrated courses of natural science in Canada, Israel and a number of other countries include similar content at the elementary level.

At the elementary level of school education in the **Republic of Belarus,** chemistry is taught as a part of a preparatory course "Humanity and the world" (grades 1 and 2). Chemical content is studied within the topic "Inanimate matter" (the program of studies allocates 6 hours to this area in the 1st grade and 14 hours in the second grade). In the first grade, students are being introduced to the following subjects: *air, water, environmental protection.* In the second grade, the scope of the studies is extended to *bodies and substances; physical and chemical phenomena; water; air; minerals; environmental hazards,* etc. Studies are being organized in accordance with the *spiral-concentric* principle, when the scope of acquired knowledge is expanded and deepened during the consecutive stages of education.

At ***the lower level of secondary school*** in **Japan,** chemical content is a part of the integrated course "Science I" (4 hours per week). It covers a number of major chemical concepts, such as *energy, structure and bonding of substances, chemical changes, evolution and equilibrium in a natural environment*. It must be noted that the periodic behavior of the properties of chemical elements and the stoichiometry of chemical transformations are regarded as fundamental chemical concepts (Shimozawa, 1982).

At the lower secondary level of education in Italy (grades 6–9), chemistry is also taught within an integrated course (6 hours per week, of which 4 hours are normally allocated for mathematics). The chemical content of this course touches upon the following subjects (Cervellati & Guardo, 1992):

- *states of matter (experiments dealing with the quantitative measures of substances and of their properties, e.g. measuring volume, mass, density, pressure, etc.; experiments illustrating phase transitions, mainly of water and other common substances);*
- *characteristics and transformations of substances (experiments with composite and pure substances, including separation of pure substances forming mixtures);*
- *atoms, molecules, their relative sizes; crystals;*
- *air (experiments dealing with combustion and other common oxidization processes).*

In **France** (Le Bihan, Le Roy & Coomber, 1992) and **Spain** (Cervellati & Guardo, 1992), chemical education starts with a two-year integrated course "Physical sciences", preceded by a preliminary (propaedeutic) stage during the first two grades in college. Throughout this stage, students acquire certain elementary knowledge of chemical processes and the structure of matter. Later it serves as a basis for studying more advanced subjects, including *corpuscular structure of matter; structure of the atom; corpuscular structure and electricity; ions; molecules; solids; water solutions; chemistry in economy and society.*

Currently, in the Republic of Belarus students take a course “Universe” at the junior stage of high school (V-VI grades). As a result of propeadeutical training in Chemistry in the frame of this course students should acquire an idea on composition and properties of certain substances as well as initial knowledge regarding chemical elements, chemical symbols, chemical formulas, simple and complex substances, compounds of substances, chemical phenomena. The curriculum allocates 16 hours in the 6^{th} grade to study this topic. Knowledge obtained at this stage of education helps students to form an initial integral perception of the world.

We shall have a more detailed look at the arrangements of comprehensive chemical education at the senior stage of secondary schools, which offer integrated courses in natural science presenting Canada as an example. The structure of education in natural sciences in Canada is reviewed in Diagram 1. Depending on individual interests and preferences the students of higher secondary schools in Canada can take one of three “Science” course levels, namely Beginner (B), General (G) or Advanced (A). Grades 9 and 12 also offer optional chemistry courses simultaneously with the general course “Science’. However, for an in-depth study of chemistry it is essential to choose level A in the “Science” course during two previous years.

Table1. Teaching of natural science in Canadian secondary schools

Grade	Course of studies	Teaching level
IX	Science	B, G, A
X	Science Environmental science	B, G, A G, A
XI	Science Environmental science Applied biology Biology Chemistry Applied chemistry	B G G A A G
XII	Science Environmental science Geology Applied physics	B G, A G, A G

	Physics Technological science	A G
XII (academic course)	Biology Chemistry Physics Science in Society	

Chemical content taught in grades XI (advanced level) and XII (academic course) is presented in the following table.

Table 2. Chemical content studied in grades XI and XII in Canadian secondary schools

Grade XI (advanced level)		**Grade XII** (academic course)	
Core units of study	Time allocations, hours	**Core units of study**	Time allocations, hours
Matter	8	Review	4
Elements and chemical bonding	20	Organic chemistry	15
Gases	15	Atomic structure and molecular architecture	13
Chemical reactions	25	Energy and rates in chemical reactions	20
Chemical-reaction calculations	13	Equilibrium — introduction	12
Solutions	20	Equilibrium — implementation	18
Industry and society	9	Redox and electrochemistry	20

The academic course is oriented towards preparation for the university studies, thus implying training in problem solving in various subjects, especially those requiring mathematical calculations, formulating hypotheses, and scientific interpretation of facts. The curriculum of this course emphasizes how important it is not only to build chemical knowledge, but also to create certain attitude towards it. In particular, it requires the students to understand relative nature of the knowledge they obtain and model character of the chemical theories they study. One of the essential components of the academic course is the Independent Research. The curriculum allocates 8 hours for this activity. Independent research implies development and implementation of a project in chemistry on a topic chosen in the beginning of the year. This project can be either experimental or theoretical (e.g. literary search). The work on the project is conducted under teacher's supervision, but independently by each student. Students formulate and define a problem, evaluate various solutions, and choose the optimal one. At the end of the year, they present the results of their research in the form of a report.

The content of the integrated “Science” course in the USA covers study material on atomic structure, structure and properties of substances, chemical reactions, motion and forces, energy conservation and increase of entropy, interaction between energy and matter. Similar content is offered to students in Great Britain, Ireland, and a number of other countries. Diversity of educational services allows American students, for instance, to study chemistry not only in the framework of the integrated course “Science”, but also within integrated courses “Chemistry in the

Community" or "Gaia" (Chemistry + Geography).

The integrated course "Chemistry and the Community" (ChemCom) was developed and distributed in the USA during the 80s due to the lack of interest among students to natural sciences and chemistry in particular. Study of chemistry in the frame of this course is grounded on socially relevant practical problems. Thus, chemical content is studied by means of discussing and solving these problems. Throughout the entire process of education the role of chemistry in everyday life and in decision-making is constantly emphasized.

The content of the course "Chemistry in the Community" is constituted by 8 large Sections. Each of them dedicated to an important chemistry-related aspect of social life, namely water resources, natural mineral resources, oil, nutrition and health problems, nuclear chemistry, chemistry of gases with respect to atmospheric problems, organic chemistry related to bioactive substances, industry and power engineering. Starting with an empirical fact, students learn to formulate a problem, and then focus on gathering additional data, to be followed by a group discussion employing numerical and visual supplementary material. About 50% of auditory time is devoted to laboratory experiment. Apart from a conventional evaluation of knowledge and skills, the standardized ChemCom exam assesses students' abilities to interpret charts and diagrams, to apply chemical knowledge in problem situations and to carry out laboratory activities.

Regulatory documents concerning education in Western countries are generally characterized by pragmatic and specific definitions of study objectives. For instance, according to the American educational standards the course "Science" should provide students with a sufficient level of knowledge and skills to

- experience the richness and excitement of knowing and understanding of the natural world;
- use appropriate scientific processes and principles in making personal decisions;
- engage intelligently in public discourse and debate about matters of scientific and technological concern;
- increase their economic productivity through the use of the knowledge, understanding and skills of the scientifically literate persons in their careers.

Establishment of the extensive interrelation between the disciplines of natural science may be considered as an undoubted advantage of integrated natural-scientific courses in general. With regard to chemistry, this also means that students develop an understanding of the significance of chemical knowledge in solving numerous vital problems. Furthermore, when selecting the optimal framework of laboratory investigations in the integrated "Science" courses worldwide the primary objective is to "introduce Chemistry by principles", meaning to apply approaches used for scientific research (Vorobiev, 1993).

A number of researchers consider shallow study of each discipline within a course as an obvious drawback of integrated courses. However, should we consider American school as an example, it must be emphasized that classes exercising conventional approach to chemistry teaching coexist with those using the ChemCom framework, making an in-depth study of chemistry available to all of the students. This relation between integrated and academic courses is well understood by the students, who show an increasing tendency to choose academic courses of chemistry (Malkova, 1996, p. 106).

Conclusions

Analysis of natural sciences education throughout the world reveals the following general trends:

1. A tendency towards stronger interdisciplinary integration in natural sciences, and for

development of unified approaches to creation of fundamental notions studied across different disciplines in modern secondary education.

2. A trend for diversifying education in order to agree with the educational capabilities of each student.

3. An increase in the practical orientation of the content of courses, manifested by enhanced emphasis on study of effects, processes and objects surrounding students in everyday life.

However, it should be emphasized that the present experience in chemistry teaching around the globe cannot be neither mindlessly replicated nor unreasonably praised. It has been written down as principles of historic continuity and multicultural identity that improvement of education in any discipline must be based above all on a nationally approved methodical system, as well as the present cultural and historic background of every country.

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Резюме

ВОПРОСЫ ХИМИЧЕСКОГО СОДЕРЖАНИЯ В ИНТЕГРИРОВАННЫХ КУРСАХ ЕСТЕСТВОЗНАНИЯ

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В формировании целостного знания о природе и человеке большая роль принадлежит изучению химии, поскольку химия по природе своей изначально интегративна, ее содержание взаимосвязано с содержанием физики и биологии. Преподавание химии в средних учебных заведениях в настоящее время реализуется как путем изучения обязательных самостоятельных курсов, так и путем включения вопросов химического содержания в обязательные интегрированные курсы естествознания (наряду с наличием самостоятельных курсов химии по выбору учащихся).

В работе рассмотрены структура и содержание химической составляющей в интегрированных курсах естествознания в Японии, Канаде, США, Великобритании, Ирландии, Италии, Франции и Испании, а также в Республике Беларусь. Показано, что интегрированные курсы естествознания являются, как правило, обязательным компонентом образования в начальной школе и на младшей ступени средней школы. На старшей ступени средних школ, практикующих преподавание интегрированных курсов естествознания, наряду с общими интегрированными курсами "Наука", "Химия и общество" или "Гея" (химия + география) предусмотрены также курсы химии по выбору. В программах учебных курсов, равно как и в других нормативных документах, цели их изучения определены достаточно прагматично и персонифицированно. Так, к примеру, изучение интегрированного курса "Наука" согласно американским образовательным стандартам должно дать учащимся достаточный уровень знаний для:

- научного понимания процессов, которые происходят в окружающем мире;
- научно аргументированного принятия личных решений;
- осознанного участия в общественных обсуждениях по вопросам науки и техники;
- увеличения личной экономической продуктивности путем использования научных знаний в личной карьере.

Проведенный в работе анализ содержания интегрированных курсов естествознания в разных странах мира показал, что несомненным достоинством рассматриваемых курсов вообще является установление наиболее полной взаимосвязи между изучаемыми естественнонаучными предметами, а применительно к химии – формирование убеждения в необходимости химических знаний для решения многих жизненно важных проблем. В школьном образовании на современном этапе следует отметить ярко выраженную тенденцию не только к усилению интеграции естественнонаучных знаний, полученных при изучении различных предметов, но и к разработке единых подходов в формировании основных понятий, изучаемых в различных естественнонаучных курсах. При этом наблюдается усиление практической направленности содержания курсов, изучение явлений, процессов, объектов, веществ, окружающих учащихся в повседневной жизни. Внедрение национальных стандартов и стремление к эквивалентности документов об общем образовании настоятельно требуют определения в разных странах единых подходов к естественнонаучным курсам в средней школе, подготовке научно-педагогических кадров, совершенствованию

преемственности школьного, вузовского и послевузовского естественнонаучного образования.

Ключевые слова: естественнонаучное образование, интегрированные курсы, химическое образование.

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