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INTEGRATION OF ENVIRONMENTAL CHEMISTRY PROBLEMS INTO THE SECONDARY SCHOOL GENERAL CHEMISTRY PROGRAM

INTEGRACJA PROBLEMÓW CHEMII ŚRODOWISKA W PROGRAMIE NAUCZANIA CHEMII OGÓLNEJ W SZKOŁACH ŚREDNICH

Abstract: At currant education situation, high school students in Latvia are enabled either to master branches of natural sciences - chemistry, physics and biology as separate courses, or to acquire an integrated course of natural sciences. In both cases, the curriculum contains various environmental problems. The standard of secondary education in chemistry, as well as in other subjects of natural sciences, foresee the formation of clear comprehension about different environmental problems together with other results obligatory for students to achieve. The mastering of environmental problems comes about during the familiarization with all the basic chapters of chemistry course - general, inorganic and organic chemistry. The teaching of general chemistry course is especially problematic in several aspects because its comparatively abstract content conflicts with the students' more pronounced concrete way of thinking at this age. Besides, there is no possibility to use neither laboratory exercises nor teacher's demonstrations during the teaching/learning of many themes in this course. These problems should be solved, because a stable general chemistry knowledge basis is essential prerequisite for further successful mastering of inorganic and organic chemistry in high school. The work with different descriptions of environmental chemistry (*descriptive texts* further in our research) as a tool for the teaching/learning of chemical regularities is a good possibility to link the abstractive for the student theoretical content of the subject with his/her everyday experience, situations existing in real life. Therefore a theoretical investigation was performed to develop a scientific justification for the exploitation of texts containing environmental chemistry information for the mastering of general chemistry course in high school. The theoretical investigation was accomplished by employing the results of the analysis of students' reading competence formation published in the education and psychology literature and by joining it with the specificity of the chemistry course mastering, as well as by leaning on authors' personal experience obtained during long years of chemistry teaching. As a result of the above-mentioned, a justification was formed for the elaboration of the work with texts on four levels considering the fact that a student should apply more and more complicated skills for the performance of every following exercise. Assuming that the teaching/learning process should be divided in several phases - initiation, comprehension and reflection, the exploitation of exercises corresponding to all these phases was analyzed in the paper.

Keywords: environmental chemistry, high school general chemistry, work with descriptive texts

Abstrakt: W obecnym łotewskim systemie edukacji uczniowie szkół średnich są zobowiązani do opanowania wiedzy z zakresu głównych dziedzin nauk przyrodniczych - chemii, fizyki i biologii - w formie osobnych kursów lub ukończenia zintegrowanego kursu nauk przyrodniczych. W obu przypadkach program obejmuje różnorodne zagadnienia dotyczące ochrony środowiska. Zrozumienie problemów ochrony środowiska następuje w czasie zapoznawania się ze wszystkimi podstawowymi działami chemii: ogólnej, nieorganicznej i organicznej. Nauczanie chemii ogólnej jest szczególnie trudne, ponieważ jej abstrakcyjne treści kolidują z bardziej konkretnym sposobem myślenia charakterystycznym dla wieku uczniów. Nadto dla wielu tematów tego działu nie ma możliwości realizacji zajęć laboratoryjnych ani demonstracji wykonanych przez nauczyciela. Trudności te należy rozwiązać, ponieważ wiedza z chemii ogólnej jest niezbędnym warunkiem do dalszego, skutecznego nauczania chemii nieorganicznej i organicznej w szkole średniej. Przeprowadzono teoretyczne badania, których celem było opracowanie naukowego uzasadnienia wykorzystania tekstów zawierających informacje o chemii środowiska do nauczania chemii ogólnej w liceum. Cele badań teoretycznych zostały osiągnięte poprzez zastosowanie wyników analizy kompetencji czytania uczniów opublikowanych w literaturze dydaktycznej i psychologicznej w połączeniu ze specyfiką

prowadzenia kursu chemii, a także na podstawie osobistych doświadczeń autorów, uzyskanych w trakcie długich lat nauczania chemii.

Słowa kluczowe: chemia środowiska, chemia w liceum ogólnokształcącym, praca z tekstem opisowym

Introduction

At present it is possible for secondary school students in Latvia to study chemistry, physics and biology as separate courses and also as an integrated natural sciences program. In both cases the curriculum includes various environmental issues. The secondary education standard [1] for chemistry as well as all other natural sciences, along with the requirements for the course, foresees students developing an understanding of various environmental problems. For example, the student:

- „knows the contents, the main ingredients and use of such every day substances as salts, fertilizers, plant herbicides and pesticides, metal alloys, solvents, washing detergents, plastics, fibres, glues, varnishes and polishes, paints, medicines, cosmetics and major food products;
- understands the importance and necessity of water and air conservation;
- can describe the proper use of regular and mineral fertilizers, lime, herbicides and pesticides;
- can explain the importance of waste recycling in the chemistry industry as well as the need for industrial zero waste technologies;
- can explain the production of ceramics, glass, building materials, metals, ethyl alcohol, saccharin, paper and polymers and production related environmental problems".

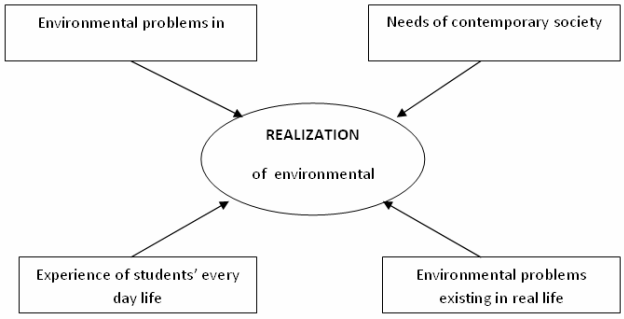

Fig. 1. Aspects of understanding environmental problems (adapted from A. Bartuseviča)

Aira Bartuseviča (now Krūmiņa) [2], one of the leading chemistry didactic experts in Latvia, addresses several crucial aspects in the development of this understanding. They are schematically presented in Figure 1.

Teachers in today's modern world have many available technologies and opportunities to develop an interesting and exciting learning process both in content and in method. A couple of questions remain: what should be stressed more in the learning process? How can traditional and modern methods be most effectively balanced? Of significant importance is organizing the learning process based on psychological peculiarities characteristic for the particular age group.

Students must come to understand environmental problems after having completed secondary school chemistry. Understanding of environmental problems does occur more or less by studying the various parts of the chemistry program including general, inorganic and organic chemistry. It is precisely general chemistry that is problematic in certain respects. Students take this course upon entering secondary school (usually at age 15 or 16). The first problem is that the fairly abstract nature of the content of this course is in direct contradiction with the distinctly concrete form of thinking characteristic for this age group. The second problem is that it is not possible to use laboratory experiments or demonstrations to learn many of the topics included in the course. However, a sound foundation of chemistry is crucial for success in organic and inorganic chemistry in secondary school. It is possible to alleviate the situation by making use of the students' everyday experience and real situations to make the course more understandable. This is possible by implementing descriptions of the many and varied chemical processes taking place in the environment as part of the methodology used to teach the course (subsequently referred to as „descriptive text").

Thus the purpose of our study: to develop a theoretical basis for the use of descriptive texts of environmental chemistry information in secondary school general chemistry.

The term „descriptive text" in the context of our study: a compilation of information from various sources (not duplicating information in the chemistry text book) presented graphically or schematically that explains the characteristics of various environmental chemical processes and that can be supplemented by additional graphs, figures or diagrams.

Results and discussion

The descriptions used in teaching a school subjects are different from those we encounter every day. They are definitely more complicated, they tend to differ in style and sentence construction. Descriptions dealing with environmental issues will include terminology and concepts accepted in this field. In order to make the best use of any descriptive texts, including those used in chemistry, the teacher must fully understand the purpose of using a particular text and the student must be fully capable of reading and understanding the text. Does the mere ability to link together letters and words mean that the student has fully understood the meaning of the descriptive text? Such an

interpretation of understanding is much too simplistic. Pedagogy uses two terms - **literacy and reading competence**. Explanations of both terms can be often found in various pedagogic literature sources [3-5]. **To sum up: literacy is seen as the ability to perceive, understand, analyze and evaluate a written text.**

International comparative studies are conducted worldwide in an attempt to answer the prevalent questions about the content and quality of education in various countries. Among other things, **student literacy** or **reading competence** is evaluated in these studies. As already mentioned, the students who take the general chemistry course in Latvia are 15 and 16 years old. Thus, it is significant to understand the context in which the literacy issue is viewed in the international student evaluation program (*Program for International Student Assessment* - PISA) of the OECD (*Organization for Economic Cooperation and Development*). This is an international study measuring the competence of 15-year-olds in literacy, mathematics, natural sciences and problem solving. In the context of the study **reading competence** is defined as „**the ability to understand, use and evaluate written texts in order to reach ones goals, to improve ones level of knowledge, ones potential and to become socially active**" [6]. Since the learning process is a distinctly personal one, the second definition, which presents a clearer goal, is the one we feel is more relevant to our study.

Various aspects of reading competence are evaluated in the PISA study [7]. A summary of student skills was compiled upon analysis of this information (see Table 1).

Upon reviewing the aspects of reading competence in order (see Table 1, pts 1-5), we see that they are progressively more difficult requiring more complex skills. Based upon the information in Table 1 and relating it to the objectives of our study, we conclude the following:

In order to ensure productive use of descriptive texts in secondary school general chemistry studies, exercises must be devised at various levels taking into account the fact that exercises at each successive level demand progressively more complex skills.

Table 1. Student skills based on the PISA study

Nr.	Evaluated aspect of reading comprehension	Student skills
1.	Broad, general understanding of the text	Can distinguish main ideas from details, can recognize summary of main ideas.
2.	Procuring information	Upon scanning the text can select necessary information.
3.	Interpretation	Can logically process information in the text resulting in a more concrete and complete understanding. Is able to compare and contrast information.
4.	Evaluation of contents	Can evaluate information in the text on the basis of what he or she already knows. Is able to connect the information with personal experience, knowledge and opinion.
5.	Evaluation of format	Can objectively evaluate the format of the text including structure, style and language nuances.

It should be noted that for purposes of the general chemistry program, it would serve no purpose to include exercises on text's form evaluation, since these exercises are more appropriate for humanities and social sciences programs. It should be noted as well that the purpose of any descriptive texts pertaining to environmental issues is to make it easier and more interesting to master the general chemistry program by presenting it from the perspective of environmental problems which are an integral component of our every day life. The descriptive texts used in chemistry lessons should not be replete with complicated and unknown terminology and difficult to understand descriptions of chemical processes. Thus it is possible to categorize four levels of exercises:

- Level 1 - definition and/or recognition of the concept using information in the text; providing answers to concrete yes/no questions about the text; formulation of the main idea of the whole text or part of the text.
- Level 2 - drawing simple conclusions, answering questions combining several themes presented in the text; grouping information in the text based on specific given criteria; formulating the main idea of the text based on its argumentation; representation of process descriptions by appropriate chemical reaction equations.
- Level 3 - transforming the graphically systematized text into a free form providing a logical description of the process while retaining the main idea; graphic organization of the text using independently selected systematization criteria; comparison of the various diagrams and graphs presented in the text pointing out commonalities and differences; independent analysis of the information in the text and comparison of the text with reference literature data.
- Level 4 - analysis of the content of the text based on a comparison with existing knowledge, providing argumentation based on previously studied topics in chemistry and other courses; evaluation of the objectivity of facts presented in the text and substantiation of ones opinion; formulation of problems inferred by the descriptive text.

The issue of how to use work with descriptive texts in specific learning phases - initiation, comprehension, and reflection - is a significant one. Is it possible to use all four levels of exercises in each phase? To answer this question we must first define the goals of each learning phase (see Table 2).

Table 2. Learning phases and corresponding goals

Learning phase	Goal
Initiation	To interest the student in the topic, to help understand and remember existing knowledge, to form a basis for new knowledge.
Comprehension	Promote acquisition of new knowledge, help the student understand the topic.
Reflection	To help the student combine new and existing knowledge, make substantiated decisions and opinions.

Answers to the raised questions arrive after joining teaching/learning goals for every teaching stage with those

skills that are necessary for accomplishing the exercises corresponding to every level. The summary of them is presented in the Table 3 where with a "+" are marked those exercises that are accordant to the descriptive text in every teaching/learning stage.

Table 3. Exercise levels and corresponding learning phases

Learning phase	The 1st level exercises	The 2nd level exercises	The 3rd level exercises	The 4th level exercises
Initiation	+	+	+	
Comprehension	+	+	+	
Reflection				+

Obviously there is quite a wide range of opportunities to use descriptive texts in the learning process.

A better insight into this can be gained by analyzing a specific text and using it in exercises at various levels. For this purpose we have selected the descriptive text „Chemical changes in the environment", which we have used as the basis for exercises at various levels for the topic „Classification of chemical reactions" in the general chemistry program.

In developing the text the following aspects were taken into consideration:

- The importance of real life situations and the student's every day experience.
- The connection with the student's previously amassed knowledge in chemistry - mainly during elementary school, since general chemistry is taught in the first year of secondary school.
- The form of expression avoiding specific and complicated terminology.
- Adaptation of the amount of text for use in one lesson.

Sample text:

Chemical changes in the environment

Air is one of the main factors determining life processes on Earth. Without oxygen, which is a component of air, metabolism and energy production in living organisms is impossible. A person uses about 28 m³ of air in a 24 hour period, thus even the tiniest amount of noxious substances in the air can be harmful to human health. It is assumed that the atmosphere is contaminated if the concentration of individual substances begins to exceed the natural concentration that has formed and stabilized over the last 500 million years having remained practically unchanged for the last 2-3 million years.

Air pollution is mainly connected with the increase in the concentration of the following substances: SO_2, CO, CO_2, NO, NO_2, NH_3 and O_3. This pollution usually occurs as the result of human industrial and economic activity. Substances emitted into the air undergo various transformations and noxious substances often do not neutralize or decompose evenly resulting in unfavorable consequences.

Many of the substances found in the atmosphere react easily with water resulting in precipitation that has an enlarged level of acidity. Rain water is usually of an intermediate acid level because the CO_2 in the air reacts with water. Sulphur and nitrogen oxides that are produced by burning various fuels enter the atmosphere and the resulting reaction produces acids lowering the pH of snow water to 4÷4.5, sometimes even lower:

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

$$H_2O + SO_2 \rightleftharpoons H_2SO_3$$

$$H_2O + SO_3 \longrightarrow H_2SO_4$$

$$H_2O + 2NO_2 \longrightarrow HNO_3 + HNO_2$$

The substances produced as a result of the above reactions can react further with other substances found in the atmosphere, water or soil. As a result of such changes free Al^{3+} ions can reach the natural water supply. This happens when the insoluble aluminum oxide found in soil water reacts with substances found in acid rain or snow.

As a result soluble aluminum compounds are produced in water. Plants absorb Al^{3+} ions directly through the roots that gradually weaken and the plant dies. Aluminum ions also have a negative effect on the reproductive system in fish.

NO_2 intensity in the air is more pronounced in cities with a higher intensity of automobile traffic. Oxygen and nitrogen burn in the high temperature and pressure of automobile engines:

$$N_2 + O_2 \longrightarrow 2NO$$

The initially produced nitrogen(II) oxide in reaction with oxygen in the air oxidizes further to become nitrogen(IV) oxide. Further chemical transformation occurs due to the influence of intense sunlight resulting in the production of ozone. Ozone, which is a strong oxidant, reacts with other substances in the atmosphere. The products of these reactions, as well as ozone itself, are harmful to life and human health. To decrease the amount of NO and CO in automobile emissions special devices called catalytic converters are installed in exhaust systems. With the help of these converters NO is transformed into molecular nitrogen and CO is changed into CO_2.

As a result of intense human economic activity, for example deforestation or burning fossil fuels to ensure various industrial and economic processes, the amount of carbon dioxide in the air is significantly increased. This is considered to be one of the factors causing the greenhouse effect. To simplify, the greenhouse effect can be compared to a glass roof that practically does not bar the sun's radiation and binds the heat from the Earth thus delaying the flow of heat into the cosmos. Scientists consider the greenhouse effect to be one of the causes of global warming. All fossil fuels now in use emit CO_2 upon combustion:

- Coal: $C + O_2 \rightarrow CO_2 + Q$
- Natural gas: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + Q$
- Gasoline (a hydrocarbon mixture whose main component is octane):

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O + Q$$

It is crucial to decrease the use of fossil fuels not only to decrease the amount of carbon dioxide in the atmosphere. Coal and petroleum, from which gasoline and natural gas are

produced, are non-renewable natural resources whose supplies are constantly diminishing. To ensure long term environmental development we must try to use alternative energy resources such as geothermal, solar and wind energy and we must sensibly use and renew our wood resources.

Student exercises for work with the descriptive text:

Sample exercises are compiled in Table 4 showing both learning phase and exercise level. Multiple uses of the text in the learning process were accented in devising the exercises.

In selecting exercises for a specific topic, the teacher must take into account various factors such as the student's level, learning environment issues (work in groups, for example), the number of lessons available for the topic among others. Some exercises can be done working independently at home not only in the classroom.

We emphasize that the issue of learning process organization is not analyzed in more detail as part of this study. Based on general and chemistry didactics precepts and the extensive experience in chemistry education of the authors of the study, we maintain that productive learning occurs only when the teacher as organizer and leader of the learning process is able to evaluate the efficacy of various teaching methods in any given situation. Only learning with understanding ensures a stable foundation in any subject. Taking into account the student's every day experience in the study of theoretical chemistry issues dealing with the environment stimulates this type of learning.

Table 4. Sample exercises based on learning phase and level

<table>
<tr><th>Learning phase</th><th>Exercise level</th><th>Sample exercise</th></tr>
<tr><td>Initiation</td><td>1</td><td>Using the text, define „atmospheric pollution”!</td></tr>
<tr><td>Initiation</td><td>1</td><td>The text provides information about three significant environmental problems caused by air pollution. Name them and note where in the text they are discussed!</td></tr>
<tr><td>Initiation</td><td>2</td><td>Find the descriptions of chemical transformations and write molecular chemical reaction equations for them!</td></tr>
<tr><td>Initiation</td><td>3</td><td>Using literature sources find various definitions for the term „atmospheric pollution”, compare them with the definition given in the text and note which definition best describes the phenomenon!</td></tr>
<tr><td>Comprehension</td><td>1</td><td>Mark the appropriate answer with an „X”
<table><tr><th>Assertion</th><th>Yes</th><th>No</th></tr><tr><td>If more raw materials are involved in a chemical reaction, always more substances result.</td><td></td><td></td></tr><tr><td>A chemical reaction can take place without a catalyst.</td><td></td><td></td></tr><tr><td>If the raw materials are compound substances, the resulting products will always be compounds.</td><td></td><td></td></tr><tr><td>Sometimes heat is produced along with a reaction product.</td><td></td><td></td></tr><tr><td>Chemical elements always change their oxidation states during a chemical reaction.</td><td></td><td></td></tr><tr><td>In specific reactions, the product decomposes back into raw material.</td><td></td><td></td></tr></table></td></tr>
<tr><td>Comprehension</td><td>2</td><td>Complete the table with descriptions and equations of the chemical reactions based on the indications given!
<table><tr><th>Indication</th><th>Corresponding equation</th></tr><tr><td>A catalyst is used in the reaction.</td><td></td></tr><tr><td>Heat is absorbed or emitted.</td><td></td></tr><tr><td>Reaction products decompose back to raw materials after formation.</td><td></td></tr><tr><td>The number and structure (simple and compound) differ for reaction products and raw materials.</td><td></td></tr><tr><td>Reaction elements change their oxidation state during the reaction.</td><td></td></tr></table></td></tr>
<tr><td>Comprehension</td><td>2</td><td>Find oxidation – reduction equations in the text and describe their electron balance using the terms oxidation, reduction, oxidizing agent, reducing agent!</td></tr>
<tr><td>Comprehension</td><td>2</td><td>Using information given in the text, make molecular and ionic equations showing how Al^{3+} is formed in nature!</td></tr>
<tr><td>Comprehension</td><td>2</td><td>Find reactions described in the text complying with all of the following criteria:
• endothermic reaction,
• non-catalytic reaction,
• composition reaction,
• irreversible reaction,
• oxidation - reduction reaction!</td></tr>
<tr><td>Comprehension</td><td>3</td><td>Evaluate all the chemical reactions described in the text (equations and description) grouping them by reaction type! Formulate the similarity!
<table><tr><th>Similarity indicator</th><th>Appropriate equation</th></tr><tr><td></td><td></td></tr></table></td></tr>
<tr><td>Reflection</td><td>4</td><td>The text describes various chemical reactions taking place in the environment. Using them as examples, explain why it is important to predict chemical processes based on conditions they occur in. Search the literature to find areas of chemistry or other natural sciences that investigate this issue. Compile the information in a table!
<table><tr><th>Branch of science</th><th>Its goals</th></tr><tr><td></td><td></td></tr></table></td></tr>
</table>

Conclusions

1. Work with descriptive texts in the exact and natural sciences program ensures not only learning the material in each course but also promotes the development of reading competence.
2. Work with descriptive texts that include descriptions of chemical processes that are part of the student's every day experience ensures better comprehension of abstract chemical concepts.

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References

[1] Chemistry. Standard of the high school chemistry education, 2007, http://www.isec.gov.lv/normdok/mk070544.htm#21 (in Latvian).
[2] Bartuseviča A.: Methods of critical thinking in chemistry. Publishing House of the University of Latvia, Riga 2004 (in Latvian).
[3] Skujiņa V. (ed.): Explanatory dictionary of pedagogy terms. Zvaigzne, Riga 2000 (in Latvian).
[4] Wikipedia: Literacy, 2005; http://en.wikipedia.org/wiki/Literacy.
[5] Wagner K.J.: Glossary of reading terms, 2006, http://www.education-oasis.com./curriculum/Reading/glossary_reading_terms.htm.
[6] Kangro A. and Geske A.: Knowledge and skills for life. Latvia in the international students' evaluation program of OECD countries, 1998-2001. Publishing House "Mācību grāmata", Riga 2001 (in Latvian).
[7] Geske A. and Ozola A.: Students' literacy achievements in Latvia and in the world. Publishing House of the University of Latvia, Riga 2004 (in Latvian).