Interdisciplinary instructional approach to the theme "Air, water, soil and food pollution and its prevention"

Enfoque interdisciplinario para enseñanza del tema "Contaminaciones de aire, agua, tierra y comida y sus prevenciones"

DRAGICA ŠIŠOVIC[1] AND DEJAN BOŠKOVIC[2]

[1] *University of Belgrade, Faculty of Chemistry*, Serbia and Montenegro
[2] *'Ivo Andric' Primary School, Belgrade,* Serbia and Montenegro

Abstract

This paper presents an elaboration of the theme "Air, Water, Soil and Food Pollution and its Prevention" in the seventh grade of primary school (students aged 13). Our aim was to examine the possibility of using the potential of this theme in order to integrate students' knowledge acquired in separate subjects (chemistry, physics, biology), as well as to make students aware of the importance and possibilities of such an application of knowledge for achieving a better understanding of the environment they live in. Additionally, we aimed at the development of students' active and participatory attitudes towards environment, as well as of a sense of responsibility for the conditions in their environment. To achieve these aims we organized four workshops. The effects of the approach were examined in a pedagogical experiment, which included one experimental group and a parallel control group. The interdisciplinary approach and the workshop technique were used with the experimental group, while the control group was submitted to traditional frontal forms of teaching and in-class discussions. The students of the experimental group showed better results in the post-testing, and the arithmetic mean difference was statistically significant at the 0.01 significance level.

Key words: environmental education, science, interdisciplinary approach, workshops.

Resumen

Este artículo presenta la metodología del tema "Contaminaciones de aire, agua, tierra y de comida y sus prevenciones" en el séptimo grado de escuela (estudiantes de 13 años de edad). El objetivo era examinar la posibilidad de usar este tema para integrar el conocimiento adquirido de los estudiantes en otras asignaturas (química, física, biología), así como para hacerlos concientes de la importancia y posibilidades de tal aplicación de conocimiento para lograr un entendimiento bueno del ambiente en que ellos viven. Adicionalmente, se apunta al desarrollo activo de los estudiantes hacia el medio ambiente, así como de un sentido de responsabilidad sobre las condiciones del medio ambiente. Para lograr estos objetivos se organizaron cuatro talleres y un experimento pedagógico con un grupo experimental y de control. En el grupo experimental se usaron el enfoque interdisciplinario y la técnica del taller, mientras el grupo de control se sometió a la enseñanza tradicional con discusiones en clase. Los estudiantes del grupo experimental mostraron mejores resultados en el examen final, y la diferencia media aritmética fue estadísticamente significante en el 0.01 nivel.

Palabras clave: educación medioambiental, ciencia, enfoque interdisciplinario, talleres.

INTRODUCTION

The authors of numerous investigations published in recent years point out that most students at all academic levels are interested in environmental science. In order to support this interest, as well as the study of environmental chemistry, various experiments related to the analysis of environmental pollutants have been suggested (GIOKAS, PALEOLOGOS & KARAYANNIS, 2003; RAMOS, MILLER & KORFMACHER, 2003; DUNNIVANT, 2002; BRESLIN & SANUDO-WILHELMY, 2001; CANCILLA, 2001; VOLKER *et al*., 2000; RUM, LEE & GARDEA-TORRESDEY, 2000). Some articles offer a methodology for the assessment of some alternative methods of waste product elimination/ reduction in chemistry and biology laboratories (LI, BARNETT & RAY, 2003). Other articles focus on the importance of environmental education and the laws concerned with environmental protection (WITTECK & LEWIS, 2000). Computers enable students to simulate various data collecting techniques, to formulate and test various hypotheses in controlled experiments (ROBINSON, 2001; PIRJOLA, 2000). Researchers have investigated the impact of experiments on students' knowledge and explanations of significant aspects of the greenhouse effect (PAPAGEORGIOU & TSIROPOULOU, 2004). Environmental education is believed to contribute to the development of critical interdisciplinary thinking, problem solving and decision making skills (ZOLLER, 2000, LUBEZKY, DORI & ZOLLER, 2004). In some articles, an interdisciplinary model for teaching is suggested too; for example, a model for teaching the topic "foods" (MAVROPOULOS, ROULIA & PETROU, 2004).

Current natural sciences syllabi, as well as those previously used in Serbia, have been predominantly oriented towards teaching scientific disciplines as separate subjects. Biology starts being taught in the fifth grade (students aged 11), physics in the sixth, and chemistry in the seventh grade. Although the importance of the connection between different natural science teaching contents has been repeatedly pointed out, the integration of separately studied contents through adequately chosen topics has not been provided as yet. Hence, natural science textbooks lack such an approach, nor is it applied in the teaching process. Knowledge integration is "left" to students to pursue by themselves if and when they "feel" a need.

On the other hand, the same syllabi do not support the development of skills that will help students to achieve a high quality of life in their natural and social surroundings. A usable and high quality knowledge of the environment is necessary for the establishment, maintenance and development of efficient interaction with the natural and social environment, and a significant, active, and participatory attitude towards the environment (PEŠIKAN & ŠIŠOVIÆ, 2003). The teaching of the natural sciences has aimed primarily at transmitting essential scientific concepts, but has not encouraged the development of students' active attitudes towards the environment: solving the problems of environmental protection and preservation, reconciling the needs and wishes of modern man under the influence of modern technology.

In this paper, we describe an interdisciplinary approach for teaching the theme, "Air, Water, Soil and Food Pollution and its Prevention" in the seventh grade of primary school. By using one theme/topic as an example, we wanted to show:

(i) how it is possible to integrate the knowledge acquired by studying separate subjects (chemistry, physics, and biology);

(ii) how students can be led into a situation of using their knowledge of different natural sciences simultaneously, and thus become aware of the importance and possibilities of the usage of such integrated knowledge in order to understand the environment in which they live.

An additional aim was to stimulate the development of the students' active and participatory attitudes towards the environment, their enthusiasm for initiating and carrying out various nature preservation activities, as well as the sense of their own responsibility for the conditions in their surroundings.

METHODOLOGY APPLIED IN THE INVESTIGATION

In the situation in which natural sciences are taught as separate subjects, the themes, the elaboration of which makes it is possible to integrate separately studied contents, are very important. We chose our theme according to two criteria: (i) the feasibility to integrate knowledge formed in different subjects; and (ii) its importance for students in their everyday lives.

The theme of this particular investigation, "Air, Water, Soil and Food Pollution and Preventive Measures", was formulated on the basis of the theme, "Environmental Protection and Improvement", in the biology syllabus for the seventh grade. Four workshops were devised for the elaboration of this theme and each will be briefly described. Workshop 1 was an introduction to the theme. Workshop 2 was about air pollution and protective measures. Workshop 3 dealt with the contamination of water, soil and food, and preventive measures. Workshop 4 was about wastes.

Description of the Workshops

Workshop 1: Introduction

In the first workshop, the students were divided into five groups, each group consisting of four or five members. All groups had the same task — to write essays on pollution, polluters, and sources of pollution—, but each group was supposed to use different sources of information:

- one group was to use chemical literature;
- the second group had to use biological literature;
- the third group had to use literature from the realm of physics;
- the fourth group had to rely on their general knowledge and experience from everyday life;
- the fifth group had to use newspaper articles as sources of information.

The suggested sources of information were selected in advance by the instructors and prepared so that the information they offered corresponded to the level of the students' prior knowledge. At the end of the session, the groups presented their "stories". The aim was to make students aware of the fact that a topic can be discussed from various perspectives, and that different perspectives offer different types of information.

Workshop 2*:* Air pollution and protective measures

In Workshop 2, all groups were given photocopies of all essays written at the previous session, as well as the equipment and substances necessary for experimental work. The first task for all groups was to select air polluters from the list of contaminators they had made at the previous session. Based on the reports of all groups, a final list of air polluters was formed. Then followed a discussion about the consequences of air pollution. Students were shown photographs of smog, in different cities, and then they themselves analyzed some characteristics of smog, after having made "artificial smog" in a jar. They observed and compared what happens to flashlight rays in a jar filled with air and the one filled with smog. The results were used to explain the photographs. A demonstration of the experiment; "the influence of SO_2 on a red rose" served as the basis for a discussion on the influence of this polluter. Then the influence of CO_2 and the greenhouse effect were dealt with. Near the end of the session, the problem of the ozone holes was discussed.

Workshop 3: Contamination of water, soil and food and preventive measures

The tasks in this workshop were devised in accordance with the school surroundings. All groups were supplied with detailed maps of all objects in the Rakovica district of Belgrade : their school, the *Rakovica* Motor Industry (MIR), the Hothouse, and the residential area. Each group was assigned different roles:

1. managers of the MIR;
2. managers of the Hothouse;
3. presidents of the tenants' councils;
4. ecologists.

The first three groups were assigned the task of considering the following questions: which ecological problems they encounter both at work and in everyday life, how and by which agents they and their neighbours pollute the environment, as well as which influences coming from others in their surroundings they themselves feel. The "ecologists" group was supposed to consider possible environmental problems and suggest optimal solutions. The results were presented in the form of a simulated TV talk show entitled, "Who contaminates us?" One student was the host of the "show", and the "guests" were the representatives of each group: the MIR and Hothouse managers, the residents, and the ecologists. The rest of the students played the part of an active audience and were expected to participate in the discussion by posing questions. Before opening the discussion, the host suggested that the participants have a look at the indicator recordings of the acid properties of rain and the acid-base characteristics of the soil taken from a nearby forest, the schoolyard, near the road, and from a flower pot. The samples of rainwater and soil had been prepared in advance, and the teacher and several students conducted the demonstration.

Workshop 4: "Wastes all around me"

Here the students were handed various articles about waste storage depots, industrial equipment, industrial products, waste by-products, mineral ore exploitation, etc. The first group received the task to make a poster on which they would give answers to the following questions: what kinds of wastes your families produce in a week, how many garbage bags they fill in a week, what is usually present in those bags, how the wastes could be grouped according to the material they are made of, where the garbage bags end up, how this affects the environment and the health of people. The poster of the second group was supposed to provide information on industrial waste by-products: which by-products, in what quantities they are produced each day, week, etc., what their characteristics are, where they are stored, how they affect the environment and the health of people. The third group made a poster about a mine: which waste products result from the exploitation of the ore, how much ore and how much dross is obtained. They made the lists of waste products according to their characteristics, where and how they are stored, and how this affects the environment and the health of people. The fourth group made a poster about health institutions: what wastes are produced in the course of everyday activities at a health centre and a hospital, how much waste they have every day and in a week, the types of wastes, where and how they are stored, and how this affects the environment and the health of people.

When the students finished their work, the posters were put on the walls and a discussion was started to establish the biggest polluter, the most dangerous waste products, what certain waste products pollute (air, water, soil, food), whether they are general (present in all four cases) or specific. Then each group presented their suggestions for solving the problems of pollution, waste storage and recycling, in order to reduce the contamination of the environment. The last activity comprised experiments on paper recycling.

Study of the effect of the interdisciplinary approach

The effects of the approach presented were analyzed in a pedagogical experiment with two parallel groups. The research was conducted during the 2002-03 school year. Four seventh grade classes (92 students) were chosen as a sample. At the beginning, the students were asked to take a pre-test, the aim of which was to determine whether they possessed the necessary level of knowledge, and to divide the classes into two groups (experimental and control) of relatively equal levels of knowledge. The pre-test contained fifteen items which comprised the basic knowledge about air, water, soil, and other mixtures and solutions in nature.

In the control group, teaching was organized according to the topic, "Environmental Protection and Improvement" in the biology syllabus and the teacher's instructions included therein. The topic "Environmental Protection and Improvement" comprises the following themes: environmental and ecological equilibrium, influence of men on all living organisms in the environment, growth of new settlements and life conditions in cities, air pollution and its prevention, water contamination and its prevention, soil contamination and its prevention, food contamination and its prevention. The frontal approach and class discussions were applied in the control group. In the experimental group, the work was organized in the manner described above.

At the end of the experiment, a post-testing was organized in order to examine the effect of the different instructional strategies on both groups. The post-test contained fifteen items. The test required students to use their knowledge of chemistry, biology, and physics in order to explain and solve the problems related to air, water, soil and food pollution. Sample tasks from the post-test might include the following requirements:

(i) Explain the effects of the drainage of large quantities of hot water used for cooling electric power plant equipment on: a) dissolved oxygen in rivers, b) salt solubility, and c) living organisms in rivers.

(ii) The global warming on Earth is caused by the greenhouse effect. We can not find this effect in the greenhouse of the "Jevremovac" Botanical Garden in Belgrade. The temperature in this greenhouse is high, but constant. Explain.

An additional questionnaire was used to reveal the students' attitudes towards the teaching strategy that had been used: what they liked, what not, how the applied method contributed to their understanding of the problem of pollution and the measures for the protection of the environment, about the connection between natural sciences and everyday life, and what they think their biology, chemistry and physics classes should be like. The questions were of the open type.

The research was carried out during eight sessions, and the same teacher (D. Boškoviæ) led classes both in the experimental and the control groups.

RESULTS AND DISCUSSION

The distribution of the pre-test results is given in table 1.

Table 1
The distribution of the pre-test results (maximal test score: 27).

Group	Experimental	Control
Number of students	42	50
Arithmetic mean	7.74	8.24
Standard deviation	4.16	5.49
Total percentage	28.7	30.5
t test	-0.46	

The t-test value showed that the difference between the arithmetic means was not statistically significant. The test result indicated a low level of prior knowledge in both groups (the total percentage of correct answers was about 30%).

The distribution of the post-test results is given in Table 2.

Table 2
The distribution of the post-test results (maximal test score: 46).

Group	Experimental	Control
Number of students	42	50
Arithmetic mean	17.43	12.98
Standard deviation	7.60	5.44
Total percentage	37.9	28.2
t test	3.26*	

*The arithmetic mean difference is statistically significant at the level of 0.01.

Although even in the post-test, the total percentage of correct answers was not high, yet in the experimental group it was higher for about 10%. The *t*-test value shows that the difference between the arithmetic means is statistically significant at the 0.01 level. The results obtained in both groups are influenced by the low level of the students' prior knowledge. However, the experimental group achieved better results in the requirements related to the "real life situations", and explained them better. For example, the explanation of the effects of the drainage of large quantities of hot water used for cooling electric power plant equipment was given by 68.2% of the students in the experimental group, and by 43.3% of the students in the control group.

The questionnaire responses showed that almost the same percentage of students of both groups were satisfied with the instructional strategy (78% in the experimental group and 76% in the control group). A number of students from the experimental group stressed that they found the applied methods motivating for learning and helpful for understanding of the problem of pollution and the measures for the protection of the environment. Additionally, they emphasized that they liked "working in a group" and experiments. On the other hand, the teacher's good work and the teaching content were stressed by a greater number of students from the control group. The students of both groups emphasized that they desired more interesting biology, chemistry and physics classes and more experiments and lessons "in nature".

CONCLUSION AND IMPLICATIONS

The described research is part of our persistent endeavors and searching for adequate themes and methods that might make possible a meaningful and useful integration of the contents of separately studied scientific disciplines. The obtained results were greatly influenced by the students' prior experience in studying natural sciences as separate subjects and by the conditions in which their learning t took place. However, the research showed that, even in the existing conditions, it is possible to take a step forward and improve the students' achievements by changing teaching strategies and stimulating the integration of knowledge diversely acquired through studies and real life.

We believe that it was a positive experience for the students to see how it is possible to apply their theoretical knowledge, acquired through different subjects, to "real life" themes. The fact is that the students started considering our theme with a limited prior knowledge, but it was this new situation that provided them with the opportunity to realize the importance of studying chemistry, biology, and physics, why such knowledge is necessary for obtaining a full understanding of the environment they live in, and how it can help them to create better and safer conditions for themselves and others.

BIBLIOGRAPHY

BRESLIN, V.T. & SANUDO-WILHELMY, S.A., The Lead Project, *Journal of Chemical Education*, **78** [12], 1647-1651, 2001.

CANCILLA, D.A., Integration of Environmental Analytical Chemistry with Environmental Law: The Development of a Problem-Based Laboratory, *Journal of Chemical Education*, **78** [12], 1652-1660, 2001.

DUNNIVANT, F.M., Analytical Problems Associated with the Analysis of Metals in a Simulated Hazardous Waste, *Journal of Chemical Education*, **79** [6], 718-720, 2002.

GIOKAS, D.L.; PALEOLOGOS, E.K. & KARAYANNIS, M.I., Micelle-Mediated Extraction of Heavy Metals from Environmental Samples, *Journal of Chemical Education*, **80** [1], 61-64, 2003.

LI, E.; BARNETT S.M. & RAY, B., Pollution Prevention Guideline for Academic Laboratories, *Journal of Chemical Education,* **80** [1], 45-49, 2003.

LUBEZKY, A.; DORI, Y.J. & ZOLLER U., HOCS - Promoting Assessment of Students' Performance on Environment-Related Undergraduate Chemistry, *Chemistry Education: Research and Practice*, **5** [2], 175-184, 2004.

MAVROPOULOS, A.; ROULIA, M. & PETROU, A.L., An Interdisciplinary Model for Teaching the Topic "Foods": A Contribution to Modern Chemical Education, *Chemistry Education: Research and Practice*, **5** [2], 143-155, 2004.

PAPAGEORGIOU, G. & TSIROPOULOU, S., The Impact of Experiments on Students' Knowledge and Explanations of Significant Aspects of the Greenhouse Effect, *Journal of Science Education*, **5** [1], 28-33, 2004.

PEŠIKAN, A. & ŠIŠOVIÆ, D. *Active Learning - Approach and Possibilities of Application in Concept of Education for Sustainable Development,* Green Pack in Serbia, Belgrade, Serbia, 34-37, 2003.

PIRJOLA, L., Local Atmospheric Chemistry and Ozone Model (LACOM), *Journal of Chemical Education,* **77** [12], 1650-1653, 2000.

RAMOS, B.; MILLER, S. & KORFMACHER, K., Implementation of a Geographic Information System in the Chemistry Laboratory: An Exercise in Integrating Environmental Analysis and Assessment, *Journal of Chemical Education,* **80** [1], 50-53, 2003.

ROBINSON, W.R., Cognitive Requirement of Open-Ended Learning Environments, *Journal of Chemical Education,* **78** [1], 20-21, 2001.

RUM, G.; LEE, W.Y. & GARDEA-TORRESDEY, J., Applications of an U.S. EPA-Approved Method for Fluoride Determination in an Environmental Chemistry Laboratory: Fluoride Detection in Drinking Water, *Journal of Chemical Education*, **77** [12], 1604-1606, 2000.

VOLKER, E.J.; DILELLA, D.; TERNEUS, K.; BALDWIN, C. & VOLKER, I., The Determination of Ergosterol in Environmental Samples, *Journal of Chemical Education*, **77** [12], 1621-1623, 2000.

WITTECK, N.B. & LEWIS, D., The Environmental Education and Laws of Protection in Sweden, *Journal of Science Education*, **1** [2], 74-80, 2000.

ZOLLER, U., Interdisciplinary Systemic HOCS Development - The Key for Meaningful STES Oriented Chemical Education, *Chemistry Education: Research and Practice*, **1** [2], 189-200, 2000.

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