

## A MODEL OF INTERDISCIPLINARY TEACHING OF ECOLOGY IN THE HIGH SCHOOL

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*Abstract* - In this paper, we present the results of pedagogical studies of biology lectures in a high school. The subject Ecology is realized in the second year of high school during 14 classes employing an interdisciplinary approach (correlation of terms from Biology, Geography, Chemistry, Physics and Mathematics) in an experimental (E) group and compared to traditional classes in a control (C) group. Students from the E group achieved significantly better success in the final test (70.60 points average) and retest (57.60 points average) than students from the C group (51.80 points at final test and 40.60 points at retest). These results point to the greater efficiency of the model of interdisciplinary teaching of ecology in relation to the traditional approach and we recommend the former to be more utilized in biology classes.

*Key words:* biology classes; ecology with protection and improvement of environment; pupils' achievements

### INTRODUCTION

In primary and secondary schools of many European countries, topics of Ecology are studied within integrated subjects or in the individual subject of Ecology. In the Republic of Serbia, they are present in the programs of several teaching subjects, mostly Biology (Đokić-Ostojić et al., 2014). These contents are complex and rather difficult for pupils. In order for them to become familiar to pupils and to achieve their efficient acquisition, it is required to introduce innovations into the teaching process. Such is the application of the model of interdisciplinary teaching of ecology contents (Bogosavljević-Šijakov and Cvetičanin, 2012). The term *interdisciplinarity* or *correlation in teaching* represents the functional correlation of the contents of different teaching subjects. Studies of Hulse (2006), Lewis (2009), Schaal et al.

(2010) and Wagner et al. (2012) have confirmed the positive effects of the interdisciplinary approach in teaching natural sciences. Positive results were especially observed in the application of the model of interdisciplinary learning in the teaching of biology and environmental protection (Conde and Sánchez, 2010; McCabe, 2011; McMiller et al., 2006; Nagle, 2013; Nelson, 2010; Tsurusaki and Anderson, 2010). These examples stress a rather frequent interdisciplinary approach to research in science, interdisciplinary studies and scientific problem solving, as well as interdisciplinary interpretations of teaching contents and their application in the real-life arena. Based on these studies, great attention is paid internationally to the interdisciplinary approach in teaching because such an approach provides the networking of knowledge from various fields, which contributes to the formation of functional knowl-

edge (Cvjetičanin and Segedinac, 2011). In the education system in the Republic of Serbia, this teaching model is marginal and it is insufficiently present in the teaching practice. This particularly refers to the teaching of natural sciences, where it could in fact be dominant due to inherent mutual correlations (Miljanović, 2004).

The interdisciplinary character of ecology in the system of biological disciplines and natural sciences is underlined by the fact that ecology brings together knowledge from biology and other natural and social sciences. Moreover, the interdisciplinary approach is desirable at all educational levels (Miljanović, 2003). In this study, an analysis was performed of the approved teaching program of biology for the second year of high school (Official Gazette RS, Educational Herald, No 8, 2008) and of the approved biology textbook for the second year (Petrov et al., 2010), as well as of programs and textbooks from subjects of other natural sciences for the first and second years of high school, for the existence of correlation between terms from ecology and terms from biology, geography, chemistry, physics and mathematics. In the first and second years of high school, pupils learn the topics from biology (cytology, morphology, systematics and phylogeny of algae, fungi and lichens, morphology, systematics and phylogeny of plants, plant physiology, morphology and systematics of animals), terms from geography (relief, atmosphere, hydrosphere and biosphere), followed by the characteristics and factors of demographic development, distribution of population on Earth, living standards in the population, the activities and effects of human actions on the biosphere. In the first year of high school, in chemistry classes the pupils encountered terms such as substance, chemical elements, chemical compounds, chemical symbols, chemical relations, types of concentrations, chemical reactions, solutions, oxide-reduction processes, allotropic modification. In physics classes, pupils learnt the terms density, gas density, gaseous mixture density, temperature, heat, radiation, solar radiation, and solar spectrum and tabular and graphical presentation of phenomena and processes within mathematics

classes. In fact, comprehension of the above topics and terms from biology, geography, chemistry, physics and mathematics is required for a more complete understanding of ecology.

Analysis in this pedagogical study has provided for the contents of the teaching Biology course topic *Ecology with protection and improvement of environment* in the second year of the High School to be realized through an interdisciplinary approach during 14 lectures for an experimental group of pupils as compared to traditional teaching in the control group.

## MATERIALS AND METHODS

The aim of this research, which was to determine the efficiency of the interdisciplinary model of implementation of ecology contents in the high school in relation to the traditional approach of contents processing, was achieved by comparing the results of pupils from the experimental (E) and control (C) groups at tests of knowledge (final test and retest).

The research sample consisted of 150 second-year pupils from two high schools in Belgrade. In the experimental group, there were 75 pupils from the 7th Belgrade High School, and in the control group 75 pupils from the 15th Belgrade High School. The research was carried out in the school year 2012/2013.

The methods applied were theoretical analysis, descriptive method and the experimental method on groups in parallel – experimental (E) and control (C).

Tests for the objective verification of knowledge, capabilities and habits of pupils in Biology were used. In each of the three tests (initial, final and retest), could the maximum score was 100 points. The tests contained tasks from three different cognitive domains: knowing (level I), understanding (level II) and analysis and reasoning (level III) of terms.

For the statistical processing of data, MiniTAB 14 Software was used. In order to determine the sig-

nificance of the differences in achievements of pupils from the two groups in all three tests, the Student's t test was used at each level. For all three tests, the following statistical parameters were given: number of students in each group (N), the arithmetic mean (M), standard deviation (SD), standard error (SE) and pertinence level (p).

## RESULTS

Analysis in this study has provided for the contents of the subject *Ecology with protection and improvement of environment* in the second year of high school, to be realized through an interdisciplinary approach over 14 lectures for the experimental group of pupils. This teaching topic included three subtopics: basic terms and principles of ecology (realized through 8 lessons), protection and improvement of environment (5 lessons) and protection of nature (1 lesson) (Official Gazette RS, Educational Herald, No 8, 2008). Thus, by the interdisciplinary creation of teaching units within all three subtopics a selection was made as well as a synthesis of correlative terms that the students learnt in the first and second years of high school in biology, geography, chemistry, physics and mathematics. The structure of the lectures consisted of standard stages (introductory, central and final part) with maximal respect for correlation principles in each. The basic aim of the introductory part was to encourage the interest of students. By presenting illustrative contents, the students were given the possibility to show initial ideas towards the teaching unit that processed in each lesson. Analysis and determination of the existence of correlative knowledge was performed by the dialogic teaching method after which the aim of the lesson was defined. In the central part, new contents were presented with emphasis on new terms and with the application of a specific technique of teaching/learning known as conceptual map. During the map analysis, the mutual interdependence of terms of teaching contents that pupils had previously learnt in biology, geography, chemistry, physics and mathematics was particularly stressed and their integration into a unique system (logic scheme) provided the connection of knowledge

from different natural sciences. The map analysis was done with the dialogic method of teaching. For the central part of the lesson of each teaching unit, the pupils were prepared in advance according to the teacher's instructions. Their task was to revise the correlative contents from biology, geography, chemistry, physics and mathematics they had learnt so far. It provided the correlation and integration of contents of these natural sciences with the contents from ecology that were processed in each individual lesson. The purpose of the final part was the application of the acquired interdisciplinary knowledge in solving problems defined in the form of different types of tasks. In this part of the lesson, students usually cooperatively solved the problems given, and presented their results orally or through an appropriate illustration. In all three parts of the lecture, the participation of students and their maximal activity was particularly emphasized.

In the teaching classes of the control (C) group, the topic *Ecology with protection and improvement of environment* is predominantly realized by the presentation of the teacher, without the correlation with teaching the contents of natural sciences and with no significant activity of students in the class.

By testing the pupils through an initial test, final test and retest, relevant data for the E and C groups were obtained, and compared.

Initial testing of the pupils referred to the determination of the acquisition of key terms from a previously processed teaching topic from biology, due to their relation to the content of the teaching topic *Ecology with protection and improvement of environment* that was realized in the course of this pedagogical research. Statistical indicators of the initial test as a whole and within individual cognitive domains (knowledge levels), are presented in Table 1.

Differences of arithmetic means between the E and C groups in the initial test as a whole were 0.00 points ( $t = 0.00$ ) and at knowledge levels: level I, 0.22 points ( $t = 0.25$ ), level II, 1.61 points ( $t = 1.96$ ) and

Table 1. Results of experimental and control group at the initial test (Student's t test was used for group comparison; see Materials and Methods for details)

Cognitive Domains	Group	N	M	SD	SE	$M_E - M_C$	t	p
Total achievement on the test	E	75	52.60	13.40	1.60	0.00	0.00	1.000
	C	75	52.60	13.60	1.60			
Knowing the facts (level I)	E	75	22.37	4.95	0.57	0.22	0.25	0.804
	C	75	22.59	5.56	0.64			
Understanding (level II)	E	75	19.17	5.40	0.62	1.61	1.96	0.052
	C	75	17.56	4.92	0.57			
Analysis and reasoning (level III)	E	75	11.06	6.31	0.73	1.39	1.37	0.171
	C	75	12.45	6.51	0.75			

Table 2. Results of experimental and control group at the final test (Student's t test was used for group comparison; see Materials and Methods for details)

Cognitive Domains	Group	N	M	SD	SE	$M_E - M_C$	t	p
Total achievement on the test	E	75	70.60	13.80	1.60	18.80	9.25	0.000
	C	75	51.80	10.90	1.30			
Knowing the facts (level I)	E	75	30.00	5.19	0.60	5.81	7.31	0.000
	C	75	24.19	4.53	0.52			
Understanding (level II)	E	75	23.11	5.07	0.59	4.19	5.13	0.000
	C	75	18.92	4.98	0.57			
Analysis and reasoning (level III)	E	75	17.49	8.03	0.93	8.80	8.21	0.000
	C	75	8.69	4.64	0.54			

Table 3. Results of experimental and control group at retest (Student's t test was used for group comparison; see Materials and Methods for details)

Cognitive Domains	Group	N	M	SD	SE	$M_E - M_C$	t	p
Total achievement on the test	E	75	57.60	13.50	1.60	17.00	7.86	0.000
	C	75	40.60	13.00	1.50			
Knowing the facts (level I)	E	75	24.82	5.40	0.62	6.42	7.47	0.000
	C	75	18.40	5.18	0.60			
Understanding (level II)	E	75	19.47	5.19	0.60	3.95	4.38	0.000
	C	75	15.52	5.82	0.67			
Analysis and reasoning (level III)	E	75	13.31	7.33	0.85	6.63	6.43	0.000
	C	75	6.68	5.06	0.58			

level III, 1.39 points ( $t = 1.37$ ), showing no statistical significance ( $p > 0.05$ ). Based on statistical indicators for the initial test, E and C groups were unified for the test as a whole as well as at all three knowledge levels.

After processing the subject *Ecology with protection and improvement of environment* by applying the innovative model of teaching in E group and traditional teaching in C group, the pupils were given the final test. The results are presented in Table 2.

The difference of arithmetic means between the E and C groups at the final test as a whole was 18.80 points ( $t = 9.25$ ) and at all three knowledge levels: level I, 5.81 points ( $t = 7.31$ ), level II, 4.19 points ( $t = 5.13$ ) and level III, 8.80 points ( $t = 8.21$ ), all in favor of the E group and statistically significant ( $p < 0.001$ ).

Retesting of the pupils from both groups was carried out 60 days after the above pedagogical study. The results are shown in Table 3.

The differences of arithmetic means between E and C groups at the retest as a whole was 17.00 points ( $t = 7.86$ ) and at all three knowledge levels: level I, 6.42 points ( $t = 7.47$ ), level II, 3.95 points ( $t = 4.38$ ) and level III, 6.63 points ( $t = 6.43$ ) were in favor of the E group and statistically significant ( $p < 0.001$ ).

## DISCUSSION

The better scores by the E group in the final test and retest points to a greater efficiency achieved by the interdisciplinary approach to learning ecology contents in high school (E group) as compared to the traditional teaching method in the C group. Statistically significant achievements of the E group in knowledge tests (final test and retest) also confirm that an understanding of photosynthesis and cellular respiration from a scientific aspect is important for the interpretation of the state of the environment (Ekborg, 2003); implementation of experiment is useful for understanding of flow of matter (Asshoff et al. 2010); knowledge of chemical interactions is important for understanding the forming of acid rains and their effect to the living world (Marinopoulos and Stavridou, 2002), and the contents of courses in natural sciences on the whole represent a reliable source for understanding the context of ozone holes, greenhouse effect and climate changes (Dawson and Carson, 2013). Pupils in the E group were more successful in answering questions and solving tasks at all three knowledge levels in the final test and retest than to answering questions and undertaking tasks of an equal difficulty in the initial test, as well as in relation to the pupils from the C group. Results obtained are

in harmony with the studies of Aivazidis et al. (2006), Milivojević and Miljanović (2006), Miljanović and Jelovac (2004), Niklanović and Miljanović (2006), Strgar (2007), Strgar et al. (2013), Pogačnik et al. (2014) and Tung et al. (2002). Higher scores by pupils in the E group in tests of knowledge (final test and retest) point to the impact of the application of knowledge from biology, geography, physics, chemistry and mathematics on a more efficient acquisition of contents from ecology in the high school. Similar results were obtained by applying the model of learning in chemistry and other natural sciences with the help of mathematics (Potgieter et al., 2007), by the application of mathematics in learning of physics (Munier and Merle, 2009), by applying the knowledge in physics for efficient learning of mathematics and their equal impact in the domain of learning natural sciences (Lützen, 2011) or by the use of the model of interdisciplinary approach in solving problems in teaching biology (Carrio et al., 2011).

## CONCLUSION

Results of the presented pedagogical research (results of the final test and retest) have shown that by applying the model of interdisciplinary learning of Ecology contents in high school, a positive effect was achieved in the knowledge acquisition of pupils from the experimental (E) group and in their ability to solve the tasks at different difficulty levels in relation to the traditional approach of learning in the control (C) group. It is also shown that the networking of knowledge from different subjects contributes to the formation of functional knowledge, with adequate selection and application of those models of teaching/learning that are suitable to pupils' knowledge, their abilities, flow and articulation (structure) of teaching lessons. Knowledge acquired by integrating terms from biology, geography, chemistry, physics and mathematics have facilitated not only the comprehension of new terms from ecology, but provided their integration as well. The achievements of the pupils in the E group point to the need for a greater presence of interdisciplinary models in teaching natural sciences in relation to traditional teaching. Its greater application in teaching ecology would contribute to

better comprehension by pupils of the scientific aspects, upgrading of their ecological awareness, and the acquisition of ecological principles in the preservation and protection of biodiversity, environmental protection, responsible use of natural resources and finally, to the better understanding of the significance of the concept of sustainable development in the local environment and in nature as a whole.

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