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The Effectiveness of an Interdisciplinary Approach in Biology Teaching in Primary School: A Comparison With Monodisciplinary Approach

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Abstract: Interdisciplinary teaching and learning is an approach that synthesizes the curricular objectives and methods of two or more disciplines or subjects focusing on a specific topic or issue. While it is being increasingly implemented in universities, at lower levels of education there are still countries where science subjects are taught and learned fragmentarily. To assess the significance of the interdisciplinary approach in primary school biology teaching, the paper aims at an experimental verification of the effectiveness of this method in relation to the quality and retention of student knowledge, compared to the monodisciplinary approach to teaching and learning biology. The paper also describes a scenario for teaching a topic in which biological and geographical contents correlate. The study applied a pedagogical experiment with parallel groups. In total, 180 students attending two primary schools in the city of Novi Sad participated in the experiment and were divided into an experimental and a control group. The findings suggest that the interdisciplinary approach improved the quality and retention of student knowledge. The experimental group was more successful in completing tasks that required comprehension and practical application of knowledge. The study thus emphasizes the need for a professional curriculum development that would enhance the interdisciplinary correlation of various disciplines.

Keywords: *Biology teaching, effectiveness, interdisciplinary approach, monodisciplinary approach, quality and retention of knowledge.*

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Introduction

Dedicated teachers and educators at all levels of education constantly experiment and develop innovative teaching approaches with the aim of improving students' learning experiences and their learning outcomes. Interdisciplinary learning is not a new teaching approach, but has become an important and challenging technique in the modern curriculum of science (a school subject that integrates three disciplines: biology, physics and chemistry), as well as in other subjects and areas of study (Czerniak, 2007; Johnston et al., 2014; Jones, 2010; Nagle, 2013; You, 2017). In the context of education, the term "interdisciplinarity" has been defined by a number of authors, but no single definition has been reached yet. As a result, various terms have been in use, such as interdisciplinary teaching, integrated teaching, thematic teaching, or synergistic teaching (Klein, 2006). Analyzing all these terms, one can conclude that all of the definitions are comparable. A more detailed explanation of the term is offered by Petrie (1992) who claims that this approach can be implemented by teams of teachers and individuals by combining information, concepts, and/or theories and techniques of two or more disciplines in order to achieve fundamental understanding and solve problems that are beyond the scope of a single area of study. Such a synthesized and in-depth approach can enrich the overall educational experience (Jones, 2010). In applying an interdisciplinary approach, the teacher plans activities from the perspective of the student, by integrating real-life knowledge and experience, and this gives a particular quality to teaching (Buljubašić-Kuzmanović, 2007).

It is evident that education aims at the development of a versatile person with a comprehensive view of the world. Due to technological advancement, modern generations of students have plenty of information at their fingertips. In such a situation, interrelating information is one of the key skills that students need to develop, and the interdisciplinary

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approach seems suitable to achieve this. In this approach, there are no strict boundaries between disciplines, and the teaching content and natural phenomena are studied versatilely and from various perspectives, similar to the way they occur in the natural world. Understanding the natural world and the problems within it requires the involvement of multiple disciplinary backgrounds and no single discipline can provide this (Glackin & King, 2018; Glackin et al., 2018; You, 2017). Thus, studying complex problems or concepts (for example, the adaptation of living things to environmental conditions) from a single discipline (i.e., biology) is not enough to provide a complete understanding and therefore requires integration and synthesis with the contents related to geographical areas, which fall within the scope of geography. The interdisciplinary approach also provides opportunities to address and clarify misconceptions that students may hold about scientific concepts and methods (Nagle, 2013). Furthermore, it may not only improve the student experience, but can also have a positive impact on teachers, as it encourages collaboration between them. By collaborating, teachers develop materials or adapt and improve existing materials and approaches for their classrooms (Broggy et al., 2017). Finally, the interdisciplinary approach, which discards fragmentation and isolation of the teaching content, encourages the development of original thinkers who are able to encounter a problem or an issue and solve it applying knowledge and ideas from various disciplines (Dryden & Vos, 2005).

With the aim of overcoming the monodisciplinary approach to teaching and learning and achieving higher efficiency in the educational process, there has been a growing body of empirical research on the interdisciplinary model of instruction. In the domain of biology, an interdisciplinary approach has been assessed by analyzing the correlation of biological topics with the contents of other science subjects (most often geography, chemistry, and physics), as well as with information technologies, at all levels of education. The results of a study of Houston's Training and Education Center, as reported by Moreno and Tharp (1999), indicate that the achievement gap in science and the loss of interest in science-related studies are already detected in primary education. As a result of this, Baylor College of Medicine initiated the project "My Health My World" which aimed at making science more appealing and relevant for students from kindergarten through grade five of primary school and easy to teach for both teachers and parents. The project implementation provided interdisciplinary instructional material for students and parents and workshops for teachers. After a year of the project implementation, higher student achievement in science-related studies was observed and at the same time, teachers showed greater interest in this concept of science teaching (Moreno & Tharp, 1999). In a study related to chemistry teaching (Crnčec, 2012), by correlating the contents of this subject and the subject Nature and applying ICTs, programmed learning, portfolios, mind maps and field classes, better acquisition of knowledge and practical work were achieved and students showed higher scores in completing problem tasks in primary school chemistry classes. In researching the correlation between the biological topic of migrating birds and geographical notions related to the basic features of countries through which birds travel on their way to Africa, Dolenec and Dolenec (2013) recommend an interdisciplinary correlation between biology and geography teaching and point to its effectiveness, particularly when group work and other forms of collaborative learning are employed. By combining teaching contents, work patterns, and different sources of knowledge, a deeper understanding of the teaching topic is achieved which leads to higher student performance. In a study centered on biology teaching in secondary education (Krajšek & Vilhar, 2010), the interdisciplinary correlation was set between the topic of diffusion and the topic of Brownian motion of particles, which is part of the physics curriculum. By engaging students actively in microscopically examining small particles, and watching computer animations and simulations of particle diffusion, students were encouraged to learn through conceptual changes and critically assess scientific models. In one the recent studies by Milanković Jovanov et al. (2022), the authors report that biology–geography correlation in teaching the content of national parks and Categories of protected natural assets contributed to higher student performance, particularly at the cognitive levels of remembering, evaluating, and creating. Furthermore, studies based on the importance of integrating the contents of science and mathematics showed that the interdisciplinary approach led to better student learning, understanding, and motivation (Czerniak, 2007), as well as additional engagement and application of mathematics and science concepts (Venville et al., 2004). There is plenty of empirical evidence that the application of interdisciplinary programmes results in an increase in critical thinking (Buchbinder et al., 2005; Nowacek, 2005), problem-solving and other higher-order thinking skills (Lattuca et al., 2004; Mansilla & Duraising, 2007).

Despite the fact that this perspective is reflected in a number of strategic documents of education policy in European countries (Eurydice, 2011), recommending a more holistic approach of education, through cross-curricular, contextual approaches in science learning, in the education system of the Republic of Serbia the interdisciplinary approach in teaching separate science subjects is still marginalized and only recently started slowly entering the educational practice with the latest educational reform (Živković et al., 2017). In most schools in Serbia, the traditional approach to teaching biological and ecological contents is still dominant, with a monodisciplinary teacher-centered approach prevailing, with students mostly acquiring knowledge in the form of simple reproduction of facts (Niklanović et al., 2014; Radulović et al., 2019). The fact that the transition towards an interdisciplinary approach in education is a long and challenging process, not only in Serbia, but in many other countries such as Czech Republic, Greece, Spain, and Romania, has been reported by a number of authors that focused on this process in their countries (Chitia & Indreica, 2018; Chrysostomou, 2004; González Villora et al., 2013; Nocar et al., 2019).

The aim of teaching biology in primary schools is gaining new and deepen existing knowledge about life and living organisms, including their structure, function, growth, adaption, evolution, identification, and taxonomy. In studying these concepts, it is important to establish a correlation with other disciplines. Thus, a study by Živković et al. (2017), which analyzed science subject's curricula for implementing an interdisciplinary approach in primary schools in Serbia, reports on a growing potential of correlating the contents of biology and geography. With the aim of overcoming the drawbacks of the monodisciplinary approach to science teaching and the current gap in providing evidence on the effects of the interdisciplinary approach on student achievement (Czerniak, 2007), the present study aims at an experimental verification of the effectiveness of this approach in relation to the quality and retention of student knowledge, compared to the traditional, monodisciplinary approach to teaching and learning biology. The term "interdisciplinary teaching" in this study is used for all the various curriculum arrangements that merge elements from two science disciplines (biology and geography). In accordance with the stated aim, the following research questions are formulated:

Q1: Does an interdisciplinary approach in teaching biology increase the students' achievement regarding the quantity of acquired knowledge, compared to a monodisciplinary approach?

Q2: Does an interdisciplinary approach in teaching biology increase the students' achievement regarding the quality of acquired knowledge, compared to a monodisciplinary approach?

Q3: Does an interdisciplinary approach in teaching biology contribute to knowledge retention, compared to a monodisciplinary approach?

It is expected that there will be a difference in the quantity and quality of the acquired knowledge and knowledge retention between the student groups, in favour of the group in which the interdisciplinary approach was applied. In that way, the findings of this study may provide useful suggestions to biology and geography teachers how to implement the interdisciplinary approach, and at the same time, they can offer better insights and values of this teaching approach to didactics and education specialists and researchers.

Methodology

General Background

Experimental research was used in this study as the research methodology. In accordance with the aim of the study, a pedagogical experiment with parallel groups was conducted. Students from the experimental group (E) studied the topic "Structural and Functional Unity as the Basis of Life" within the biology classes for the fifth grade of primary school by means of the interdisciplinary approach in which biology and geography contents were correlated horizontally. At the same time, the students of the control group (C) studied the same contents by means of the traditional approach, i.e., monodisciplinary learning strictly from the aspect of biology. The effectiveness of the two approaches was assessed by comparing the E and C group achievement in knowledge tests (posttest and retest). Student achievement is seen as the quantitative and qualitative aspects of students' performance in two tests that were designed by biology and geography teachers for the purpose of this study. The quantitative aspect of student achievement is perceived as the total test score, while the qualitative aspect refers to the quality of student performance at the following three levels: knowledge acquisition, understanding, and application, in compliance with the revised version of Bloom's taxonomy.

Sample of Research

In total, 180 students from two primary schools in the city of Novi Sad, Serbia, participated in the research. Each group (E and C) consisted of 90 students. The respondents were fifth-grade students in a primary school, aged 11-12. For conducting this research, an informed consent from the school headmasters, teachers, counselors, school boards, and all participants and their legal guardians were obtained.

Instruments and Procedures

The experiment was carried out during regular biology classes in the fifth grade of primary school, on the contents of the topic "Structural and Functional Unity as the Basis of Life" and lasted for 5 weeks. The recommended number of lessons for this topic, according to the national curriculum, includes 5 lessons for the presentation of the topic, 4 lessons for revision and 1 lesson for assessment. Prior to the experimental period, the biology teacher, in communication with the geography teacher, carefully analyzed the possibilities of correlating the teaching contents of the two subjects and familiarized herself with the principles of interdisciplinary teaching.

At the beginning of the research, both the E and the C group students took a pretest in order to synchronize the previous knowledge necessary for acquiring the contents of the topic "Structural and Functional Unity as the Basis of Life". The test checked students' knowledge of biological and geographical contents that are acquired in the fourth grade of primary school as part of the subject Nature and Society. Both groups took the pretest on the same day. The test was designed with a maximum score of 100 points and incorporated three subtests referring to the following cognitive levels: Remember (level I), with a maximum score of 30 points; Understand (level II), with a maximum score of 40 points, and Apply (level III), with the maximum score of 30 points. The first subtest (level I) included 6 questions that required knowledge at the level of recall and reproduction, without a deeper understanding of notions, facts, and principles. The second subtest (level II) comprised 8 questions that were more complex than those at the level I and required understanding of facts and specific terms and causal relationships between notions. The third subtest (level III) included 6 questions that required knowledge at the level of application in everyday life, new circumstances, and various situations. All tests applied in this research, including the pretest, were developed by a teacher of biology and a teacher of geography, both with extensive teaching experience. The pretest validity was assessed by a group of experts including two university professors in the area of biology teacher education, two primary school biology teachers and two pedagogy experts. The validity check ensured that the questions covered a variety of topics that complied with the curriculum, that they were meaningful and of suitable length and that the used terminology was adequate for the student's age. Internal consistency expressed by Cronbach α coefficient was .75, indicating acceptable reliability.

After pretesting, the topic "Structural and Functional Unity as the Basis of Life" was taught by implementing two teaching approaches: an interdisciplinary approach in the E group and a monodisciplinary approach in the C group.

The interdisciplinary approach in the E group implied a horizontal correlation between biology and geography contents, based on the fifth-grade primary school curricula of these subjects. An outline of the integration of biological and geographical contents in the E group biology classes is given in Table 1.

Table 1. An Outline of Integrated Biological and Geographical Curricular Contents for the Fifth Grade of Primary School

Teaching topic in biology	Teaching units in biology	Teaching units in geography
Structural and Functional Unity as the Basis of Life	- Living things in their natural environment; - Adaptation of living things to the environmental conditions; - Life in terrestrial communities; - Life in still freshwater; - Life in running fresh water.	- the Earth's shape and its dimensions, distribution of land and water area on Earth; - Revolution of the Earth and its effects: variable duration of day and night during the year, season succession, calendar, thermal belts; - Atmosphere (composition, structure, and its significance); - Climatic factors, main types of climate; - Terrestrial water storage: groundwater, rivers, lakes; - Distribution of plants and animals on Earth.

In the introductory part the teacher tried to raise the students' interest in the topic and encourage them to express their initial ideas related to the topic. This part implied the use of illustrations and dialogue communication through which the teacher assessed the students' background knowledge and ability to correlate biological and geographical contents. The main part of the lesson mostly involved group work, in which students were expected to complete certain tasks, carefully guided by the teacher who directed them to relevant sources of information and knowledge. The appendix illustrates a segment of a worksheet with a task for students relating to the topic 'Life in deciduous forests', which was part of the lesson focusing on the teaching unit 'Life in terrestrial communities'. The worksheet tasks synthesized biological and geographical contents and their completion thus required correlating the knowledge of these two disciplines. The final part of the lesson focused on the application of the acquired interdisciplinary knowledge in new problem situations. This problem-based situation usually included concept maps completion, providing examples, analyzing and describing graphs and other schematic designs and materials. This part of the lesson served as a feedback to the teacher, as to how well the students understood the content, what were the learning outcomes and to what extent the goal of the lesson was achieved.

The monodisciplinary approach in the C group was organized in a conventional manner. That implied frontal lectures, student group work, and discussion on the topic contents, but contrary to their E group peers, the C group class activities focused exclusively on biological aspects.

Upon the completion of the analysis of the teaching topic "Structural and Functional Unity as the Basis of Life", students from both groups took a posttest on the same day. Then, 60 days after the posttest, both groups did a retest (the repeated posttest) that had not been announced and that served for assessing the maintenance of knowledge acquired by the interdisciplinary and monodisciplinary approaches. Similar to the pretest, the posttest/retest also comprised items at three cognitive levels and identical scores for all three levels. Cronbach α coefficient was used for measuring the posttest reliability and the value of .821 showed an optimal internal consistency.

Analysis of Data

The Kolmogorov-Smirnov test was used for testing the normality of pretest data distribution. The obtained values pointed to a normal distribution, as the significance level in both groups was greater than .05. The mean score and standard deviation on the pretest, posttest, and retest were determined for both groups. For testing the difference in the E and C group students' total scores and the scores for each of the three cognitive levels, the t-test and ANOVA with multiple comparison tests were applied. The software package SPSS 23 was used for statistical analyses.

Results

Students' Performance on the Pretest

The synchronization of the E and C group was done through pretesting of all students prior to the experimental period, i.e., the application of the interdisciplinary approach in the E group classes.

Statistical parameters for the total scores and the scores referring to the three levels of knowledge on pretest, and the corresponding *t* values, are presented in Table 2.

Table 2. Descriptive Statistics and the t - value for Performance on the Pretest

Pretest	Group	N	M	SD	df	t	p
Level 1	E	90	21.40	4.789	178	.029	.979
	C	90	21.39	3.644			
Level 2	E	90	23.23	7.287	178	.007	.991
	C	90	23.22	5.953			
Level 3	E	90	13.28	7.725	178	.050	.965
	C	90	13.21	6.257			
Total	E	90	57.91	15.623	178	.026	.984
	C	90	57.82	12.229			

The obtained results point to the absence of any significant differences with respect to the quantity and quality of the E and C group knowledge on the pretest, thus leading to the conclusion that the two groups of students were homogeneous in the obtained pretest scores. Analyzing the students' scores for each of the three levels of knowledge, it is observed that the students of both groups showed the highest performance in the level I tasks (mean score in E group: 71.33%; C group: 71.30%), somewhat lower performance in the level II tasks (E: 58.07%; C: 58.05%), while the level III part of the pretest was the most demanding part for the students of both groups (E: 44.27%; C: 44.03%).

Students' Performance on the Posttest

Table 3 contains statistical parameters for the performance of the E and C groups on the posttest, considering the total test scores and scores for the three levels of knowledge.

Table 3. Descriptive Statistics and the t - value for Performance on the Posttest

Posttest	Group	N	M	SD	df	t	p	dCohen
Level 1	E	90	22.89	3.125	178	.089	.962	.018
	C	90	22.18	4.598				
Level 2	E	90	30.02	3.449	178	5.458	.000*	.152
	C	90	23.51	5.002				
Level 3	E	90	21.26	6.024	178	6.242	.000*	.117
	C	90	13.19	7.621				
Total	E	90	74.17	11.254	178	7.489	.000*	.130
	C	90	58.88	12.287				

**p < .001*

As can be seen in Table 3, the E group students achieved a significantly higher mean score on the posttest (74.17%), in comparison to their C group peers (58.88%). By comparing the mean values of the results achieved in each of the three levels of knowledge, it can be noticed that the E group significantly outperformed the C group in completing the II and III level tasks, which required understanding and application of the gained knowledge. As for the level I part, which focused on recognizing and recalling certain facts, no significant difference between the groups was obtained.

Students' Performance on the Retest

Table 4 contains statistical parameters for the performance of the E and C groups on the retest, considering the total test scores and scores for the three levels of knowledge.

Table 4. Descriptive Statistics and the t-value for Performance on the Retest

Retest	Group	N	M	SD	df	t	p	dCohen
Level 1	E	90	22.01	3.114	178	0.075	.976	.006
	C	90	21.77	5.225				
Level 2	E	90	29.43	3.254	178	6.852	.000*	.207
	C	90	21.18	4.589				
Level 3	E	90	20.76	5.856	178	9.156	.000*	.203
	C	90	8.56	6.159				
Total	E	90	72.20	9.163	178	8.299	.000*	.187
	C	90	51.51	12.647				

**p < .001*

As shown in Table 4, the E group students, similar to the posttest results, achieved a significantly higher mean score on the retest (72.20%), in comparison to the students in the C group (51.51%). When the means obtained for the three levels of knowledge are compared, it is again observed that the E group students were more successful than their C group peers in dealing with the II and III level tasks. No statistical difference was observed in completing the level I tasks, indicating that the students of the two groups showed identical performance only in completing the tasks of the lowest cognitive level ($p > .05$).

The repeated-measures ANOVA was performed for both groups. It pointed to statistically significant differences between the two measurements (tests) in the E group. These differences were observed regarding the overall tests, as well as in relation to certain levels of knowledge. Statistical differences were also observed in the C group scores, in relation to the overall test and between the levels II and III (Table 5).

Table 5. Repeated-Measures ANOVA for Both Groups

Group	Repeated measures	Wilks'λ	F	df	p
E	Level 1	.356	38.445	2/88	.000*
	Level 2	.453	28.781	2/88	.000*
	Level 3	.397	36.645	2/88	.000*
	Total	.221	81.227	2/88	.000*
C	Level 1	.967	.859	2/88	.291
	Level 2	.796	5.478	2/88	.003**
	Level 3	.478	30.587	2/88	.000*
	Total	.418	31.342	2/88	.000*

**p < .001; ** p < .01*

In order to determine exactly between which measures, i.e., tests (both overall tests and specific levels of knowledge) there was a significant difference and in which direction these changes moved, LSD multiple comparison procedure was applied. Table 6 shows changes in the performance of the E group participants during the research period (from the pretest to the retest).

Table 6. Changes in E Group Students' Performance during the Research Period

Knowledge	Repeated measures	$M_1 - M_2$	SE	p
Level I	Pretest-posttest	-1.49	.434	.004**
	Pretest-retest	-.61	.364	.387
	Posttest-retest	.88	.476	.521
Level II	Pretest-posttest	-6.79	.878	.000*
	Pretest-retest	-6.20	.876	.000*
	Posttest-retest	.59	.659	.385
Level III	Pretest-posttest	-7.98	.972	.000*
	Pretest-retest	-7.48	.943	.000*
	Posttest-retest	.50	.702	.376
Total	Pretest-posttest	-16.26	1.582	.000*
	Pretest-retest	-14.29	1.443	.000*
	Posttest-retest	1.97	1.193	.278

**p < .001; ** p < .05*

The obtained results suggest that the E group students showed a significant improvement on the posttest and retest (both in the overall test and in relation to the level of knowledge) in comparison with the pretest performance. The difference in students' performance on the posttest and retest is insignificant (p > .05). In other words, after a period of 60 days, the E group students showed the same level and quality of knowledge as they had on the posttest. Table 7 shows changes in the performance of the C group participants during the research period (from the pre-test to the re-test).

Table 7. Changes in C Group Students' Performance during the Research Period

Knowledge	Repeated measures	$M_1 - M_2$	SE	p
Level I	Pretest-posttest	-.79	.705	.278
	Pretest-retest	-.38	.586	.446
	Posttest-retest	.41	.443	.521
Level II	Pretest-posttest	-.29	.469	.874
	Pretest-retest	2.04	.655	.001**
	Posttest-retest	2.33	.671	.001**
Level III	Pretest-posttest	.02	1.031	.925
	Pretest-retest	4.65	1.012	.000*
	Posttest-retest	4.63	.763	.000*
Total	Pretest-posttest	-1.06	1.528	.542
	Pretest-retest	6.31	1.745	.000*
	Posttest-retest	7.37	.984	.000*

**p < .001; **p < .01;*

As the results suggest (Table 7), the C group students showed similar performance on the pretest and post-test (both in the overall test and in relation to the level of knowledge) as the difference in the measurements was not statistically significant. However, their retest performance showed significantly lower scores at levels II and III in comparison with the posttest and pretest scores. This difference may be attributed to the traditional model of teaching with the monodisciplinary approach to explaining biological contents.

The overall results point to a beneficial effect of correlating biological and geographical contents in biology classes in terms of increasing the quantity and quality of students' knowledge, particularly when it comes to the development of higher thinking skills, such as understanding and application.

Discussion

This research compares the effectiveness of interdisciplinary and traditional/monodisciplinary approaches in biology teaching in primary school. The obtained results indicate that contrary to the traditional teaching approach focusing on monodisciplinary study, the interdisciplinary approach produces positive results in biology teaching. The positive results are reflected in significantly increased students' academic achievement, particularly in dealing with issues at higher cognitive levels – understanding (level II) and application of knowledge (level III), as given in revised Bloom's taxonomy. The students in the experimental class also showed better retention of knowledge at the second and third levels of cognition. On the other hand, the interdisciplinary approach showed no significant effect on recognizing and recalling of facts (I level of cognition).

A number of studies (Acarli, 2020; Frykholm & Glasson, 2005; Owen, 2015) emphasize that the curricula structured around separate and isolated subjects are disadvantageous, as they prevent students from combining various areas of knowledge and analyze a large spectrum of phenomena in the dynamic world of 21st century, and therefore advocate the use of interdisciplinary teaching and learning. Johnson and Dasgupta (2005) also support the idea that a comprehensive view of the world can be achieved through various perspectives, and in the context of teaching this implies combining biology, geography, physics, chemistry, and mathematics. Analyzing the primary school syllabi of biology and geography in the Republic of Serbia, it can be concluded that a majority of the contents can be studied interdisciplinary. As these subjects in Serbia are studied as two separate subjects from the fifth grade of primary school, and both of them focus on nature – biology through studying living things, and geography by studying abiotic components – there is a great potential for their integration and combining. With this in mind, the present research focused on the teaching topic "Structural and Functional Unity as the Basis of Life" as the interdisciplinary approach, in this case, offers plenty of opportunities for achieving effective learning outcomes such as: identifying the adaption of the external structure of living beings to environmental conditions, including the basic feeding relations and distribution of organisms; providing simple drawings of biological and geographical objects that are observed and marking their key features.

Our findings are in line with those reported by Milanković Jovanov et al. (2022) as they claim that the interdisciplinary approach in biology and geography primary school classes, more precisely in teaching the contents of national parks and Categories of protected natural assets considerably improved the quantity and quality of students' knowledge, as well as its retention. The differences in students' achievement were particularly significant at the first (remembering) and third (evaluating and creating) cognitive levels, in favour of the interdisciplinary approach. Our findings support the claim that interdisciplinary learning provides a wider, more comprehensive view of natural phenomena and concepts, thus enabling students to solve problems of higher cognitive levels. Experimental verification of the effectiveness of the interdisciplinary approach in high school biology teaching on the topics of ecology and environmental protection was the focus of the study by Niklanović et al. (2014). Students who studied these topics correlating notions in biology, geography, chemistry, physics, and mathematics showed significantly higher quantity and quality in knowledge (at all three levels) and better knowledge retention than their peers in monodisciplinary classes. The integration of disciplines and positive students' attitudes towards interdisciplinary learning in this case resulted in the creation of functional knowledge. Acarli (2020) provided empirical evidence that the integration of biology and chemistry in teaching the topic of proteins in primary school contributed to the development of critical and creative thinking skills. As reported, the E group was more successful in dealing with concept maps through which they associated their knowledge related to the disciplines of biology and chemistry than the C group. Similar findings are reported by Abdella et al. (2011) who emphasized that the interdisciplinarity between biology and chemistry provided students with a wider view and attitude towards science. There are other literature sources reporting that the interdisciplinary approach results in the development of students' skills such as knowledge interpretation, setting up conceptual associations, making inferences, thinking analytically, and problem-solving, and in this way, the approach contributes to permanent and meaningful learning (Demirel & Diker Coşkun, 2010; Drake & Burns, 2004; Harrell, 2010; Jacobs, 1989; MacMath et al., 2010; Satiansiriwiwat et al., 2018; Slavinec et al., 2019; Suraco, 2006). The present results also support these findings.

Knowledge retention is affected by a number of factors, such as student motivation, instructional approach, learning environment, and the aspect from which a certain issue is approached. Interdisciplinary learning is actually a method that enables students to approach a certain content from various aspects. Accordingly, the current findings show that the knowledge gained by combining biological and geographical contents retains longer, as the E group had better retest scores at the levels of understanding and applying knowledge. The findings corroborate with reports of other researchers (Marsh & Stock, 2006; Milanković Jovanov et al., 2022; Niklanović et al., 2014) that a sensible correlation between several areas of study considerably affects the quality, and by that also the retention of knowledge, as well as the possibility to integrate knowledge.

Based on the current results and other numerous studies it can be concluded that the interdisciplinary approach is beneficial for the teaching and learning process but its application requires more time and energy for lesson planning, preparation, and implementation. For the purpose of the current study, biology and geography teachers, as well as the authors of the paper, invested considerable time and energy to prepare lessons for the E group. This means that the application of interdisciplinary approach implies teachers' readiness and will, as well as their professional development for applying the approach. Due to the dominance of a single discipline curricula in teacher training programmes at Serbian universities, in-service biology teachers usually lack adequate knowledge from other disciplines that would enable them to combine it in their teaching practice, as it was also concluded in a study by Dervişoğlu and Soran (2003). At this point, there is a need for reforming the teacher training university curricula by providing more space for interdisciplinary instruction so that future teachers can fully understand its potential in the teaching practice and develop an interdisciplinary approach perspective. Some study findings (Dervişoğlu & Soran, 2003; Labudde, 2003) showed that many subject teachers felt unprepared for team teaching and mutual preparation of the teaching material. In order to overcome this in the application of an interdisciplinary approach, subject teachers should be encouraged to attend professional development programmes where teachers of various subjects could exchange ideas, materials, and experiences that would ultimately boost their motivation for applying this approach in their teaching. Until the school year 2018/2019 Biology syllabi in primary education in Serbia were organized in a linear manner and as such were overloaded with contents, which made it hard for teachers to find time for interdisciplinary practice. How important this factor is for applying the interdisciplinary approach has been stressed in several studies (Aslan Yolcu, 2013; Dervişoğlu & Soran, 2003; Reinhold & Bünder, 2001). Since the school year 2018/2019 a revised Biology curriculum has been in use in Serbian primary schools and its emphasis is on reaching learning outcomes through the implementation of various forms of teaching and learning, including an interdisciplinary approach as well. The results of the current and other studies show that the interdisciplinary approach deserves to be part of the teaching practice as it deepens and enriches the knowledge that can be applied in various everyday situations.

Conclusion

The significance of the current study is perceived in offering empirical evidence that the interdisciplinary correlation of biological and geographical contents in primary education contributes to higher student achievement and gaining of functional knowledge, in comparison with the monodisciplinary instruction. The students who studied biological contents on the adaption of living organisms on various environmental conditions by relating them to geographical notions were better at understanding and solving problem tasks than their peers who were taught only from biological aspects. The E group performance points to the need for a greater presence of an interdisciplinary approach in teaching sciences in relation to monodisciplinary approach that is the cornerstone of the traditional teaching practice. There is a huge potential for applying interdisciplinary science teaching in primary education and due to the many advantages, that it offers, there is a need for its greater and more frequent implementation in teaching separate science subjects or a general Science course. The implementation requires an inventive and skillful teacher who is familiar with modern teaching tendencies and knows how to play them in his/her teaching practice. Therefore, a systematic professional development of future teachers and the development of their cross-curricular competencies through initial teacher education and continuous professional development may contribute to a more frequent application of interdisciplinary teaching which would result in educational innovations and enhancement of the educational process. The current results may serve as a basis for syllabus changes and organization of work at teacher-training institutions which would result in a more intensive application of this approach in a deeper understanding of its didactic and methodological principles. Future studies therefore could provide new guidelines in the search for more efficient and productive strategies of teaching and learning and thus enhance the whole education process.

Recommendations

Following are some recommendations for further research on the efficiency of the interdisciplinary approach in biology education. The present research was conducted on a sample of 180 students from the same locality. Further studies may include a larger number of students coming from different localities in Serbia to ensure more reliable conclusions. Further research could also involve students of different grades of primary and secondary education, as well as at the university where the interdisciplinary correlation between biology curriculum and other disciplines and their curricular contents could be examined for experimental verification of its effectiveness in the teaching practice. In our study, the effectiveness of the interdisciplinary approach was assessed in relation to the quality and quantity of student achievement. Future research could offer the assessment of instructional efficiency of interdisciplinary approach by two parameters: student achievement and mental effort invested in completing tasks while applying different pedagogical treatments, as indicated in the latest research (Radulović, 2021; Radulović & Stojanović, 2019; Županec et al., 2018). To ensure more frequent application of this approach in biology classes, future research articles should encourage and support teachers by offering detailed scenarios for biology lessons organized in a multidisciplinary manner. Greater availability of teaching materials applicable in the classroom may stimulate teachers to take innovative challenges and implement them in their classes to ensure better learning outcomes. Stimulated and encouraged teachers may also apply this approach in horizontal enlargement of the teaching content in their work with gifted students (Radulović & Krstić, 2022), as teacher competencies are crucial for the cognitive, social and affective development of students (Radulović et al., 2022).

Limitations

The first limitation of the study refers to the sample size, as in future research it should be larger in order to obtain more reliable results relating to monodisciplinary teaching and learning. The second limitation refers to the length of the experimental treatment. A five-week intervention is a relatively short period for investigating the effectiveness of an instructional approach and therefore future research should involve a longer pedagogical experiment. The third limitation refers to the assessment of the interdisciplinary approach efficiency on the basis of students' achievement at three levels of cognition. As stated in the recommendations, further research may also assess this approach in relation to the level of mental effort that students invest while dealing with various tasks as well as in relation to the level of their motivation for interdisciplinary learning. The current conclusions address the effects of interdisciplinary correlations between two subjects (biology and geography) in teaching one teaching topic "Structural and Functional Unity as the Basis of Life", which is certainly another limitation of the present research that may be avoided in the future.

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Authorship Contribution Statement

Županec: Concept and design, resources, methodology, investigation, data analysis, drafting manuscript. Lazarević: Resources, statistical analysis, data analysis, drafting manuscript. Sekulić: Conceptualization, methodology, data acquisition. Pribićević: Data acquisition, conceptualization, resources. All authors have read and approved the final manuscript.

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Appendix

One Segment of a Worksheet for Students in E Group

The appendix shows a segment of a worksheet for E group of students. The worksheet task *Life in deciduous forests* was used as part of the teaching unit *Life in terrestrial communities*. The worksheet comprised 4 segments: Climate, Distribution, Plant and Animal Communities.

Instructions for students: Together with your group peers, complete the following tasks using your Biology and Geography course books.

A) CLIMATE – Deciduous forests are found in temperate continental climate regions.

- In which thermal belt is the temperate continental climate?
- Mark on the map (Figure 1): *the position of the thermal belt* with temperate continental climate; *parallels* within which this belt stretches: name them and write their latitude values;

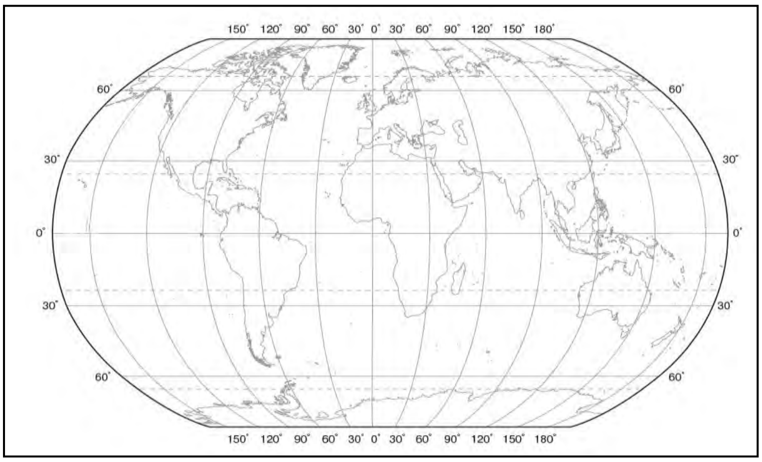

Figure 1. The World Map

- Figure 2 shows the climate-diagram of temperate continental climate. Study it carefully and think of the main features of this climate type. Then answer the following questions analyzing the diagram: What is the coldest month? What is the hottest month?

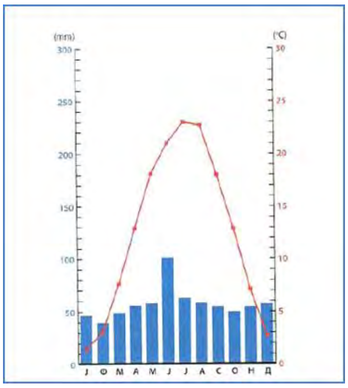

Figure 2. Climate-Diagram of Temperate Continental Climate

B) DISTRIBUTION

- The map below (Figure 3) shows the position of deciduous forests on the Earth. On which continents of Northern Hemisphere can we find this type of forest?

Figure 3. Position of Deciduous Forests on the Earth

– On the figure below circle the belt and the altitude at which deciduous forests are found.

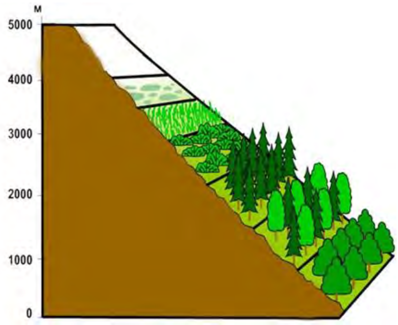

Figure 4. Diagram of Vertical Distribution of Forest Zones

C) PLANT COMMUNITIES IN DECIDUOUS FORESTS

– Deciduous forests are characterized by layers. Fill in the gaps in Figure 5 with the following expressions: a) layers – forest floor, shrubs, trees; b) Fill in the lines below each layer with the names of plants that live there.

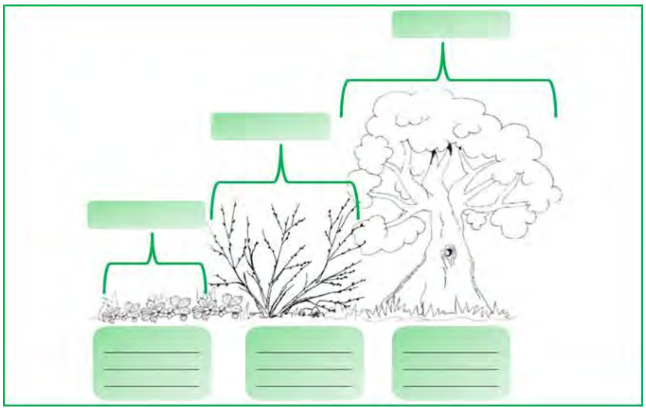

Figure 5. Layers in the Deciduous Forest