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Оригинални научни рад

Effects of Using Project-Based Learning in Biology Teaching

Abstract: *Project-Based Learning (PBL) enables students, by solving tasks within the project, to be much more active in classes and acquire knowledge through practical activities and experiences. The aim of the research was to determine the effects of the application of PBL in terms of student success in knowledge tests, then in terms of the durability of knowledge and mental effort that students invest by applying different teaching models. The sample included 406 fifth-grade students from four elementary schools in Novi Sad (Serbia). For the needs of the research, the following instruments were designed: knowledge tests (pre-test, post-test, re-test) and the scale of assessment of students' mental effort, which were applied in the research. The research has shown that PBL is more effective than traditional teaching (ex-catedra teaching), because students who attended this type of classes achieved better results on knowledge tests, their knowledge is more permanent, and mental effort is lower. The obtained results have theoretical and practical significance and suggest that PBL should be applied more in elementary schools within the subject of biology, but also within other subjects and higher levels of education.*

Keywords**:** *project-based learning, project-based teaching, teaching biology, elementary school*

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Introduction

Biology as a multidisciplinary natural science offers numerous opportunities for organizing classes. However, biology classes are still mostly conducted in a traditional way, where the teacher teaches the material in front of the class. In such classes, most students are passive observers of the teaching process, while only a few of them are active in class. Changing the teaching approach could contribute to the motivation of students who expect the school to follow modern trends in teaching and classroom organization (Žderić i Miljanović, 2008; Radulović et al., 2019).

The results of previous studies indicate that students will not be motivated to learn when they are involved in meaningless and insignificant activities such as continuous practice of skills that they have already mastered, rewriting definitions and terms used in class or through working on tasks that do not lead to achieving a specific, pre-set learning goal (Brophy, 2004). On the other hand, the findings of some studies indicate that students' sense of efficiency is of crucial importance for learning (Peetsma et al., 2005) and that students who experience success in school are motivated to continue working (Yair, 2000).

One of the ways for students to independently discover and actively master the material is to introduce a larger number of projects in the classroom, so that students will work on the project to independently discover and actively master the material. At Project-Based Learning (PBL) the focus is on the student, while the teacher is only the coordinator of the teaching process. PBL should develop better interdisciplinary competencies in students, so that the knowledge acquired in this way would be not only at the level of reproduction, but also at the level of application, analysis, evaluation, and creation. Project-based learning is a teaching approach built on learning activities with real tasks and challenges that students need to solve. These activities generally reflect the types of learning and work that people perform in everyday life, outside the classroom (Goodman & Stivers, 2010).

For the realization of PBL, students are usually divided into groups in which they work together to achieve a common goal. This type of teaching enables students not only to learn certain contents, but also the skills of how to solve a problem, as well as the way in which they should function in a group, which builds team spirit and a good atmosphere. These skills include communication, organization, time management, research and questioning skills, self-assessment and thinking skills, group participation and leadership skills, as well as critical thinking. Learning performance is assessed on an individual basis, taking into account the quality of the obtained product, the depth of the demonstrated understanding of the content and the contribution of each student within the group during the project implementation. Project-based learning allows students to think about their ideas and make decisions that affect project outcomes and the learning process in general. The end product results in a high quality, authentic knowledge and presentation of content (Goodman & Stivers, 2010).

PBL is a learning method in which students identify a problem in the real world and develop ideas for solving it using evidence that supports a given claim. This type of learning is not something new, only teachers simply did not use it to a greater extent. As early as the beginning of the 18th century in Europe, the final exams of architecture and engineering students consisted of solving real and practical problems. The concept of learning through projects by solving practical problems at the end of the 19th century was introduced in industrial art high schools (Knoll, 2012). The project method was introduced into literature by William Heard Kilpatrick at the beginning of the 20th century. During the 20th century, PBL was applied occasionally, mainly due to a weak motivation of teachers to prepare such classes which require much greater commitment to prepare than for the class itself (Pecore, 2015).

Greater popularization of PBL occurs in the 21th century, when this type of learning, with the development of new, digital technologies and the accumulation of knowledge in science, takes on a completely different dimension. While one accepted definition of PBL does not exist, the Buck Institute for Education (BIE) offers a concise overview of definitions focused on broad-based standards. According to BIE (Markham et al., 2003: 4), project-based learning is "a systematic teaching method that engages students in acquiring knowledge and skills through an expanded examination of a process structured around complex, authentic questions and carefully designed products and tasks". It is not enough to consider the implementation of a project or activity as project-based learning if the five definitive characteristics are not met. The important characteristics of PBL include: 1) central design; 2) constructivist focus on important knowledge and skills; 3) learning activity in the form of a question-problem-challenge complex; 4) research conducted by the student guided by the teacher's instructions; and 5) a real-world project problem that is authentic for the student (Barron & Darling-Hammond, 2008; Thomas, 2000). Problem-based learning through a project is a teaching approach that presents students with an open and clearly defined problem which can take the form of a case study (Herreid, 2003; Pecore, 2009).

PBL is a specific approach, not the result that a student or group have reached by working according to clear and pre-agreed instructions from the teacher. In this process, students are encouraged to research, discuss, evaluate, work and create, and the end result is not defined in advance, especially not by teachers. The result is planned by the students and they present their findings obtained from their research and work to a wider community, outside the narrow circle of students in the class in which they worked (Petrović i Hoti, 2020).

PBL carries a real paradigm shift and that is what encourages its more intensive use, especially in the conditions of distance teaching, where students are required to be much more engaged than in direct school teaching. This teaching model encourages interdisciplinary perspectives and allows students to play different roles and build expertise that is applicable outside of a pre-defined context. Finally, PBL allows for a range and variety of outcomes open to multiple solutions, rather than a single correct answer obtained by applying predefined rules and procedures (Goodman & Stivers, 2010).

It is true that PBL is no longer a matter of the future but a practical reality in many classrooms in the world and in our country. Using online communication tools, such as Viber, Skype or Zoom, although a good step in the right direction when it comes to remote learning, is not project teaching, but just that – remote teaching (Petrović i Hoti, 2020). However, thanks to the advancement of digital technologies, PBL is something that now, more than ever, has the potential to be applied, and it will certainly be easier to continue its application even when students return to the classrooms. It is a paradigm shift that we hope for. PBL has a number of advantages over the traditional approach both in terms of remote teaching (Bredley-Levin et al., 2010) and on-site, in the classroom (Smith et al., 1995; Sonmez & Lee, 2003).

In Serbia, many creative teachers are already applying PBL (Petrović i Hoti, 2020). Support for the introduction of PBL in teaching was provided by publishers in terms of several manuals and The Institute for the Improvement of Education which prepared training dedicated to the issues of project-based learning. About 55.000 teachers and school counselors attended this training. The application of PBL in educational practice is ongoing in the educational system of Serbia. Namely, in the school year 2018/2019 project learning was implemented in the first cycle of education as a mandatory form of teaching, implemented once a week (Đerić et al., 2021).

Although some empirical studies have shown the positive effects of PBL on the better quality of knowledge among students from Serbia (Prtljaga & Veselinov, 2017; Ristanović, 2018), there is a small number of studies examining the effects of PBL in the teaching of biology. In this regard, the aim of this research was to examine the effects of PBL in elementary school biology teaching. In connection with the goal, three research tasks were set: 1. to examine the effect of PBL on the achievement of students in biology; 2. to examine the effect of PBL on the consistency of acquired knowledge and 3. to examine the difference in students' mental effort during traditional teaching and project-based learning.

Research Methodology

General procedure of research: At the beginning of the pedagogical research, the students of groups E (experimental group) and C (control group) were equated on the basis of the results on the pre-test which measured students' prior knowledge of the contents of the subject "The World Around Us" (a subject that includes biology content in the lower grades), which was a prerequisite for successful work, understanding, and adoption of the topic "The Origin and Diversity of Life". This teaching topic was chosen because it is difficult and abstract for elementary school students. By equalizing the students of E and C groups before the beginning of the research, further course of the pedagogical experiment was enabled - introduction of an innovative teaching model for E group students and drawing valid conclusions after its implementation.

Pre-test measurements: In the first step, using a pre-test to look at measures of central tendency, Skewness and Kurtosis, arithmetic mean (*M*), standard deviation (*SD*), minimum (Min), maximum (Max), a descriptive statistical analysis was performed. Differences in achievement between students of the experimental and control groups were examined by t-test.

Post-test and re-test measurements: After the pre-testing, two different teaching approaches were applied in teaching biology contents in two groups of fifth-grade students. The students of E group worked on the teaching topic "Origin and Diversity of Life" by applying PBL through the given mini-projects. This model of teaching was applied by implementing the didactic manual "The Basket of Ecological Ideas" (Milenković i sar., 2018) which contains a large number of mini-projects adapted for these biology contents. This manual is divided into three parts (Forest Enchantment, Magical Meadow, and Water Adventure). Each of these units contains activities with detailed instructions for their implementation. The instructions for the implementation of the activity contain the goal of the activity, a list of necessary materials, the duration of the activity and recommendations for implementation in the form of quick ideas. Biology classes for E group students took place in the biology laboratory and then in the school yard.

In the classes of group C, the teaching work was in accordance with the traditional way of teaching the topic "Origin and Diversity of Life". Biology classes for students from group C took place in biology classroom. Immediately after finishing the pedagogical experiment a post-test was conducted, and, after a month, a re-test in order to check the durability of the acquired knowledge with different teaching models. The post-test and re-test included the contents of the teaching topic "Origin and Diversity of Life" which were also processed during the research. For the post-test and re-test, a descriptive statistical analysis was also performed. Differences in achievement between the students of the E and C groups were examined by t-test.

The efficiency of the two teaching models in relation to the achievement of students in biology on the post-test and re-test was determined by a combined analysis of variance, and the data were compared in relation to the group of students.

Student's mental effort assessment: In order to examine the effects of PBL in relation to traditional teaching according to the criterion of mental effort of students, the post-test was performed to assess the mental effort of students. Results were obtained using t-test.

Sample of research: The sample included 406 students from 4 elementary schools in Novi Sad, Serbia. The respondents were fifth-graders and attended 2020/2021 school year. The average age of the respondents was between 11 and 12 years of age. A total of 202 students from the two schools formed the experimental group (E) and 204 students from the other two schools formed the control group (C).

Instruments: For the purposes of this research, three instruments were constructed and applied in the research:

- Pre-test: a test that was applied for both groups before starting the research;
- Post-test: test in which the Likert scale for assessing the mental effort of students is integrated, which tested both groups after the implementation of different teaching approaches;
- Re-test: a test that is, in fact, a modified final test (does not measure the mental effort of students) and is applied one month after the post-test.

The pre-test contained assignments from the subject "The World Around Us" which precedes the subject Biology in elementary school. The range of points on this test was from 0 to 24. The internal consistency of the questions within the test was good (Cronbach α = 0.79), which indicates that the test is reliable.

The post-test contained 24 questions, so that a student could win at least 0 and at most 24 points on this test. Within each question, on the final test, there was a five-point Likert scale for the self-assessment of the mental effort that the student invests when solving the tasks. The students answered by circling one number, from number 1 "extremely easy" to number 5 "extremely difficult". The reliability coefficient (Cronbach α) for the final test is 0.82, which indicates good question consistency within the test and its good reliability.

The re-test as an instrument for measuring knowledge is a test that should indicate the degree of permanence of knowledge after a certain period of time and it is the same as the post-test, except that it did not contain the Likert scale for testing students' mental effort.

Data analysis: Data analysis included different parameters. Because the data had the parameters of Skewness and Kurtosis within the limits of acceptability for the application of parametric procedures (Tabachnick & Fidell, 2013), parametric procedures were used in the analyses (p=.05). The data on the progress of students in groups E and C from the initial to final testing of knowledge and the re-test were processed by a combined analysis of variance (Two Way Mixed ANOVA).

Research Results

In this section, the main results of the current study are presented. The pre-test results are shown in Table 1.

Table 1. Descriptive statistical analysis and t-test value for pre-test

	N	Min.	Max.	M	SD	Skewness	Kurtosis	t(df)	p
E group	202	4	24	17.65	3.62	-0.69	1.32	0.01 (404)	.99 (>.05)
C group	204	8	24	17.66	3.03	-0.07	1.08		

As can be seen in Table 1, students in both groups had approximately the same achievement. The existing differences were examined and tested and the results of the t-test showed that the differences in the achievement of students in groups E and C were not statistically significant. These data indicate the fact that the E and C groups, before the application of the experiment, are well balanced, which is one of the basic prerequisites for the validity of the further course of research.

In the post-test, the students of the experimental group achieved higher achievement than the students of the control group (Table 2). The difference in achievement on the post-test between the students of groups E and C reached statistical significance. These data indicate the fact that the students of group E, thanks to the application of the innovative teaching model (PBL), are statistically significantly more advanced than the students of group C.

At the re-test, the students of the experimental group had higher achievement than the students of the control group (Table 3). The difference in the re-test achievement between the students in groups E and C also reached statistical significance. These data indicate the fact that students' knowledge within E group is more permanent thanks to the application of the PBL.

Comparative analysis of students' results on the pre-test, post-test and re-test: Figure 1 gives a comparative graphical representation of the average achievement of students in groups E and C on all three tests of knowledge (pre-test, post-test, re-test).

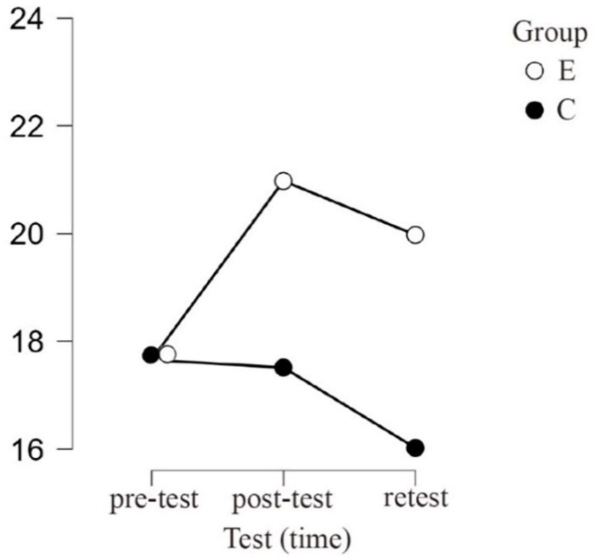

Figure 1. Average achievement of students in two analyzed teaching models on the pre-test, post-test and re-test in relation to the experimental (E) and control (C) groups

The results of the assessment of students' mental effort are shown in Table 4.

Table 2. Descriptive statistical analysis and value of t-test for post-test

	N	Min.	Max.	M	SD	Skewness	Kurtosis	t(df)	p
E group	202	10	24	20.98	3.89	-1.35	1.32	9.57 (404)	<.01
C group	204	10	24	17.51	3.38	-0.12	1.16		

Table 3. Descriptive statistical analysis and value of t-test for re-testing of students

	N	Min.	Max.	M	SD	Skewness	Kurtosis	t(df)	p
E group	202	10	24	19.97	3.55	-1.23	1.47	12.23 (404)	<.01
C group	204	8	24	16.02	2.93	0.06	1.33		

Table 4. Statistical significance of the difference in achievement in biology topic "Origin and Diversity of Life" between students of E and C groups measured on the pre-test, post-test and re-test in relation to retention time

	F	df1	df2	p	?$^{2}_{p}$
Group	81.48	1	404	<.001	0.168
Testing	46.68	2	808	<.001	0.104
Interaction Group x Testing	77.52	2	808	<.001	0.161

The results in Table 4 show that there is a statistically significant main effect of the unrepeatable *Group* factor, because the difference between the E and C groups on the post-test and re-test is significant. A significant main effect is also manifested in the repeated factor *Testing*, since the result for both groups on the post-test and re-test is statistically significantly different, both from each other and in relation to the initial test. Interaction *Group* x *Testing* factor also proved to be statistically significant, as there is a significant difference between E and C groups on the post-test and re-test compared to the results of E and C groups on the pre-test.

Results of student mental effort assessment: In order to examine the effects of PBL in relation to traditional teaching according to the criterion of mental effort of students, the post-test was performed to assess the mental effort of students. The results were obtained using t-test.

The obtained values indicate less mental load of students in group E, compared to students of group C (Table 5). This shows that the students of group E invested less mental effort in solving the tasks on the post-test of knowledge, compared to the students of group C. The value of the t-test indicates the statistically significant difference in the expressed mental effort between students in groups E and C. The difference between the mental efforts of the two groups proves that, from the aspect of mental load of students, PBL is more efficient than traditional teaching.

Discussion

One of the basic features of effective teaching is that students can apply the acquired knowledge in practical, everyday life (Gagić et al., 2019; Radulović & Stojanović, 2019; Radulović, 2021; Županec et al., 2018). In order to achieve this goal, students need to be motivated by changing the way of working. In such an organization of teaching, the role of teacher also changes. He/she becomes the organizer of the process in which students acquire knowledge in the most accurate way and solve the problem set for them. The development of students' independence is a stimulating factor for the innovation the teaching process, and a high degree of students' motivation is achieved through the successful implementation of innovative forms of work in the classroom (Goodman & Stivers, 2010).

The data obtained from the research indicate that the students of group E, thanks to the application of the innovative teaching model (PBL), made the statistically significant better progress than the students of group C.

Table 5. Statistical significance of differences in mental effort of E and C groups measured by t-test

	N	M	SD	t(df)	p
E group	202	2.082	0.533	4.453	<.01
C group	204	2.316	0.527	(404)	

Also, the knowledge of students in group E is more permanent thanks to the application of PBL, and the value of the t-test indicates the existence of a statistically significant difference in the expressed mental effort between students of groups E and C. The difference between the mental efforts of the two groups proves that, from the aspect of mental load, PBL is more effective than traditional teaching.

By applying PBL, students actively develop logical and critical thinking and thus prepare for later coping in the world of science and technology and develop the need for and awareness of lifelong learning. PBL develops interdisciplinary competencies of students, such as teamwork, problem solving, cooperation, propensity for entrepreneurship, etc. Given that the learning process is a very complex action, the development of project-based learning must take place systematically (Fernandes et al., 2014; Kapusuz & Can, 2014; Mohedo & Bujez, 2014).

The results of the research showed that PBL is more efficient than traditional teaching, because the students of the group that applied the project-based teaching model achieved statistically significant better results than the students of the other control group , both on the final test and on the re-test applied a month after the final test. The learning process using PBL focuses on the student who is going through a meaningful learning experience (Afriana et al., 2016), which effectively increases the effectiveness of learning (Eliana et al., 2016).

In the context of PBL, students are expected to research independently and they are, therefore, in a situation to use different sources of information, while students who participate in more traditional classes are in most cases referred only to the textbook of a given subject. We can assume that this is one of the factors that affect the durability and quality of knowledge. The results of previous research have shown that the project-based model of learning can improve students' scientific skills in the learning process, as well as activities focused on the learning process and problem solving (Maghfiroh et al., 2016; Safaruddin et al., 2020). These findings were also confirmed by Corvers et al. (2016) and Rofieqet al. (2019), according to which PBL increases students' activities focused on the process of learning and problem solving.

The project-based learning model has a good impact on collaboration skills through working together on a task (Al Rasyid & Khoirunnisa, 2021). Research in this area has shown that the organizational context of PBL can be viewed as a reflection of the opportunities for useful learning or organizational practices. These findings reflect the view that learning within an organization is "nested" - it occurs at several different but interconnected levels simultaneously (Levinthal & March, 1993). This concept implies a substitution effect: learning at one level can replace learning at another level. With regard to specific projects, it can be suggested that conditions that promote learning within projects, including knowledge integration, can be balanced with conditions of simplification and specialization that facilitate organizational learning (Postrel, 2002). In this context, projects can be used as a way to overcome some of the shortcomings of specialization (Ekstedt et al. 1999; Lundin & Midler 1998). This view of PBL is supported by some studies that highlight the difference between the high level of learning generated within the project activities and its limited approach in relation to a broader context outside the project (Newell et al., 2003; Keegan & Turner, 2001).

The results of the previous research (Sasson & Dori, 2015) indicate that students in an innovative learning environment have shown a significant advantage in critical thinking over their peers in traditional classroom. The findings of the study indicate the possibility of developing thinking skills among students in a relatively short time, even among students who have previously been educated using traditional learning methods. These results confirm the effectiveness of the constructivist approach in developing students' ability to ask questions, search for information that lacks sufficient data, and take a reasoned stance. They support the findings of the previous studies (Hug, 2010; Lea et al., 2003; Loyens & Gijbels, 2008; Matthews, 2002) regarding the contribution of constructivist learning environments to the development of higher thinking skills, particularly critical thinking and questioning.

PBL also confirmed its efficiency through testing the mental effort of students. This study showed that the experimental group of students invested significantly less mental effort in solving tasks compared to the control group of students. PBL includes a series of dynamic tasks, the solution of which leads to an active knowledge acquisition through working on a project. Complex cognitive skills consist of a set of sub-skills that may or may not be repetitive (Van Merriënboer, 1997). Non-repetitive skills are based on knowledge learned through a scheme-building process (project), which stimulates students to apply a diverse range of tasks (Singley & Anderson, 1989). This research has shown that by building knowledge through practical activities, students gain experience that later enables them to use that knowledge with much less mental effort than students who acquire knowledge in traditional way, by learning facts from textbooks.

PBL could be effective in achieving higher learning goals in elementary and secondary education. This study provides evidence of the values of PBL, with students who participated in this model of teaching being more effective. We assume that the mode of operation in which students arrive at solutions independently is more interesting than the mode of operation in traditional teaching because, in traditional teaching, students can be motivated by the teacher's ability to generate interest through charisma and potential challenges, whereas students' internal motivation was mostly absent (Wong & Day, 2009). This study implies that PBL should be more prevalent in schools, which would create conditions for exploring this instructional model within different subjects.

Conclusions and Implications

The aim of the research was to examine the effects of Project-Based Learning (PBL) in teaching biology in elementary school. This research has shown that Project-Based Learning is more effective than traditional teaching. The effects of this teaching model are reflected in the better results of students in the experimental (E) group who attended project-based classes compared to students in the control (C) group who attended traditional classes. This study also proved that PBL not only contributes to better student results in terms of their knowledge at the time of testing, after the implementation of the teaching content, but is also more efficient in terms of durability of knowledge compared to traditional teaching. Also, this research showed that students who learned through projects, invested less mental effort than students in traditional lessons, which indicates the fact that project-based teaching is more efficient than traditional in this regard.

The obtained results have theoretical and practical significance. They complement the empirical findings on the effectiveness of PBL in teaching biology in elementary education and provide significant guidance to teachers, not just biology teachers, for introducing PBL into the teaching process. These findings encourage a wider application of PBL in teaching, which may be an incentive for teachers and researchers to test the effectiveness of PBL in other subjects or in higher-level education (secondary schools and colleges) in future research.

Research Limitations

Finally, it is necessary to point out the limitations of the conducted research. Namely, the sample covers only one teaching topic in one class, so in future research it would be desirable to include more teaching topics, not only from one grade, but from the entire second cycle of elementary education, which would allow the results to be generalized to the entire elementary school biology curriculum.

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ЕФЕКТИ УЧЕЊА ЗАСНОВАНОГ НА ПРОЈЕКТИМА У НАСТАВИ БИОЛОГИЈЕ

Бројне студије указују на то да традиционална настава, у којој наставник заузима централну улогу, а ученици углавном нису много активни на часу, не даје очекиване резултате у вези са ученичким постигнућима у настави. То доказују и релативно слаби резултати наших ученика на међународним тестирањима као што су ПИСА и ТИМСС. Једно од решења за превазилажење овог проблема јесте шира примена пројектне наставе (у даљем тексту: ПН) у школама (енг. Project Based Learning – PBL).

Биологија као мултидисциплинарна природна наука нуди бројне могућности за организовање наставе, како у учионици, тако и у природном амбијенту, што додатно отвара нове перспективе за примену пројектне наставе. Пројектна настава омогућује да ученици, решавајући задатке у оквиру пројекта, буду активнији на часовима и да знања стичу кроз практичне активности и искуства.

Циљ истраживања био је да се утврди ефикасност примене ПН по питању успеха ученика на тестовима знања, затим по питању трајности стечених знања и менталног напора који ученици улажу применом различитих модела наставе.

Узорак истраживања је обухватио 406 ученика из четири основне школе у Новом Саду (Република Србија). Укупно 202 ученика из две основне школе чинила су експерименталну групу (Е), а 204 ученика из друге две основне школе чинила су контролну групу (К).

Инструменти истраживања који су креирани за потребе експеримента су: иницијални тест знања, финални тест знања, ретест и скала процене менталног напора ученика. Ученици Е и К групе су на почетку педагошког истраживања изједначени на основу резултата иницијалног теста знања, који је мерио предзнање ученика о садржајима из предмета Свет око нас, што је био предуслов за успешан рад ученика, разумевање и усвајање садржаја наставне теме „Порекло и разноврсност живота" у оквиру наставног предмета Биологија. Након иницијалног тестирања примењена су два различита наставна приступа у реализацији биолошких садржаја у две групе ученика петог разреда. Ученици Е групе су наставну тему „Порекло и разноврсност живота" реализовали применом ПН, путем задатих мини-пројеката. У одељењима К групе наставни рад је био у складу с уобичајеним, традиционалним моделом реализације наставне теме „Порекло и разноврсност живота". Непосредно по завршетку обраде предвиђених наставних садржаја у оквиру педагошког експеримента спроведен је финални тест, а након месец дана и ретест како би се проверила трајност стечених знања различитим моделима наставе. Финални тест и ретест су обухватали садржаје из наставне теме „Порекло и разноврсност живота", који су и обрађени током истраживања. У оквиру сваког питања, на финалном тесту, налазила се и петостепена

Ликертова скала за самопроцењивање менталног напора који ученик улаже приликом решавања задатака.

Статистичка обрада података урађена је у програму JASP. За испитивање разлика у постигнућу ученика на иницијалном тесту, финалном тесту и ретесту коришћен је т-тест, уз праг значајности p=.05. Подаци о напредовању ученика Е и К групе од тестирања на иницијалном до тестирања на финалном тесту знања и ретесту обрађени су комбинованом анализом варијансе (енг. Two Way Mixed ANOVA).

Резултати истраживања су показали да је пројектна настава ефикаснија у односу на традиционалну наставу, јер су ученици Е групе остварили статистички значајно бољи резултат у односу на ученике К групе, како на финалном тесту знања, тако и на ретесту, који је примењен месец дана након финалног тестирања. Тиме је доказано да су знања до којих су ученици дошли применом ПН квалитетнија и трајнија у односу на знања стечена традиционалном наставом, јер је у оваквој организацији наставе ученик уједно и носилац наставних активности. Сам процес учења применом ПН је усмерен на ученика који пролази кроз смислено искуство савладавања градива. Такође, ментални напор који су ученици Е групе уложили у решавање задатака на тесту знања је статистички значајно мањи у односу на ученике који су похађали традиционални тип наставе.

Добијени резултати имају теоријски и практични значај. Они употпуњују емпиријске налазе о ефикасности ПН у настави биологије у основном образовању и пружају значајне смернице не само наставницима биологије већ свим наставницима за увођење ПН у наставни процес. Ови налази охрабрују ширу примену ПН у настави, што може бити подстицај за наставнике и истраживаче да се у будућим истраживањима провери ефикасност примене ПН у оквиру других наставних предмета или у оквиру виших нивоа образовања (средње школе и факултети).

***Кључне речи**: пројектно учење, пројектна настава, настава биологије, основна школа*