PROBLEM BASED LEARNING AS AN EFFICIENT WAY TO INTRODUCE PUPILS OF LOWER GRADES OF ELEMENTARY SCHOOL TO UNDERSTANDING METHODS OF CAUSAL INFERENCE

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Abstract

The article is a representation of the results obtained in an experimental testing of learning by solving problems according to Bloom's taxonomy. The authors had hoped to find out whether the application of problem-based and creative systems and strategies, both didactic and methodical, in the teaching of Science and social studies corresponds to the development of pupils' intellectual abilities such as long-term memory and acquisition of knowledge and different forms of self-teaching which can increase their level of independence in working and managing everyday life's situations. The causal method – experiment with parallel groups and the descriptive method – method of theoretical analysis were used to check this hypothesis. Problem based learning, as a contemporary teaching system and a didactic-methodical strategy enables teachers to introduce natural phenomena in a new, creative way, by putting their pupils into the position of subjects who approach the data received critically and creatively, thus developing their curiosity and the ability to learn abstract notions such as MAGNETISM and ELECTRICITY.

Key words: *pupil, problem based learning, research activity, Science and social studies, Bloom's taxonomy*

INTRODUCTION

Problem based learning is a system of teaching deeply rooted in the history of education. The year of 1965, when a symposium on problem-based teaching was held in New York, is considered the beginning of this teaching system.

Numerous authors have defined problem-based learning starting from what they find most important about it. Despite all the differences, two elements appear in each definition: research activity and the search for new solutions. These are the two main characteristics of this system of teaching (Vilotijević, 2008). It can most precisely be defined as the type of teaching that is characterized by individual research activity through which the students, while overcoming problem difficulties, find new solutions and acquire scientific truths.

It would be terribly wrong to consider problem solving a universal or preferred over numerous other didactic systems. All didactic systems share the characteristic that each of them can only solve one pedagogical problem, each of them has good sides and bad and none of them is universal, and each is therefore insufficient for solving all the tasks of modern-day education.

The terms problem and task should not be equated. Task is a much broader and much more comprehensive term. Problem is also a task, one that needs solving and is characterized by the following:

- different number of possible solutions (one or more),
- high complexity (solving asks for the use of a large number of complex logical operations),
- solution cannot be found by the ususal algorithm form but asks for a creative approach and experience,
- by solving the problem, knowledge is deepened, new structures of learning are acquired and intellectual abilities are developed (Vilotijević, 2008).

Questions starting with question-words such as Who…, What…, Where…, cannot be problem questions since they only ask for memorizing facts. Whereas questions starting with question-words and verbs, such as: How…, Why…, Explain…, Elaborate…, and the tasks starting with: Observe…, Analyze…, Note…, Compare…, Determine…, Check…, Prove…, Fill in…, Replace…, Expand…, Rate…, Illustrate…, Give a new example of…, Demonstrate…, are all examples of tasks and questions which ask for divergent thinking and imagination (Samardžija, 2004).

RESEARCH METHODOLOGY

The subject and the problem of research

The subject of this research was an experimental check of the students' possibilities for advancement with the application of problem-based learning. We started our research from the theory of the cognitive domain of Bloom's taxonomy. As the research problem, we identified the progress possibilities of students in the subject of *Science and social studies* by applying problem-methodical organization of the teaching process

The goal and the tasks of the research

The main research goal was to determine the effects of the problem-based teaching on the quality, permanence and applicability of knowledge in *Science and social studies* (by comparing the results achieved on the final tests in the experimental and in the control group).

Based on the preformulated goal, the following task was set: *To determine whether the testees from the experimental group, in which problem-based teaching was applied, would achieve better results on the final tests than the testees from the control group.*

Research hypothesis

Based on the problem, the subject and the goal of the research, the hypothesis was set: It was assumed that the pupils from the experimental group in which problem-based teaching of *Science and social studies* was applied (as the experimental factor) would achieve better results in comparison to the control group.

Research sample

The sample consisted of 195 third-grade pupils from elementary schools in Kikinda. The research was done on the sample made of 4 experimental and 4 control groups, i.e. eight classes in total. The experimental group consisted of 4 classes (100 pupils) from the elementary school "Jovan Popović". The control group consisted of 4 classes (95 pupils) from the elementary school "Vuk Karadžić".

ORGANIZATION AND THE COURSE OF THE RESEARCH

The experiment was done during the academic 2010/2011. The initial test was done in February 2011, and the experimental program was realized during March, April and May 2011.

During the period in which the experimental program was realized, the pupils from the experimental group performed experiments without the help of the teacher, they set hypotheses, did their own research and discovered relevant facts and the laws of nature related to the field of electricity and magnetism. The pupils were given the opportunity to manipulate and experiment with different objects such as magnetic rod, compass, electromagnet, and electrical circuit. They were also given the possibility to follow up their experimental and learning activities by art and construction activities which further contributed to the deepening of the knowledge they had acquired, and on the other hand, provided feedback for the teacher. The pupils spent more time outside where the analyses and systematizations of knowledge were conducted, followed by direct observation and the dialogue between the teacher and the pupils.

Methods, techniques and instruments used in the research

During research, the authors used the method of theoretical analysis, the descriptive method, its Survey procedure, and the causal (experimental use) and comparative methods.

Test was chosen as the research technique. As far as the instruments are concerned, the authors used knowledge tests (initial and final) composed for checking the knowledge on contents determined by the curricula for the first, second and third grade of elementary school, after consulting elementary school teachers.

Knowledge tests – initial and final (IT, FT)

Since this research was based on the experiment method, the authors used knowledge test as an instrument for researching the initial state of pupils and as the basic instrument for researching the final state of pupils.

Initial test

The initial test was used to check the previously acquired knowledge of the pupils about non-living natural phenomena in the first and second grade of elementary school.

The initial test consisted of 15 tasks, awarded the maximum of 60 points and covered three different knowledge levels:

1. **Reproduction level** – within which there were two groups of tasks: "complete the sentences" and "underline the terms" (tasks numbers 1, 2, 3, 5, 9, 14); all the tasks checked the ability to reproduce knowledge in its original form.
2. **Understanding level –** within which there were two groups of tasks: "organize the data" and "fill in the table" (tasks numbers 4, 6, 10, 12, 13); all the tasks checked the ability to recognize and connect main ideas, and describe the main course of events or processes.
3. **Application level -** within which there was one group of tasks: tasks in the form of images (tasks numbers 7, 8, 11, 15); all the tasks checked the pupils' ability to solve problems in a new situation by applying previously acquired knowledge and rules in a new way.

Final test

The final test measured the level of the acquisition of new knowledge immediately after the experiment was finished. The test consisted of 12 questions, awarded the maximum of 60 points and covered three different knowledge levels:

1. **Reproduction level** – the first four tasks (1, 2, 3, 4); all the tasks checked the ability to reproduce knowledge, define, list, describe, or revise the contents.
2. **Understanding level –**tasks numbers (5, 6, 7, 8); all the tasks checked the ability to recognize and connect main ideas, classify and interpret facts, or predict new ones.
3. **Application level –** tasks numbers (9, 10, 11, 12); all the tasks were designed to develop the pupils' ability to apply the acquired knowledge and solve problems in new situations.

For determining the pupils' achievements in both tests, the key with the defined number of points for each task was prepared.

Test results and their interpreting

Our research included several different tasks. The results obtained are represented in the table and accompanied by a commentary.

The results of the initial testing and the balancing of the groups

We started our research from the assumption that the pupils from the experimental group in which problem-based teaching of *Science and social studies* (as the experimental factor) was applied would achieve better results than the pupils from the control group. We first conducted the initial testing.

The initial testing preceded the introduction of the dependant variable, which in our case was the application of the concept of problem-based teaching in the teaching of units dealing with magnetism and electricity. The initial testing was aimed at testing the pupils' previous knowledge acquired in the course of *Science and social studies*, i.e. *World around us* in the first and the second grade of elementary school.

The initial testing involved our determining how significant the differences were between the experimental E and control C groups of pupils related to the following characteristics:

- Pupils' age (third grade of elementary school);
- Pupils' grades in *Science and social studies* at the end of the first term;
- Pupils' GPA at the end of the first term;
- Pupils' results achieved in the initial testing, i.e. their success rate in solving the tasks of the levels of remembering, recognizing, reproducing, understanding and applying knowledge.

The results we obtained are presented in Table 1.

Table 1: The overview of the results achieved in the intial knowledge test

	Experimental group	Control group
Number of pupils tested	100	95
Total number of points scored	4214	3956
Maximum number of points	6000	5700
Percentage of points scored	70,91%	69,40%

In the initial testing, the pupils from the experimental group scored 4214, and the pupils from the control group scored 5700 points. Given the total number of pupils in the experimental and the control group, their results do not differ significantly – the percentage of points scored in the experimental E group was 70,91%, and the percentage in the control C group was 69,40%. Therefore, we can note a solid balance in the total sample of pupils in relation to their previous knowledge about non-living natural phenomena taught in previous grades.

Based on these results, the success of the groups tested cannot be considered satisfying and is far below our expectations. The testees mostly provided incorrect and incomplete answers at the levels of knowledge application and knowledge understanding. We can thus raise the question of what the possible causes that bring to such achievement, i.e. lack of achievement are. We assume that due to a small weekly number of revision classes the process of forgetting is faster. At that age, the contents are easily forgotten if they are not constantly revised. The traditional teaching method, in which the pupils are not asked to engage intelectually more often and more intensely, is one of the causes of poor results the pupils achieved in the initial testing. Besides the causes mentioned, there is a whole other group of causes which could result in such an outcome – from the organization of the teaching process, to the methods and work forms applied with the pupils when teaching them about non-living natural phenomena in the first two grades of elementary school, as well as the pupils' motivation and interest.

Comparative analysis of the results in the final test – between the experimental and the control group

The final testing of both groups followed 8 classes of working on the contents related to magnetism and electricity, which spanned over about three months in the second term of their third grade. During this period, we encountered minor problems within the experimental group such as: communication within the group during the class, since the pupils were so exicted that they *all* wanted to speak and do at the same time and be the first to do the task. Group work and the seating arrangement were unfimiliar to them and it took them some time to get used to them and accept such a way of working and learning. We had to organize classes we had not planned before, and to explain the class phases and how they should behave during each of them.

Based on the final knowledge test in the experimental and in the control group of testees, we can conclude the following:

Table 2: Table representation of the success in solving tasks in the final test – scores and percentages of correct answers

Questions	1	2	3	4	5	6	7	8	9	10	11	12
E group	189	189	318	310	342	347	955	927	1137	1175	1171	1123
K group	183	174	297	271	291	317	859	836	991	980	857	713
	%											
E group	98,4	98,4	82,8	80,7	89,0	90,3	82,9	80,4	74,0	61,2	60,9	58,4
K group	96,3	91,5	78,1	71,3	76,5	83,4	75,3	73,3	65,2	51,5	45,1	37,5

Based on the analysis of the data shown in table 2, it can easily be seen that the difference between the control and the experimental group is evident at all the answers in the final test, in favour of the experimental group.

The first four tasks in the test checked reproduction of knowledge (listing, describing, and repeating the contents learned). The testees were asked to say what types of electricity there were and what they were called.

The table shows that in the first question: *Complete the sentence: There are two types of electricity and they are known as ________________ and ________________,* the pupils scored a high level of correct answers, especially in the experimental E group where there was 98,4% correct answers. Only one pupil, whose GPA was satisfactory, gave the wrong answer. The control C group had the achievement percentage of 96,3%, i.e. it can be seen that the experimental E group was slightly more successful.

Seven pupils from the control C group gave wrong answers to this question, three of them had satisfactory GPA, two had good GPA and one had very good GPA. Based on these facts, we can assume that the wrong answers could be a result of the lack of understanding the concept of learning about electricity, lack of motivation, or simply a matter of lack of careful attention when reading and answering the question.

The second question from the test: *Magnet has two poles named ________________ and ________________* was formulated similarly to the first one. This question showed significant difference between the two groups, and in favor of the experimental group, in which the pupils had the opportunity to hold a magnet in their hands, to solve problem-based situations with it, to test its properties, in comparison to the control group, in which the pupils only SAW the magnet in teachers' hands, or were just shown a picture of it.

This question asked the pupils to answer what the names of the magnet poles were. The pupils from the experimental E group gave 98,4% of correct answers, and the pupils from the control C group gave 91,5% of correct answers. It can be concluded that the pupils from the experimental E group were more successful. Only one pupil, with a good GPA, failed to give the correct answer, whereas the control C group had 9 pupils whose answers were not correct. These were mostly pupils with satisfactory or good GPA and two pupils with very good GPA.

Based on the pupils' answers to the third question in which they were asked to name the electricity of attraction and repulsion of small balls, the following can be easily noted: the success percentage of the experimental E group is 82,8%, and the control C group's percentage is 78,1%. Mostly pupils with lower GPA gave wrong answers to this question. The solving of this task asked the pupils to remember the notion of the types of electricity. Besides remembering, the pupils here showed whether they understood this property of magnet. Statistical data show there is an average degree of correct answers to this question, which points to partial understanding of the notion related to this particular magnet property.

Pupils from the E group were more successful in answering this question as well, being the ones who had had the opportunity to test out the behaviour of the electrified balls, in comparison to the pupils from the C group, who had only heard about this property of magnet.

The next question, number four, asked for recalling information, repetition and reproduction of knowledge about marking the poles of a magnet in such a way so they would attract and repulse one another. Regardless of the fact that they did not go into explaining these properties, but only marked the north and the south pole of a magnet, the pupils from the experimental group were more accurate in solving this task, and the result was: experimental E group – 80,7%, control C group – 71,3%.

Tasks 5, 6, 7, 8 represented the level of understanding knowledge (the ability to interpret the contents and clearly see their structure, as well as to anticipate future sequence of events).

The fifth question asked the pupils to answer the question of what appears around an electrified object. Experimental E group scored 89,0% and the control C group scored 76,5%. The groups' success differs in this question. Group E achieved a better result.

According to these statistic data, experimental E group had excellent results, which points to good factual knowledge of these pupils. The rest of the pupils gave wrong answers, and such an outcome, as we assume, is the result of the lack of understanding the contents, lack of motivation in pupils or their inability to perform well in such activities.

Without any explanation, the pupils simply state that around an electrified object, an electrical field is created. This significant difference can again be explained by experimental group pupils' active knowledge acquisition, since they had had an opportunity to experience an appearance of electrical field by causing it to appear, whereas the pupils from the control group were only explained how this field was created.

Analysis of the answers to the question number six, *What is created around the magnet poles* (magnetic field), shows that the the results were: experimental E group 90,3%, control C group 83,4%.

Based on their own practical experience and directly available perceptive data, the pupils answered that a magnetic field is created around the poles. The pupils from the control group had the opportunity to play with magnetic fishes who "ate", i.e. attracted small metal objects: nails, hair pins, metal swerves.

The tasks given to the pupils from the experimental group were, among other things, to find by themselves small metal objects for which they thought they would react to a magnet, and then to try out all these objects. The control group only listened about that. We should add that the pupils also made the fishes by putting small magnets into them, which guaranteed their remembering of the process of the creation of a magnetic field. This was an activity in which all the pupils participated. The significant difference between the groups can again be explained similarly.

In the next task, task number 7, in which the pupils were asked to choose among the answers given, i.e. to identify items which are good electricity conductors (The answers given: wooden spoon, plastic cup, aluminium ring, iron nail, copper pot, rubber bottle cap), the answers were:

Experimental E group achieved 82,9% of correct answers, whereas control C group had the result of 75,3%. The pupils who were unsure about giving their answers circled several given alternatives which points to their confusion by the given answers and the negative scores they had. This leads us to the conclusion that they do not fully understand this phenomenon.

When trying to explain the differences in achievements of the experimental E group and control C group, in addition to the organization of problem-based teaching, we can add another element: teaching aids. By providing a large number of teaching aids of different purpose and function, showing them to pupils, allowing them to hold these aids, or creating tasks from them or with them, the effects of the teaching become much greater. The worksheets with tasks in which pupils were asked to colour the objects they thought were electricity conductors in blue, and to colour yellow those who they thought were not, had a significant effect on consolidation of their knowledge.

Question number 8 was related to the level of knowledge application, to the objects attracted by a magnet (The answers given: iron key, pencil, aluminium box, plastic hairpin, copper ring, rubber doll). Experimental E group scored 80,4% of correct answers, and the control C group 73,3%.

Same type of exercises applied to the previous question can be applied to this one too. The pupils, stimulated by selecting these objects in a colouring activity in the preparatory test questions, achieved better results when solving this particular task as well.

The task of the next question was to list all the elements of an electrical circuit. The experimental E group scored 74,0% of correct answers, and the control C group 65,2%. This question belonged to the group of more complicated ones, since it represented a synthesis of the contents related to the field of ELECTRICITY.

In this synthesis, the pupils in the experimental group paid much more attention to finding, collecting and analyzing the objects that can be used to form an electrical circuit. These objects and aids were not fictitious, but real, available in real situations and collected. This helped the pupils discover and expand new classes of answers and the polyprofility of thinking.

The pupils were shown a picture of an electromagnet. They were asked to mark its elements. Experimental E group achieved 61,2%, and the control C group 51,5%. The significant difference was probably caused by the difference in their learning experiences. Pupils from the experimental group had held an electro-magnet in their hands and used it, while the pupils from the control group only saw a photo of one.

An electrical circuit was shown, and the pupils were asked to circle the answer to the question of whether the lightbulb was on and why. The answers were quite interesting because they showed high differentiation: the experimental E group answered correctly in 60,6% of cases, and in the control C group the percentage was 45,1%.

This statistically significant difference is again the result of direct pupils' participation in the making of the electrical circuit, which enabled them real knowledge and insight into causal-consequential relations. In their knowledge, the electrical circuit remains a collection of elements purposefully connected by the relationship they saw themselves, since they participated in its occurrence, i.e. by practical manipulation and by following a process. It can be added that most of the pupils from the experimental E group empirically acquired and understood general knowledge.

In the next task, number 12, the pupils were shown two magnets of equal length and asked whether these magnets connected in that way could attract iron nails (YES; NO; WHY?). This task also showed high differentiation, in favour of the experimental E group – 58,4%, whereas the control C group had 37,5%. This significant success leads directly to the assumption that the performing of these experiments, which was done in the experimental group, led to their high percentage of successfulness when giving answers. This is basically about stable knowledge, created by direct involvement in solving problems with the help of different experiments, i.e. actions, which could even be called games, done by pupils from the experimental E group.

Both groups achieved poorest results in the last two questions (11 and 12).

These were thinking problem tasks, in which pupils of this age prove to be least successful, both because of their age characteristics and because of the mainstream classical organization of the teaching process, to which pupils from both groups were already used to, and which keeps the pupil's mind in deep passivity, i.e. it is based on giving lectures to pupils and asking them to memorize the data, almost by heart, which gives them shorterm knowledge and no real understanding.

This type of organizing the teaching process can also explain the setback noticed in the control C group and their poor results, especially in the tasks numbers 9,10,11 and 12. Rigid curricula, dull and obsolete textbooks, and the teaching process based excusively on the traditional pedagogical psychology, didactics and formal logic – are all causing disfunctionality of the pupils' knowledge. On the other hand, we cannot be fully dissatisfied by the results achieved by the control C group, especially when it comes to the tasks asking for knowledge reproduction.

We should also mention the dominant frontal work form in the classroom which would be much more successful if it were sometimes replaced by groupwork (where the groups would be formed by the teacher in accordance to the pupils' previous knowledge, their interests levels and their progress). By saying this, we want to point to the fact that the traditional logic scheme of this type of teaching is deeply imbedded in the teaching process, from the very first days of school.

In the modern teaching of *Science and social studies* "there should dominate pupils' independent work on acquiring new knowledge from different sources, their intellectual endeavour in searching for and discovering the new, solving problems and practical application of the learned. Only in this way shall teaching and learning precede development and encourage pupils' overall development." (Jukić, 2001)

Based on the results obtained, we can accept the first assumption – *that the pupils from the experimental group in which problem-based teaching of Science and social studies was applied (as the experimental factor) would achieve better results in comparison to the control group.*

CONCLUSION

Research in the field of problem-based learning in the field of magnetism and electricity in lower grades of elementary school has practically never been done. This was the focus of analysis of several teachers, pedagogues and psychologists within their research projects dealing with the topic of active teaching process.

We hope our research has opened and initiated new questions and tasks that could be realized in some future researches with similar topic. We shall point out several possible guidelines:

- Development of suggestions for more modern organization of the teaching process and the development of active, independent and creative work of the pupils,
- Introducing innovations in the curricula for *Science and social studies,*
- Encouraging more modern concepts of textbooks for *Science and social studies* contributing to a more efficient teaching process,
- Encouraging teachers to constant professional development and self-education so they would be prepared for continual observing the pupils' development and their need to research, because only a wise person, eager to acquire new knowledge and information seeks for knowledge on its own or asks others for knowledge and information,
- Practical implications of this research can be related to the question of the didactic-methodical shaping of not only textbooks but also methodical manuals that would be based on theoretical claims and specificities of the subject of *Science and social studies* and the pupils' age, from the point of the application of problem-based learning in the teaching process.

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