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Efficiency of Virtual Experiment in Elementary Chemical Education

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Abstract
In this paper the efficiency of virtual chemical experiment on acquiring chemical knowledge in elementary education was investigated. Virtual experiments were presented as video-clips of laboratory chemical experiments, recorded and edited by authors of this paper. In this research we used a convenience sample which comprised 87 eighth-grade elementary students (age 14) who all attended chemistry lectures conducted by one teacher only. Research was organized and conducted as a pedagogical experiment with parallel groups. Control group was a classical teaching approach group, in which only frontal method was applied. Students neither did nor saw any laboratory experiments; they were only described to students verbally. Students in the treatment group 1 didl laboratory experiments either as individual or as demonstration experiments. Students in treatment group 2 were shown video-clips of the same experiments. Students were randomly assigned to one of these three groups, and the initial equivalence of groups was checked by comparing their chemistry grade. Effects of teaching methods were determined by testing students' knowledge by four subtests from the educational theme "Biologically important organic compounds", and also a final test, conducted a month later. Analysis of students' achievements shows that there exist significant differences between achievements of three groups. The best results were achieved by the treatment group 1, both in subtest and in final testing. Results of the treatment group 2 were slightly lower, but significantly higher that the scores achieved by control group. These findings implicate that virtual material can be successfully used as a replacement for hands-on laboratory experiments in situations when it is impossible to conduct them during. However, it is important to emphasize that, although acquired knowledge of students reaches the satisfactory level, it cannot be expected that they will reach the same level of competencies in manual techniques and laboratory skills.

1. Introduction
Learning of fundamental chemical concepts represents a problem for almost all students. It is the result of the discrepancy that exists between understanding theory underlining chemical concepts and practical application of the learned content [1]. The solution for this problem is implementation of laboratory experiments, which enable students to anticipate, observe, note and compare objects and phenomena, draw conclusions and check results [2,3].
Many schools in Serbia are not fully equipped for experimental work. They lack chemicals and laboratory equiopment; furthermore, the syllabus is very ambitious and doesn't leave enough time for quality experimental work. The consequence is very few or even no experiments conducted during chemistry classes. In such situation, virtual chemical experiments can play a significant role in elementary chemistry education [4].
Virtual experiments represent graphic surroundings for data acquisition, analysis, presentation or simulation [5]. Virtual experiments have numerous advantages [6]: they are efficient, they can be repeated without wasting chemicals or time, they are safe and well organized. Although they aren't as interesting as real experiments, they provide excellent visibility to all students in the class. They are designed to fully imitate real-time conditions in the laboratory. Well designed virtual experiment leads to better understanding of chemical phenomena [6].

2. Methodology
2.1 Rationale
Syllabi for elementary chemistry contain compulsory laboratory experiments, organized either as teacher's demontrations, or as individual experiments. Previous research has revealed that some teachers conduct thempartially or even don't conduct them at all [8]. According to Adamov (2012), 75% of 195 seven- and eight-grade students who took part in the survey agreed that *„they like to conduct experiments in the chemical laboratory"* but 80.5% of them stated that they rarely or never have the opportunity to do them in chemistry classes [9]. In the same survey, 76% teachers said that

they rarely conduct compulsory experiments. Only 2% of the teachers said that they do all planned experiments, and 16% never conducted a single experiment in the class.
Many teachers agreed that the video clips of the experiments could be useful in chemistry classes. But the number od teachers who actually do use video clips in classes is very limited [9].

2.2 Aim of research

Aim of this research was to compare the efficirency of real and virtual laboratory experiments in chemistry classes. The research was organized with an aim to determine whether there exists a statistically significant difference between achievement od students who do not conduct or see experiments, and those that conduct them regularly during chemistry classes; whether the achievement od students in treatment groups differ in test problems that are related to theoretically presented chemical content and the content that was presented through experiments.

2.3 Research sample

Students sample consisted of 87 elementary students (44 boys and 43 girls, all aged 14) from the city of Novi Sad (Serbia), who were randomly assigned to one of these groups:

- *control group*: students attended theoretical lectures, conducted in the traditional way.
- *treatment group 1:* students conducted all the experiments planned in the syllabus, as well as the same additional experiments as students in the treatment group 2;
- *treatment group 2:* students did not conduct any real experiment, but all compulsory and some additional experiments were shown to them as video-clips during lectures.

Before conducting this pedagogical experiments, the initial equality of the groups was checked according to average grade of groups at the end of the first semester. There existed no statistically significant difference between three groups in 2011/12 academic year (Table 1).

Table 1. Average chemistry grade in three groups at the end of the first semester (2011/2012)

	Control group	Treatment group 1	Treatment group 2
Average grade	3.08 ± 0.62	3.10 ± 0.58	3.07 ± 0.55

2.4 Experimental design

Pedagogical experiment was conducted during Spring semester of the 2011/12 academic year. Same teacher delivered lectures in all groups. Control groups had only theoretical lectures, in which all phenomena to be observed experimentally were explained verbally. In the treatment group 1 students conducted laboratory experiments themselves Treatment group 2 watched the same experiments on a video-projector. For this purpose, 20 short video clips were recorded and edited to realistically present experiments. At the end of each unit students were tested by a subtest containing problems related both to the facts that were explained theoretically and facts concerning explained/shown/conducted experiments. After a month, a final test was given to all three groups, comprising most important facts from the whole topic “Biologically important chemical compounds“. Average scores of three groups were compared using one-way ANOVA for testing hypotheses by analysis of variance (alpha=0.05). *Post hoc* analysis of individual differences between pairs of means was performed using Tukey HSD test.

3. Results

Average achievement of students in control and treatmnent groups in subtests is shown in Table 2.

Table 2. Average scores in control and treatment groups in four subtests

Subtest	**Average score of students in groups (in % of maximal score)**		
	Control group	Treatment group 1	Treatment group 2
Lipids	54.7±10.3	70.4±8.9	64.6±7.7
Monosaccharides	76.0±10.6	79.0±9.5	76.6±7.8
Oligo- and polysaccharides	47.1±5.4	70.9±5.7	68.0±3.8
Amino acids and proteins	76.6±6.7	98.6±8.9	80.7±6.3
TOTAL	**63.6±0.2**	**79.7±0.2**	**72.5±0.2**

As expected, best results were achieved by the students who individually conducted all the experiments. Differences in total average achievements between all groups were statistically significant (p<0,0001). This fact points out that vitual chemistry experiment, presented as a video clip, cannot completely replace the real laboratory experiment; however, it is an efficirent tool in achieving better quality of knowledge when real experiment is unavailable. In some subtests, the average achievements of students in two treatment groups did not differ significantly, indicating that video clips can be sucessful in acquiring facts about chemical substances and processes.
Average achievement of students in control and treatment groups in final tets is shown in Table 3.

Table 3. Average scores in control and treatment groups in the final test following the educational topic "Biologically important chemical compounds"

Average scores of students in groups (in % of maximal score)		
Control group	Treatment group 1	Treatment group 2
38,0±1,3	**82,0±1,3**	**78,4±1,4**

Results of final test indicate the more pronounced difference between the score of control group and the two treatment groups. Students in the control group scored very poor in the final test. The difference between two treatment groups was not statisstically significant. This shows that both real and virtual experiment have a great impact on retention of chemical knowledge and that virtual experiment can be a successful replacement for the real experiments in case it is impossible to conduct them in the class.
Comparison of the average achievement of students in questions concerning facts that were delivered verbally to all three groups and questions that were related to the facts observed experimentally, both in subtests and in the final test, are shown in Table 4.

Table 4. Average achievements of students in questions related to theoretical facts and facts observed experimentally in both subtests and the final test

	Average achievement (in % of maximal score)					
	Control group		Treatment group 1		Treatment group 2	
	E*	T**	E	T	E	T
SUBTESTS						
Lipids	55,4±15,2	52,2±6,7	63,8±11,8	77,6±4,9 *	58,2±10,9	75,9±8,7 *
Monosaccharides	80,8±3,1	68,3±17,9	86,7±3,7	72,3±15,6	81,9±3,0	70,6±12,3
Oligo- and polysaccharides	53,4±4,1	41,9±8,6	86,9±3,3 *	48,1±12,2	77,0±2,3 *	46,0±7,3
Amino acids and proteins	79,4±0,7	74,7±10,2	98,9±0,7 **	98,5±1,1 **	83,9±8,3	77,3±1,2
TOTAL	**66,4±0,3**	**61,1±0,3**	**84,0±0,2 ***	**73,9±0,3**	**80,0±0,2 ***	**65,6±0,3**
FINAL TEST						
	46,0±0,2	**35,1±0,3**	**83,7±0,2 ***	**80,8±0,3 ****	**80,8±0,3 ***	**76,2±0,3 ***

*E - achievement in questions related to facts observed experimentally or in video, or explained verbally, T - achievement in questions related to facts delivered theoretically in all groups; * p<0.001 compared to control; ** p<0.001 compared to other two groups*
As expected, treatment group 1 achieved the best results in questions related to the facts that students observed while conducting experiments themselves. Results of the treatment group 2 were slightly lower, and students in control group scored worst. The same was observed for all subtests, as well as for the final test.
Although the theoretical content was delivered by the same teacher, results of three groups are not the same for questions related to the theoretical knowledge. Similar to experimental questions, treatment group 2 scored best, followed by the treatment group 1. In most subtests, control group had significantly lower achievement than other two groups. This observation indicates positive impact of conducting experiments on grasping theoretical knowledge. This means that virtual experiments can influence quality and quantity of chemical knowledge in students, but this effect is weaker than in case of conducting real-time experiments. Results of the final test confirm this conclusion.

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