The contribution of different types of laboratory work to students´ biological knowledge

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Abstract. *In Science teaching, laboratory work is recognized as one of the cornerstones. In school science laboratory work, computers can be used for computer-supported laboratory work (real) and for virtual laboratory work. Lower secondary school students aged between 11 and 15 years performed three laboratory exercises (Activity of yeast, Gas exchange in breathing, Heart rate) as classic, computer-supported and virtual laboratory. When they were asked which method they liked the most, their first choice was computer-supported laboratory work, followed by classic laboratory, with virtual laboratory at the end. The contribution of these differing methods to the quality of the resulting knowledge is clear: there are no statistically significant differences between these laboratory methods.*

Keywords. Biology, Computer-supported laboratory, Digital competences, Simulations.

Introduction

Laboratory and experimental work is recognised by many experts as a method where students can learn several skills and obtain knowledge of high quality [1, 2, 3, 4, 5 and 6]. It can be performed in many different ways, some of which can include computers and other information and communication technology (ICT) equipment. In recent decades we have witnessed many innovations concerning the use of ICT in our daily routines. The importance of ICT is so great that the EU has recognised working with ICT as one of the key competences that every citizen should possess (Recommendation of the European Parliament and of the Council) for success in life. Computers have become part of our civilization; schools have therefore been unable to avoid this prevalent trend. There are many opportunities for using ICT in Biology instruction and many rationales for the inclusion of virtual and real computer-supported laboratory (CSL) exercises in Biology teaching. In the first case, "virtual" laboratory entails interactive simulations and animations, while "real" laboratories involve bench-top experiments utilizing data acquisition systems. From our previous research we know that our students like active learning [7], experimenting in the laboratory and working with ICT, but the greatest obstacle to including ICT in laboratory work is not the students but the teachers [8], in spite of much research confirming that using ICT increases students' mental progress and creativity [9, 10 and 11]. We cannot prepare students with old-fashioned methods of learning and technology for their future life but must use up to date equipment and resources.

The focus of the paper was the investigation of three different biology laboratory methods in class: classic laboratory, computer-supported laboratory and computer simulation, each used for at the three biology exercises.

We wanted to establish the contribution to biological knowledge of each laboratory method and which method of laboratory work students preferred.

Results are planned to be used in the development of a new generation of tested experiments to help teachers introduce active and motivational methods of teaching into their daily routine for developing one of the eight key competences - digital competence.

Methods

This paper reports on data that formed part of a study about the contribution to biological knowledge made by three different laboratory methods. We did a pilot test with 170 students and a second test with 455 other students. A group of 625 students of both genders from lower secondary Slovenian school, aged between 11 and 15 (6th to 9th grade) performed three laboratory exercises (Activity of yeast, Gas

Andreja ŠPERNJAK & Andrej ŠORGO (2010). The contribution of different types of laboratory work to students´ biological knowledge M. Kalogiannakis, D. Stavrou & P. Michaelidis (Eds.) *Proceedings of the 7th International Conference on Hands-on Science*. 25-31 July 2010, Rethymno-Crete, pp. 94 – 98 **http://www.clab.edc.uoc.gr/HSci2010**

exchange in breathing, Heart rate) as classic, computer-supported and virtual experiments. Each student performed all three experiments, but each experiment with a different method. For example: one group of 2-4 students from the same grade performed the exercise «The activity of yeast» as classic laboratory, «Heart rate» as computer supported laboratory and «Gas exchange in breathing» as interactive simulation. In this way, results were collected as 3x3 matrixes, which enabled us to search for differences between groups. Students' opinions and personal data were collected using a pre-test and an equal post-test for each exercise developed for the purpose of the research. The tests were equal for all students. Reliability tests were done after the pilot group with Cronbach α; for the exercise «The activity of yeast», the Cronbach α was 0.84; for the exercise «Gas exchange in breathing» the Cronbach α was 0.74, and for the exercise «Heart rate» the Cronbach α was 0.86. The statistical analyses were done with the Statistical program SPSS 17.0 (ANOVA).
The focus of the paper is the contribution to the stage of knowledge achieved by each exercise according to different laboratory methods.

Description of laboratory exercises

A. Activity of yeast

This exercise is standard because of safety reasons, availability of materials and potential for use at different points and contexts (rising of bread, fermentation, enzymatic activity, etc.) in teaching. The effect of temperature on the activity of yeast is examined. The speed of production of carbon dioxide is measured. In real experiments (both classic and computerized), a suspension of yeast obtained from a local store was prepared. A spoon of table sugar was added to the suspension. The suspension was divided into three bottles and put into water baths at different temperatures (see Fig. 1). Ice cubes were added to the first one, the second one stayed at room temperature, and the third one was warmed to a temperature between 35 and 40°C. In the "classical" variant, the rising of balloons indicates the speed of the reaction; in the computerized laboratory, the rise in gas pressure was measured using gas pressure sensors and in the interactive simulations, results are presented as graphs and flasks with balloons.

Figure 1. The ˝classic˝ variant of the Activity of yeast laboratory exercise

B. Gas exchange in breathing

The main goal of the exercise is to show that the composition of gasses in inhaled air is different from that in exhaled air.

Oxygen is consumed in respiration and carbon dioxide is released. The differences are not constant but are in correlation with the activity.

In the classical variant a volunteer has to exhale air through a straw into a sealed plastic bag with known volume. After that, the exhaled air is poured into distilled water. Carbon dioxide forms a weak acid with the water which results in a change of pH.

Figure 2. The computerized laboratory gas exchange in breathing

The drop in the pH can be registered with a pH meter or as a change in the color of bromthymol blue as an indicator. In the computerized version of the experiment, a volunteer has to exhale air into a plastic bag, and a gas oxygen sensor is used to record changes.

Experiments can be repeated under other conditions (after some kind of activity) with the same or other volunteers (see Fig. 2). In interactive simulations changes are present as a drop in the concentration of oxygen in inhaled air and a rise of exhaled carbon dioxide in exhaled air.

C. Heart rate

The main task of the exercise is to examine differences in heart rate among students, changes caused by some sort of activity and the speed of recovery to an initial state (see Fig. 3).

Figure 3. The classical method Heart rate

Using a stop watch to measure arterial pulse is the classical method; a heart rate monitor was used in the computerized laboratory. In simulations, students can choose between three different persons of either sex (scholars, athletes and on overweight) and examine differences in their heart rates before and after the activity or between persons.

Results

Contribution to students´ knowledge

In the case of the «Gas exchange» exercise, the contribution to student knowledge was greatest with computer-supported laboratory in 6th and 9th grade but in the 7th and 8th grade with the simulations. For the «Activity of yeast» exercise the best contribution to student knowledge occurred with the classic method of work, except in 9th grade, and for the «Heart rate» exercise, the greatest contribution to student knowledge came from computer-supported laboratory, except 7th grade (see Table 1).

Table 1: Overview of results from laboratory exercises showing laboratory methods and students´ grades

Exercise		*«Gas exchange»*								
Method of laboratory work		CL*			CSL*			SIM*		
		∑ results of points in %	$F_{(3.\ 205)}$	*p*	∑ results of points in %	$F_{(3.\ 191)}$	*p*	∑ results of points in %	$F_{(3.\ 179)}$	*p*
grade	6th	46.5	8.07	< **0.01**	**55.4**	6.49	< **0.01**	49.8	7.10	< **0.01**
	7th	55.0			56.8			**58.3**		
	8th	60.3			60.3			**61.0**		
	9th	66.1			**71.4**			68.2		
Exercise		*«Activity of yeast»*								
Method of laboratory work		CL*			CSL*			SIM*		
		∑ results of points in	$F_{(3.\ 190)}$	*p*	∑ results of points in %	$F_{(3.\ 203)}$	*p*	∑ results of points in %	$F_{(3.\ 185)}$	*p*
grade	6th	**73.7**	4.00	< **0.01**	66.7	7.21	< **0.01**	67.1	9.05	< **0.01**
	7th	**70.5**			69.6			68.7		
	8th	**76.5**			70.1			70.2		
	9th	83.0			82.9			**84.2**		
Exercise		*«Heart rate»*								
Method of		CL*			CSL*			SIM*		

		∑ results of points in %	$F_{(3. 177)}$	p	∑ results of points in %	$F_{(3. 177)}$	p	∑ results of points in %	$F_{(3. 208)}$	p
grade	6th	62.6	9.12	**< 0.01**	**68.0**	7.82	**< 0.01**	54.2	7.70	**< 0.01**
	7th	**68.1**			63.1			64.0		
	8th	65.2			**71.3**			71.0		
	9th	83.7			**84.3**			83.7		

*CL – classic method of laboratory work, * CSL – computer-supported laboratory, *SIM - simulations

The contribution to students' knowledge of each laboratory method as compared between students in the same class is not statistically significant, but between classes using the same laboratory method there are statistically significant differences (see Table 1).

Students' attitudes toward different methods of laboratory work

Students gave their opinions about the popularity of different laboratory methods (classic, computer-supported laboratory – CSL - and computer simulation).

Table 2: The most popular laboratory method ranked by students in lower secondary school

		laboratory methods		
class		CL*	CSL*	SIM*
6th	number of student opinions	40	**41**	15
7th		61	**84**	31
8ht		52	**62**	34
9th		48	**55**	30
Total		201	**242**	110
	percent %	36.3	**43.8**	19.9

*CL – classic method of laboratory work, * CSL – computer-supported laboratory, *SIM - simulations

From the results presented in Table 2, we can conclude that in all grades their first choice was computer-supported laboratory, followed by classic laboratory, with virtual laboratory in last place. Differences between genders were not statistically significant ($\chi^2_{(6)}$ = 4.42; α = 0.62 in $F_{(3,549)}$ = 0.79 (p = 0.50)).

Conclusions

In Science teaching, laboratory work is recognized because of its active learning methods as one of the cornerstones. With laboratory exercises and experimental work, we can achieve an understanding of many natural processes and empirical goals [12]. Laboratory work can be performed by different methods but according to our study the differences in contributions to students´ knowledge according to different methods of laboratory work are not statically significant, and none of the methods tested in this study can be called the best method of laboratory work. The results of this study confirm the results of other authors [13]. One method is best for one laboratory exercise and another for second activity, it is teachers who select which method is most effective in a particular group of students.
According to our results (see Table 1), older students acquired more knowledge than younger ones, but the older ones had more pre-knowledge than the younger which is the most important factor in the post-test. The authors [14] claim that what and how you learn is controlled by what you already know. The most important single factor influencing learning is what the learner knows. Ascertain this and teach accordingly [15].
When students in our study were asked which method they liked the most, their first choice was computer-supported laboratory, followed by classic laboratory and virtual laboratory at the end (see Table 2). Computer-supported laboratory is preferred because it is a blend of classic laboratory with computer and other ICT equipment. Clicking on the bottom of the computer mouse can quickly become boring, and that is why virtual laboratory ranks last among the preferred methods of laboratory work.
Teachers must incorporate ICT into education because they cannot prepare students for modern life with obsolete methods of teaching.

Acknowledgements

We greatly acknowledge the support of the Ministry of Education and Sport of the Republic of Slovenia and the European Social Fund in the framework of the "Project: Development of Natural Science Competences" carried out at the

Faculty of Natural Sciences, University of Maribor.

Special thanks to native speaker Dr. Michelle Gadpaille from the Faculty of Arts, University of Maribor for editing the article.

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