PERSPECTIVES ON THE INTRODUCTION OF COMPUTER-SUPPORTED REAL LABORATORY EXERCISES INTO BIOLOGY TEACHING IN SECONDARY SCHOOLS: TEACHERS AS PART OF THE PROBLEM

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Abstract

Computer supported virtual and real laboratories are recognized as tools that can help in raising the quality of biology instruction, and raising development competences in students. Yet biology teachers have been treating the computer as typewriter, as a source of information and as a tool for communication, all of which usages are common to all subjects. The uses of ICT that can significantly help in developing scientific literacy and that are primary tools in science teaching – such as the use of data loggers – are only rarely on the syllabus. The lack of equipment is not the most important reason for failure to use such applications; instead, this is probably due to teachers' attitudes, opinions and knowledge. Students cannot be recognized as an obstacle in working with ICT. Lower secondary school students aged between 10 and 14 performed three laboratory exercises (Activity of yeast, Gas exchange in breathing, Heart rate) using three different methods: classic, computer- supported and virtual laboratory. As a result of testing, we know that all three methods are suitable even for younger students. When students were asked which method they liked the most, their first choice was computer-supported laboratory, followed by classic laboratory, with virtual laboratory in third place.
Key words: *computer- supported laboratory, ICT, laboratory work, simulations.*

Introduction

In recent decades information and communication technologies (ICT) no longer signify only secure computers served by trained experts but have become a part of everyday experience for a large number of people in homes, offices, workplaces and entertainment areas, with the potential to change virtually every aspect of human lives (Katz & Krueger, 1998). With innovations emerging on a daily basis the skills needed to survive in the reach ICT world are increasing daily, and the gap between those who possess knowledge and technology and those who do not, is becoming wider and wider (Mariscal, 2005). Nowadays someone who is not digitally literate cannot, for example, without the help of others, communicate with a government, find a book in a library, or purchase a flight ticket or cheaper phone. Moreover, the Internet is only the tip of the iceberg of ICT usage. The importance of ICT is so great that the European Union has recognized working with ICT as one of the key competencies that every citizen should possess (Recommendation of the European Parliament and of the Council, 2006), and terms like computer, ICT and digital revolution (Pohjola, 2002; Hassan, 2003) or digital literacy (Bawden, 2001) have been introduced to address the importance of computer based technologies.

The key role in ICT education has been assigned to schools, and the heaviest load has been confidently delegated to teachers, often with little acknowledgement that buying equipment for a school is the easy part of the job (Hawkins, 2002; Hepp 2004; Resnick, 2002). The role of ICT usage in schools for learning purposes is twofold. The first one is to serve societal expectations, and the second is to raise the quality of education. Yet the presence of ICT cannot by itself raise the quality of education. ICT is only a prerequisite and a tool for improving the quality of teaching and learning as dominant school activities (Mooji & Smeets, 2001; Tearle, 2003).

The implementation of ICT in schools is not – either logistically or materially – a simple task and generally can follow two tracks. One is through specialized subjects like Computer Science or Informatics, while the second is the currently prevailing idea that ICT must be incorporated into the teaching of every subject by all teachers. As a consequence, teachers have to possess, in addition to subject-specific competences, the knowledge, skills, and flexibility to incorporate ICT into their teaching practice, a requirement that can in practice be accompanied by many practical problems. (Selwyn, 2000; Tondeur, van Braak & Valcke, 2007).

Teachers of science subjects occupy a somewhat specific situation in comparison with other teachers because they must possess additional knowledge about the use of specific applications not used in every subject, a demand that brings additional responsibility. Students can use computers as sophisticated typewriters, as desktop libraries, communication tools and for multimedia in literally every subject, while the use of ICT units as processors, controllers, and data-loggers can be introduced in only a limited set of school subjects or activities (Haydn & Barton, 2007). In this case, if, for example, one teacher at a school does not promotethe use of computers in the classroom as a tool for finding information, the loss for students is minor, because with equivalent work in other subjects they can fill the gap. If, on the other hand, science teachers do not use data-loggers in the school laboratory, there is nobody at school to cover the missing knowledge.

There are many possibilities for using ICT in biology (science) instruction. Besides creating documents, collecting information, communication and the use of multimedia, the most important are virtual and real computer-supported biological laboratory (CSL) exercises (Rogers, 1994; Strømme, 1998). CSL offers many advances in biology (science) teaching. Students like to work with ICT, and performing experiments (Šorgo & Špernjak, 2007; Špernjak & Šorgo, 2009) in, what they consider, an interesting way results in skills and knowledge of high quality (Pickering, 1980; Beatty & Woolnough, 1982; Kirschner & Meester, 1988, Špernjak, Puhek & Šorgo, 2009), especially when inquiry and problem-based approaches are used (Domin, 1999). By using such techniques they are developing a wide set of generic and key competencies (Michael, 2006).

Yet the usage of ICT in Slovenian schools outside of specialized subjects like Computer Science or Informatics is welcomed but not obligatory for teachers. In existing teaching practice there exists an asymmetry with the expectations of students, who expect the teaching of biology tp involve a mixture of interesting, multimedia supported lectures with frequent laboratory and field work. In reality they most often get direct instruction intended to cover the textbook content in detail with the success on final examinations as the ultimate goal of education (Šorgo and Špernjak, 2007).

Based on plausible experiences with the introduction of CSL into general high school biology courses (Šorgo and Kocijančič, 2006; Šorgo, Hajdinjak & Briški, 2008), we are planning to instruct biology teachers in introducing computer-supported laboratory exercises into lower secondary schools. Our research question was the following: what obstacles can we expect in the introduction of such work into primary and lower secondary schools? Our research was based on the idea that, besides equipment availability, which is the most often reported reason for not using computers in the SITES 2 study (Pelgrum, 2001), there must be some other underlying factors that function as barriers, one of which is proficiency in computer usage.

In the first phase of our investigations we tested the suitability of computer-supported real and virtual laboratory work with a group of students between 10 and 14 years of age, to examine the suitability of such laboratory work for younger students.

The second part of our survey was to find out if teachers can be obstacles in introducing computerized laboratory work into in school practice. To set a baseline, a sample of biology and natural science teachers completed a questionnaire about their use of ICT in teaching and the equipment available on demand in order to compare findings from research in general secondary schools (Šorgo, Verčkovnik & Kocijančič, accepted for publication). The underlying reason for such research was an earlier finding among upper secondary schools that, even when teachers do have data-loggers at schools, they fail to use them (Šorgo, 2007).

Results are planned to be used in the developing a new generation of tested experiments to help teachers introduce active methods of teaching into their daily routine.

Research Methodology

Questionnaire for biology teachers

Data from upper secondary school Biology teachers (N= 70), (which is close to half the upper secondary school Biology teachers in Slovenia) was collected in a large survey as part of the thesis entitled ‘The Influence of a Computerized Laboratory on the Quality of Biology Teaching, and the Development of Competency in High School Students’ (Šorgo, 2007). The partial aim of the thesis was to find an answer to a research question based on the empirical knowledge, that between the years 2001 and 2003, all general and technical high schools received from the Ministry of Education and Sport computers equipped with data-loggers to be used in Science teaching. Three years later we observed that only a couple of teachers were using them. Because teachers could not cite lack of equipment as a reason not using the donated equipment, we set out to identify the obstacles in the domains of knowledge and experience, as well as attitudes towards laboratory work and ICT. A questionnaire with more than 200 items in several subscales was developed to address our research question. The questionnaire is available online (in Slovene language) as appendix to the thesis (Šorgo, 2007) Some of the findings of the survey have been published (Šorgo, Verčkovnik & Kocijančič, 2007; Šorgo, Verčkovnik & Kocijančič, accepted for publication).

For the purpose of our new survey about the usage of ICT in lower secondary schools, we used parts of the already tested questionnaire concerning the usage of ICT. Because some new applications (smart boards, virtual classrooms) were already available to be used in schools, we modified the questionnaire by adding new items. This questionnaire has three parts. In the first part teachers were asked to provide demographic data, in the second part we asked how many computers they had on demand when they wanted to use them. The third and central part of the questionnaire was a list of 20 different applications (Table 1), together with usage frequencies to be checked (1 = never; 2 = occasionally; 3 = once or twice a month; 4 = once or twice a week; 5 = more than twice a week).

The questionnaire was delivered to lower secondary school science and Biology teachers. In Slovenia Science is taught as an integrated subject in the sixth and seventh grades and as Biology, Chemistry and Physics in the eighth and ninth grade of nine-year compulsory school. All science subjects are compulsory for all students. Because a teacher in his/her pre-service education can major only in one or two Science subjects, Biology, Chemistry and Physics are taught by at least two different teachers at every school. Science in the sixth and seventh grades is taught by one of these teachers, who is required to complete in-service qualification in the third (missing) subject. Moreover in-service training in, for example, Biology does not give a Chemistry and Physics teacher the right to teach Biology in the eight and ninth grades.

We collected questionnaires from teachers who attended study groups and from pre-service biology students’ mentoring teachers at their teaching practice in the year 2009. Our sample is not random because mentor teachers are chosen experts, while those attending study groups are probably the most interested teachers. We delivered over 300 questionnaires, but 196 teachers refused cooperation. The reason is probably twofold. The first reason is that the community of teachers is rather small; they take part regularly in different surveys. The second reason is that they perceive surveys as a form of control. At the end of the collection period, we had assembled 106 questionnaires, which is close to 20% of the total population of Slovene Biology teachers at lower-secondary schools. The Reliability of the questionnaire expressed as Cronbach's Alpha is 0.86, a figure which can be considered very good.

Methods of laboratory work

To test the suitability of a computer-supported real and virtual laboratory and to examine differences among styles of laboratory work, we prepared sets of three laboratory exercises. Each laboratory exercise in a set is prepared as classical laboratory work, computer-supported (real) laboratory work and as interactive virtual laboratory work. Initially, familiar and easy to perform laboratory exercises from current school practice were chosen. In the second phase these were modified into computerized laboratory exercises. Vernier's interface, sensors and software (http://www.vernier.com) were used, but other acquisition systems would also work. Data obtained in the computerized laboratory were used to produce realistic graphs in interactive simulations developed for the purpose of the project. For hands on laboratory work in both the classical and the computerized version, glassware common in the school laboratory was used. To date three such sets have been tested. The first is a laboratory exercise about the activity of yeast; the second is an examination of the heart rate, and the third is the consumption of oxygen during respiration (Špernjak, Puhek & Šorgo, 2009).

To date we have tested experiments on 198 students between 10 and 14 years of age. Each student performs all three experiments, but each experiment in a different way. For example, the activity of yeast as classical laboratory, heart rate as computer-supported laboratory and oxygen consumption as interactive simulation. In such a way data were collected as a 3x3 matrix, which enabled us to search for differences between groups. Students' opinions and personal data were collected using a questionnaire developed for the purpose of the research.

Statistical analyses of data

Because we were interested in general patterns of ICT usage in schools, we conducted our analyses with our sample as a single group. We did not break down our group into subgroups to search for differences, for example, between genders. Results of answers measured by scales (1 = never; 2 = occasionally; 3 = once or twice a month; 4 = once or twice a week; 5 = more than twice a week) are presented as means [M] and standard deviations [SD]. The analyses were performed with the statistical package SPSS 17.0.

To compare differences between teachers coming from lower and upper secondary schools, Cohen's d was used (Thompson, 2007). It was calculated by using Effect Size Calculators (http://web.uccs.edu/lbecker/Psy590/escalc3.htm).

Results of Research

Results of the survey are presented in the form of tables.

Table 1. Frequency of use of different ICT applications for school work among teachers (LST (N = 106) = Lower secondary school biology and science teachers; UST (N = 70) = Upper secondary school Biology teachers. Frequencies for calculation of means: 1 = never; 2 = occasionally; 3 = once or twice a month; 4 = once or twice a week; 5 = more than twice a week)

	LST		UST		Cohen's d
Application	M	SD	M	SD	
Searching for information on the internet	3.9	1.1	3.9	1.1	0
Word processing	3.7	1.4	4.1	1.1	0.3
E-mail	3.5	1.6	3.7	1.3	0.1
Presentations (PowerPoint, etc.)	3.3	1.2	2.8	1.4	0.4
Multimedia	2.8	1.2	2.2	1.1	0.5
Viewing films, or photos; listening to music.	2.6	1.1	2.1	1.2	0.4
Interactive programmes dedicated to school	2.3	1.0	2.0	0.9	0.3
Processing of your own films, pictures, etc.	2.1	1.2	2.0	1.1	0.1
Spreadsheets (Excel, Access, etc.)	2.1	1.1	1.7	0.9	0.4
Participation in forums or in interest groups.	1.8	0.9	1.4	0.8	0.5
Virtual classroom (Moodle)*	1.8	1.0			
Computer simulations and virtual laboratory	1.7	1.0	1.4	0.7	0.3
Games	1.6	0.8	1.2	0.7	0.5
Programmes for drawing (Paint, etc.)	1.5	0.7	1.3	0.5	0.3
Maintaining a web page (FrontPage, FTP, etc.)	1.4	0.8	1.3	0.8	0.1
Interactive board*	1.4	1.1			
Statistical packages (SPSS, Statistica, etc.)	1.3	0.6	1.3	0.5	0
International e-projects (Net Days, etc.)	1.2	0.6	1.2	0.6	0
Computer supported laboratory (data-loggers)	1.1	0.3	1.4	0.8	0.5
Programming (Basic, Pascal, C, etc.)	1.1	0.3	1.0	0.2	0.4

**Applications were not listed in the version of the questionnaire administered to upper secondary school teachers.*

Table 2. First choice in the election of three types of laboratory work among lower secondary school students (N = 198).

Class	5		6		7		8		9		Total	
Gender	F	M	F	M	F	M	F	M	F	M	F	M
	%	%	%	%	%	%	%	%	%	%	%	%
Classical experiment	38.6	30.0	29.4	41.7	30.6	25.0	34.8	29.1	34.8	62.5	33.0	34.8
Computer-experiment	30.7	40.0	58.8	33.3	55.6	58.3	39.1	37.6	43.5	12.5	47.3	37.9
Interactive simulation	30.7	30.0	11.8	25.0	13.8	16.7	26.1	33.3	21.7	25.0	19.7	27.3

Discussion

From the results presented in Table 1, we can conclude that we cannot be satisfied with the usages level of ICT in Biology classrooms. The majority of teachers do use computers but very selectively and not in whole potential for teaching. Only three applications – word processing, searching for information on internet and e-mail – are used on average at least every month by both groups of teachers. This can only mean that these teachers have adopted computers primarily as desk-top libraries and as a source of information. We did not find any differences (Cohen's d = 0) (Thompson, 2007) among lower and upper secondary school teachers. From the perspective of biology teaching, we can predict that if computers are made visible in appropriate numbers and a sufficient number of web pages in Slovene are accessible (Šorgo & Kocijančič, 2004), introduction of web based activities into the classroom would be possible without greater obstacles. An interesting detail is that, even if practically all teachers at least occasionally browse the internet, this does not mean that all of them also use e-mail. In this detail both groups of teachers are almost equal (Cohen's d = 0.1).

Teachers have embraced computers as typewriters and use them regularly for preparing documents such as tests, school documentation and work sheets. Common to such applications is that texts can be prepared in advance at home or in the staff room and later delivered to students in paper form. Upper secondary school teachers are heavier users of word processors than lower secondary school teachers, but differences are minor (Cohen's d = 0.3).

The upper part of the table includes usages which can be covered under the umbrella terms multimedia and presentations. Teachers use these less frequently, a finding which can be partially explained by the nature and availability of computers in the classroom. Word processing and searching the internet are used for preparation of lessons, which can later be delivered without the use of computers; this is not the case with multimedia presentations or the use of educational software. Differences between the two groups of teachers are evident, yet differences are only moderate (Cohen's d ≤ 0.5).

Even if almost 60% of teachers reported the presence of one computer in the classroom and little more than half of them computers with projectors (data not presented), this can only mean that multimedia presentations are slowly replacing old fashioned overhead projectors and transparencies. This transition can improve the quality of multimedia presentation and the potential for demonstrations of experiments but cannot be recognized as a major step toward the development of hands-on activities, a problem and inquiry approach and competences. Interactive boards are finding their way into classrooms, and teachers who possess these are also using it which is plausible.

The lower part of the table reports on usages which, when practiced by students, would greatly influence the quality of instruction but are most often neglected by teachers regardless of school level.

In our mission to introduce CSL to classrooms, we can foresee two groups of obstacles. The first one is the availability of data loggers in lower secondary schools (upper secondary schools already possess such equipment). However from lessons learned in upper secondary schools it is clear that merely giving schools equipment without support is a waste of resources (Šorgo, 2007). An even greater obstacle that can be envisaged is education of Biology teachers. Most of them were never asked to work with such equipment as a part of their pre-service studies or in-service training. In the long term perspective, the best solution is the education of pre-service teachers but it could be years before they can influence existing school cultures. The introduction of the virtual laboratory is foreseen with greater optimism, and from the widespread use of Internet among teachers we can conclude that the introduction of virtual laboratory exercises will precede computer-supported real laboratory.

If one seeks excuses, one cannot include students as one of these. We were able to establish, that students have no problems with the use of computers in laboratory work even at the age of 10. What is more, we believe that even younger students can easily work with computers, and the suitability of CSL among younger classes will undoubtedly be tested.

From the standpoint of introducing CSL into biology/science teaching it is obvious that at the moment virtual laboratory exercises could be introduced with few reservations into classrooms. Owing to the limited availability of ICT, the virtual laboratory could be introduced primarily for use by teachers for demonstrations, and with limited potential for use those as an interactive tool in individual or small-group student work. At the moment schools are not equipped with data loggers even though the technology has been commercially available in recent decades. Somehow it has not found its way into school science laboratories, a failure which can be recognized as one of the major obstacles to the introduction of novel experimental practice in schools.

Conclusions

From our study we were able to find that the computer supported laboratory would be warmly accepted even by 10-year old students. The greatest obstacles to its introduction are the lack of equipment and an even more important factor - teachers. As teacher educators who recognize the importance of CSL in the development of competences as one of the highest goal of education, we should follow three steps. The first one is to inform teachers about the suitability and importance of CSL; the second step is to educate them in using such equipment, and the third one is to help them in their efforts to acquire the equipment needed for their classrooms.

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