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THE USE OF A VIRTUAL LABORATORY AMONG SLOVENIAN PRIMARY SCHOOL CHEMISTRY TEACHERS

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Introduction

Teaching and learning chemistry is a demanding process because it includes abstract concepts and notions which cannot be seen or touched. The use of modern technologies offers assistance in overcoming this kind of difficulties since it enables visualisation of science phenomena which are too small (atoms), fast (electrons), abstract (forces) or immense (solar systems) for direct observation. Many studies show that the use of visualisation materials (physical models, analogies, animations, simulations, sub-micro presentations) enhances the understanding of chemical concepts. Chemical contents can be visualized by using a virtual laboratory which also enables the visualisation of the sub-microscopic world.

Slovenian primary and high school teachers are well aware of the importance of ICT use in their classes also due to the project Computer Literacy which brought computers much closer to students and teachers. However, the actual execution of ICT supported classes and their efficiency have not been studied jet.

A conceptual approach to teaching chemistry combines experimental work, problem oriented teaching methods and the use of the information communication technology with the goal to facilitate efficient learning and students' motivation on all levels of the learning and teaching processes. Visualisation of abstract concepts and a safe experimental environment are only two reasons which points in favour of the use of a virtual laboratory in chemistry classes. The goals of this contribution are (1) to analyze the use of a virtual laboratory in chemistry classes among Slovenian primary school chemistry teachers and (2) to identify potential limits and obstacles in its use. This kind of research has not been carried out in Slovenia yet.

New media and technologies are changing education

Information communication technology, multimedia and interactive elements of virtual simulation bring new possibilities and capacities for teaching by opening a new creative education world for students and teachers, and thus effect the transformation of education. The traditional educational framework which was limited by the size of the classrooms, laboratories and availability of the study materials in the past changed substantially in the last years. In a current dynamic social, production and service environment, traditional education methods are not sufficient anymore and, therefore, they are transforming into technologically supported methods (Balram & Dragićević, 2008; Špernjak & Šorgo, 2009). ICT supported instruction can be more motivating and enables the introduction of "animators" which contribute to more efficient and easier learning process. Instruction can be adapted to students' learning styles, and therefore maximise the students' abilities. The use of ICT enables inquiry-based learning and constructivist approach.

By using ICT, some educational goals are achieved faster and with higher quality which has a significant influence on long term knowledge (Rebolj, 2008). In the past, independent learning applications were used by teachers, whereas today the use of learning environments is increasing (Edwards et al., 2011). Besides general computer presentations, Mayer (2013) highlights five advanced learning concepts. These are: (1) animated pedagogical agents, (2) virtual reality, (3) games, simulations and microworlds, (4) hypermedia and (5) e-courses.

The use of experiment in education

One of the most important visualisation elements in chemistry instruction is certainly experiment. Experiment allows visualisation of abstract concepts, and therefore helps overcoming the gap between abstract basis of chemical knowledge and the ability of perception. The advantages of the real-world practical work are the development and training of experimental research skills and acquisition of practical knowledge about science or chemical concepts. Experimental and problem-based research instruction enables students to acquire the principles of experimental work: from planning experiments, collection, presentation and analysis of data to assessment of results and their integration with theory. Experimental work allows students to acquaint themselves with the properties of substances, develop safety measures related to hazardous substances and gain basic experimental skills. As a rule, experimental work should be included in every lesson (Glažar, 2006).

As experiment is an economic category, it should be performed with minimal costs and maximum effect. To achieve that, modern information technology (IT) can be of assistance by allowing the dynamic presentation of chemical concepts and phenomena in 2D or 3D environment with animation, simulation or interactively by using the combination of videos and symbols. The number of experiments carried out at schools is usually limited due to safety reasons, lack of adequate infrastructure and equipment, time and space limitations, and also due to the poor precision in the implementation of experimental exercises (Sokoutis, 2003).

Virtual laboratory

By introducing computers in schools, a useful tool for educational purposes and also laboratory work was acquired. In a laboratory, a computer equipped with interface and measure instruments is used as a tool for acquiring results. These working methods are called a computer-based laboratory. A computer-based chemistry laboratory enables easier data recording, analysis and tabular and graphical presentation of data.

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Virtual reality technology represents an important technological progress which offers new forms of education. Its primary goal is to enable realistic simulations of chemical phenomena in completely immersive, interactive and three-dimensional virtual world. Simulation-based learning is an important learning strategy which adapts to the needs of modern students who have grown up in the digital world and are accustomed to visual learning. Simulations play an important role in education not only because they provide realistic models which allow students to gain experiences from the real world through interaction, but also because they provide safe environments where students are able to repeat procedures without any safety hazards.

The use of virtual laboratories in chemistry classes can facilitate the learning process and overcomes limitations that are typical for real-world experiments. A virtual laboratory enables observation, experimentation and also cooperation between students carrying out experiments. A virtual laboratory uses IT to presents the reality and copy the homonymous environment of the material world. Execution of expensive and dangerous experiments and observation of experiments that occur too fast or too slow in physical environment are the advantages of a virtual laboratory. Didactically efficient virtual laboratories allow for collaborative work. Students are able to affect the process of experiments, individually or in groups. They can render their parameters. Students should be offered the chance to discuss the results with each other and with the teacher. Experiments are an integral part of chemistry; however, the use of virtual laboratories offers an alternative educational approach which provides a valuable supplementary tool for distance teaching and learning (Georgiou et al., 2008).

Methodology

The purpose of the study was to describe the existing practice of Slovenian science and chemistry teachers with the focus on the use of a virtual laboratory in chemistry instruction. The study is based on a descriptive and causal non-experimental method of empirical pedagogical research. Questionnaires were submitted to primary school teachers who thought chemistry in the school year 2012/2013. The research is based on convenience non-random sample of 48 teachers from various parts of Slovenia.

The data was collected by online questionnaires. The online questionnaire links (https://www.1ka.si/a/25361) were emailed to science and chemistry teachers. The email also contained all the important information regarding the purposes of the study. The questionnaire was created using the free online survey tool 1KA. The data was collected in the period from May 2013 to August 2013.

The online questionnaire was created in accordance with the purposes of the study. It consisted of open-ended and close-ended questions; however, close-ended questions with verbal answers and answers by degrees were prevailing. The reliability of the questionnaire was ensured by the exact nature of the questionnaire instructions. The reliability of the questionnaire was determined by using Cronbach's reliability coefficient which confirmed the reliability of the instrument (α = 0,707).

By conducting the questionnaire, we wanted to answer the following questions:

- What limitations teachers encounter when carrying out real experiments?
- How do they facilitate visualization, if real experimenting is not available?
- Do they use virtual experiments instead of real experiments?
- What limitations teachers encounter when carrying out virtual experiments?
- How many teachers included in the survey use the virtual laboratory Crocodile Clips Chemistry?
- Would teachers use virtual laboratory if there were no limitations?
- How often do teachers encourage students to use e-materials for studying at home?

The data was processed in accordance with the purposes and expectations of the study using the SPSS 17.0 for Windows. Tabular and graphical presentations of absolute (f) and percentage (f%) frequencies were used.

Results

As a rule, experimental work should be included in each lesson (Glažar, 2006). Our research focused on the reasons and factors which prevent teachers to carry out experimental work in each lesson. Figure 1 presents the factors which limits the execution of experimental work. It shows that the most frequent reasons are large departments, time consumption of experiments, lack of chemicals and inadequate experimental infrastructure.

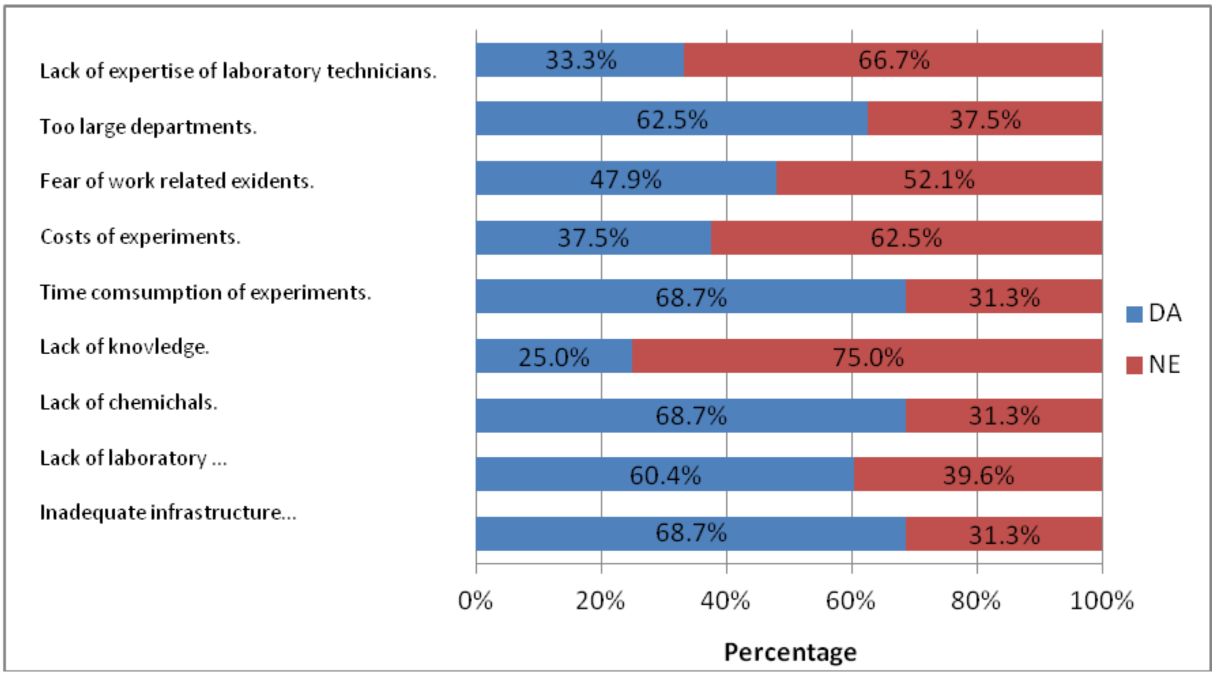

Figure 1. Factors that limit the execution of experimental work

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Inadequate infrastructure, lack of chemicals, the size of departments and time consumption of the experiments were the factors that limited the execution of experimental work the most. All these factors can be nullified by using a virtual chemistry laboratory. Therefore, we were interested if the teachers who participated in our survey use virtual laboratories instead of real laboratories? Table 1 shows that only one-fourth of teachers who participated in our survey (27.1%) used virtual laboratories in their classes. 72.9% of teachers who participated in the survey did not use virtual laboratory.

Table 8: Number (f) and structural percentage (f%) of the use of a virtual laboratory in classes.

The use of a virtual laboratory	f	f%
Yes	13	27.1
No	35	72.9
Total	48	100

Figure 2 shows the percentage of the factors that limited the use of a virtual laboratory. Most of the teachers (68.8%) were not familiar enough with virtual laboratories to use them for instruction, 41.7 of the teacher who participated in the survey did not possess the virtual laboratory software. 10.4% of the teachers stated that they did not have the required equipment, such as computers, projectors and interactive whiteboards, at their disposal. Their classrooms were not equipped with modern ICT. In this kind of schools, the alternative is the use of computer classrooms; however, one-fourth of the teachers (25%) stated that the computer classrooms were occupied and not at their disposal.

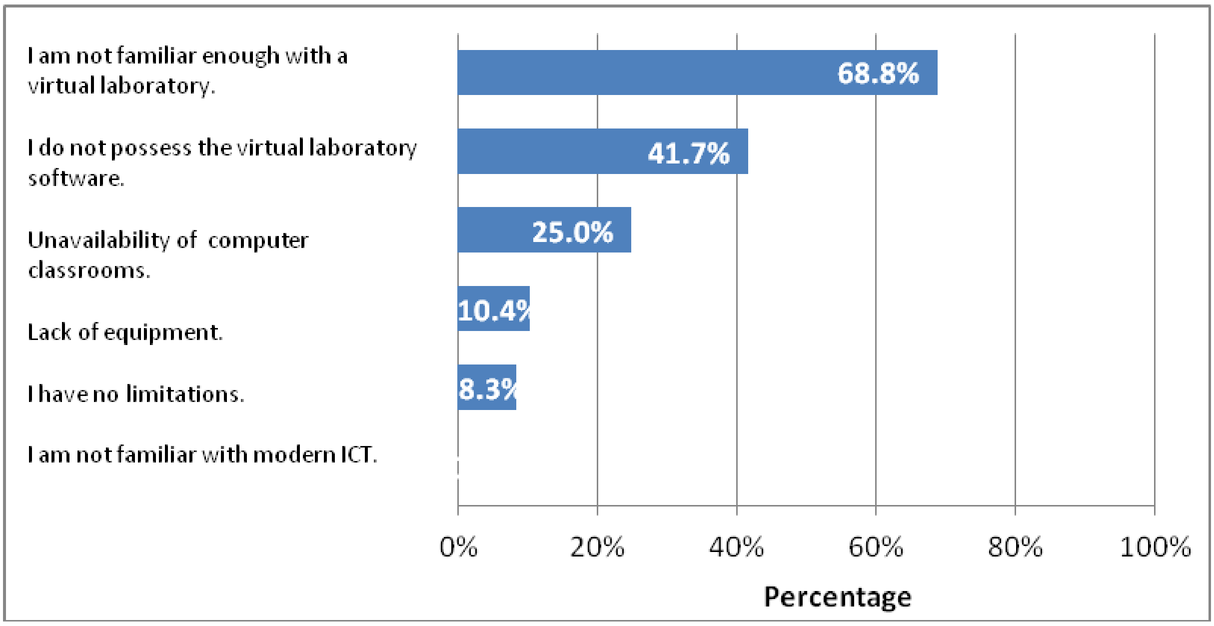

Figure 2. Factors that limit the use of a virtual laboratory

Figure 3 presents the methods teachers used instead of experiments which they were not able to carry out. Most of the teachers included in our survey (91.7%) used online videos instead of experiments. The second most frequent answer (62.5%) was the use of a picture, sketch, outline or photograph from textbooks or other sources. 56.3 % of teachers used CDs with videos of experiments. One-third of teachers used virtual interactive chemistry laboratory.

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14.6% of teachers who participated in our survey carried out an experiment in a virtual world by using a virtual laboratory.

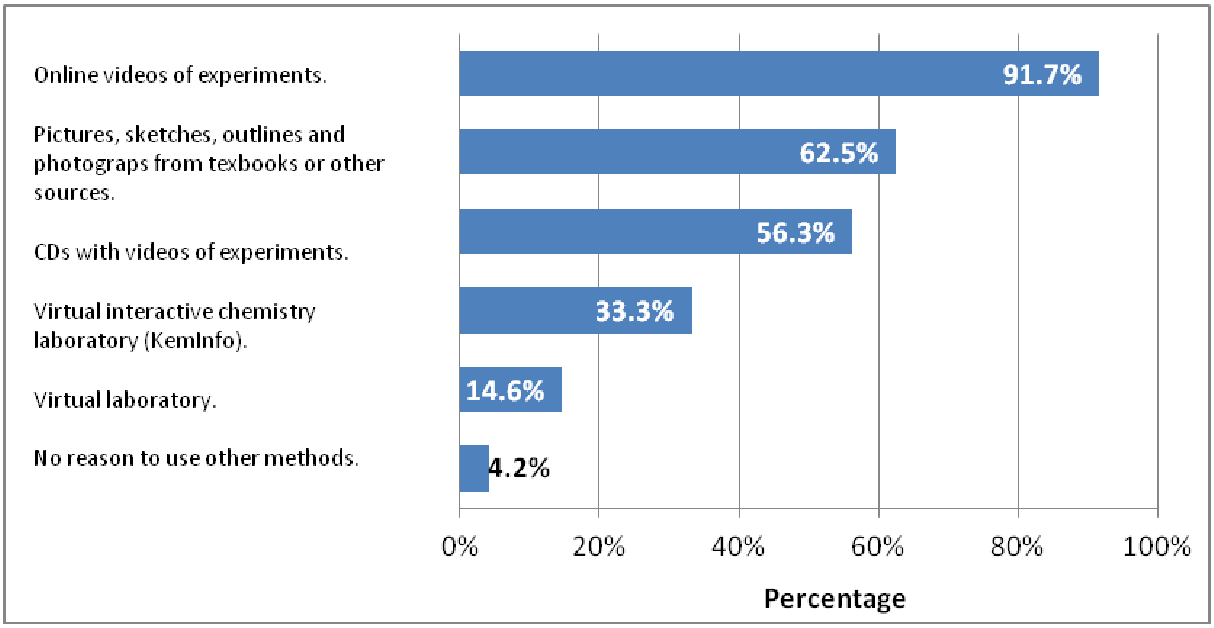

Figure 3. Methods used instead of experiments

To the question about hypothetical use of a virtual laboratory, if the before mentioned factors that limit the use of a virtual laboratory were absent, 81.3% of the teachers answered positively – that they would use it.

Crocodile Clips Chemistry is the software that enables virtual experimentation. If schools purchase the licence, it is also available in Slovenian language. In Table 2 we present the use of the virtual chemistry laboratory by teachers included in our survey. The results reveals that only one-fifth (20.8%) of the teachers used it.

Table 2: Number (f) and structural percentage (f%) of the use of Crocodile Clips Chemistry

Hypothetical use of a virtual laboratory	**f**	**f%**
Yes	10	20.8
No	38	79.2
Total	48	100

Virtual laboratories are a useful supplementary tool for distance teaching and learning. There are a number of educational websites available to teachers and students which allow for independent e-learning. However, our study reveals that more than a half of teachers included in our survey (54.2%) rarely instructed students to use the above mentioned educational websites at home. 31.3% of the teachers often instructed students to use e-materials at home, one teacher always instructed students to do so and 12.5% of the teachers included in our survey did not recommend the use of online sources to students.

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Discussion

Experimental and problem-based research instruction represents the basis for achieving the goals of chemistry education. Inadequate infrastructure, lack of chemicals, large departments and time consumption of experiments are the main factors that limited the use of real experiments according to our survey. These factors can be nullified by the use of a virtual chemistry laboratory which allows students to work independently or in groups. By experimenting with virtual laboratories, students have a wide range of chemicals and tools at their disposal. Execution of experiments by using virtual laboratories is safe and fast, because we can omit the uninteresting parts of real experiments. Besides other educational goals, a virtual chemistry laboratory contributes to the understanding of chemistry concepts and phenomena, drawing logical conclusions and explaining the experimental results by using theory. For chemistry teachers, it is important that some virtual laboratories enable the presentation of chemistry concepts on all three levels, also the sub-microscopic level of particles, which enables students' conceptual understanding. Interactive simulations and virtual reality provide learning environments that encourage active learning. Studies have shown that the inclusion of visualisation and animation in learning process is one of the most efficient ways to motivate students to learn science (Barak et al. 2011; Barak & Dori 2005). Studies also suggest that the use of a virtual laboratory in chemistry instruction can lead to better learning achievements (Sun et al., 2008; Abdulwahed & Nagy, 2009; Rizman Herga & Dinevski, 2012). However, we would like to highlight that a virtual laboratory should be used as an additional teaching strategy only, and not as a replacement for real experimentation.

If teachers were not able to execute real experiments due to the above mentioned reasons, only 4.6% of them carried out an experiment by using a virtual laboratory. Over 90% of teachers in this case used online videos of experiments which allow students to visualise the phenomenon; however, they were not actively involved. Only one-quarter of Slovenian teachers used virtual laboratory in chemistry instruction. Software in Slovenian language was available for most of these teachers at their schools. They used virtual laboratory Crocodile Clips Chemistry. The rest of the teachers included in our survey did not use a virtual laboratory because they did not have the required software. 60.6% of Slovenian schools believe that the responsible ministry is not stimulating individuals and companies enough to create Slovenian education software (Gerlič, 2010). More than 80% of the teachers would use virtual laboratories, if they were available to them.

The use of virtual laboratories is mostly limited by the fact that teachers are not familiar with the software. Nearly 70% of teachers stated that they did not possess the required knowledge about virtual laboratories. However, it is important to stress the fact that science teachers are willing to improve their methodological knowledge for the use of information communication technology (Ferk Savec & Vrtačnik, 2007).) In the article "Stanje in Trendi Uporabe Informacijsko Komunikacijske Tehnologije v Slovenskem Izobraževalnem Sistemu", Gerlič (2010) states that teachers still lack subject-related didactical knowledge for computer use in instruction.

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Slovenian primary schools use mostly free software (Gerlič, 2010). There are a number of educational websites available to teachers and students which allow for independent e-learning. Free chemistry e-materials are available also in Slovenian language. Over a half of chemistry teachers included in our survey rarely instructed students to use e-materials, although e-materials enhance the efficiency of instruction and independent learning, especially through motivation. Students are motivated by media which they are familiar with and techniques which are proven to enhance memory and comprehension.

Conclusion

Information technology, multimedia and interactive elements of virtual simulation offer new forms of education. A virtual laboratory is a tool that enables independent learning, improved individualisation, differentiation and acquisition of generic and specific competences of subjects. The use of a virtual laboratory as an additional teaching and learning method allows for better acquisition of some education goals like (1) understanding of science concepts and phenomena, (2) derivation of logical conclusions based on the results of experimentation and (3) explanation of conclusions by connecting the experimental results with theory and integrating the three levels of science concepts.

The primary aim of the research was to determine the extent of the use of a virtual laboratory as an additional modern teaching strategy among Slovenian primary school chemistry teachers and which factors limited their use of a virtual laboratory. Online survey revealed that only one-third of teachers who participated in our survey used a virtual laboratory for instruction. However, when it was not possible to carry out real experiments, only a few teachers decided to use virtual experiments instead of real experiments. In this case, teachers preferred online videos of experiments.

We discovered that there are mostly two reasons for the lack of use of a virtual laboratory as an additional modern teaching strategy in chemistry instruction; firstly, the unavailability of free experimental software in Slovenian language (only a few teachers did not have hardware at their disposal) and secondly, according to teachers that were included in our survey, the lack of knowledge of virtual laboratories. Teachers feel they are not familiarised enough with virtual laboratories to be able to use them. Therefore we conclude that chemistry teachers still lack subject-related didactical knowledge for the use of virtual reality technology.

Teachers that participated in our survey are well aware of the fact that the use of a virtual laboratory brings new capabilities and capacities for chemistry instruction. They expressed interest and desire to use virtual laboratories. A successful instruction depends on teachers' personal willingness to use virtual laboratories; however, it will take time to achieve the level of the use of a virtual laboratory as an additional tool for everyday chemistry instruction comparable to the use of smart phones, tablets and similar technology by students. Students are more capable to use the IT then teachers; therefore, it is important to enable teachers to use the IT and allow them to acquire, upgrade and develop the required subject-related didactical knowledge.

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