REAL, VIRTUAL LABORATORIES TOGETHER IN GENERAL CHEMISTRY EDUCATION: STARTING POINTS FOR RESEARCH PROJECT

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Abstract

The combination of real and virtual environments in general science (chemistry) education is a current challenge for school curriculum in the period of information society. The article describes theoretical background, starting points and design of a research project in this area. Possibilities of real and virtual school chemical experiment and their combination will be analyzed. These approaches are named remote and virtual laboratories. They are the important part of a virtual learning environment (VLE) as the up-to-date trend in natural science instruction supported by ICT. They bring a new dimension not only to laboratories, but also to everyday life of students, teachers and every other person interested in science education. New possibilities to measure, to control anything from any computer, to receive current data from the opposite part of the world – these are and will bring immense motivation. The project design, including pilot results, is presented on the example of laboratory work "pH measuring". Two as much as identical scenarios were prepared using either real or virtual pH-meter, managed by worksheets containing tasks of three levels: pH measuring of different solutions, answers to problem-based questions and open-task to create set of next pH measuring. The project is ready for piloting in the K-LaMPa Centre, which is situated in laboratories of the Chemistry Department, Faculty of Education, University of Hradec Kralove, and enables running experimental activities of primary and secondary school pupils and students. The received results will be presented and discussed on conferences and relating actions. Now the authors offer the cooperation concerned to widening of the research.
Key words: *early chemistry education, experimental activities, general science education, real and virtual chemical experiment, simulations.*

Introduction

The orientation of chemistry instruction towards methodological tools in natural science cognition, i.e. empirical methods (e.g. observation, measurements, school chemical experiment), and theoretical methods (e.g. modelling), originates not only from its basis and subject of chemistry as scientific discipline, but mainly from the characteristics of the methodology. When researching chemical features of matters or phenomena, it is necessary to join both empirical and theoretical processes in running a real experiment as the most powerful methodological means in natural science cognition. Its position is unsubstitutable even in the chemistry instruction, where it appears in various forms, e.g. it works as the demonstrational and pupil experiment, and provides:

- motivation,
- starting information about the studied object,
- information on veracity of the learning content.
- Following tasks are to be solved, so as experimental activities could be improved and their wide range of functions in the process of cognition was emphasized:
- define single phases of observation focused on finding basic features of the observed objects or system,
- work out the process of cognition, including the thought experiment in chemistry, which is understood as a certain form of modelling,
- analyze an experiment as method of cognition, mainly from the point of its function in the process of cognition,
- aim practical activities in running the experiment at problem-solving instruction.

Certain results are received from the works which concentrate on the position and functions of current chemistry methodology elements and other natural sciences in their didactic systems. Following aspects and approaches may appear, e.g.:

- relation between the problem-solving principle and system of experimental activities in chemistry instruction,
- mathematics and logic in the methodologically run chemistry instruction (mathematics as methodological tool in the process of natural reality cognition),
- modelling and models in teaching chemistry and other natural science subjects,
- the issue of the development of material didactic means for methodologically oriented chemistry instruction etc.

This area also includes innovations of material didactic means. Attention is paid e.g. to those supporting school experiments with data administered by computer, computer simulations in the form of web applets, remote and virtual laboratories etc.

The subject of chemistry is again affected, as it was in late 1980s, by discussions on new content proposals, questions on the effectiveness of organizational forms, methods and procedures, adequacy of applied didactic means. It keeps on emphasizing general rules defined by Hellberg (1983):

- increase demands on abstract thinking in the process of instruction,
- remove unimportant items and emphasize general character of single subjects,
- learn to understand the given subjects in relation to similar ones.

This requires increasing effectiveness and frequency in the use of the essential methodological tool of natural sciences – i.e. school chemical experiment, and at the same time applying new didactic means, mainly those on the digital basis.

Theoretical Background of the Research Project

Currently the real life brings more and more virtual environment items, new virtual worlds etc. Both children and adults are strongly motivated by experimenting, discovering and understanding things in their own way. The school experiment is to be purposeful, i.e. clear, appropriated to pupils´ age, simple, well organized, visible and safe. Is the remote or virtual (simulated) experiment able to meet these requirements? The objective of our research project is to discover possibilities and their limits in the use of virtual environment supporting early science education, paying special attention to the early chemistry instruction. It means to research effectiveness of the computer simulations and natural science (chemical) animations applied in primary science education (basic school, grades 8–9), either independently, or in various combinations with the real experiment. The core of the research is to conclude relations and recommendations for meaningful and effective use of computer simulations and animations, remote and virtual laboratories, remote sensing, and to research pedagogical-psychological phenomena as pre-concepts, children's concepts, visual literacy etc.

Mathematics and natural sciences cannot exist without being supported by information and communication technologies (ICT). The digital technology has become their organic part and in important ways it enables discovering new pieces of knowledge, principles and shifting in current theories. This fact is realized by most of teachers, students and pupils at all levels of the educational system. For the presented reasons the today's Science teacher is expected to master not only the field and subject, but also have basic knowledge in Informatics and applied software. It is quite demanding because of a wide range of hardware and software products used in science and technical practice, and their continuous development. Progress in digital technologies and their applications in natural science and technical fields are rapid, so it cannot be expected teachers will minutely master most of the offered products. What is expected, it is general knowledge and orientation in the principles, and paying more attention to perspective information systems according to the subject they teach (Cyrus, Slabý a Bílek, 1997). New didactic means, both material and non-material, and their application into the process of instruction in certain subjects belong to the field didactics (subject didactics, i.e. former theory of instruction, field methodology). Current concept of subject didactics (subject methodology), and contemplated interdisciplinary didactics (Trna, 2005) takes into consideration the latest results of development in new technologies. Thus it is insufficient to define the subject didactics as the combination of a subject and didactics only, but it is necessary to discover wider relations and contexts. A new item has appeared to connect all subject didactics – technology of education. This new stimulus supported by serious research activities should facilitate the implementation of latest technologies and models into the process of instruction. This is the only way how the educational sphere is able to keep abreast of development in society called "information".

Methodological aspects cannot be omitted even in applications of information technologies in the science (chemistry) instruction. Starting from this point of view, the basic and general methodological tools (methods) are as follows:

a) empirical methods: simple and controlled observation, real experimenting, working with empirical hypotheses,

b) theoretical methods: thought experimenting, modelling on different theoretical levels (material, mental, mathematical, etc.), working with theoretical hypotheses.

Simultaneously it is possible to advocate that two sciences function each other as methodologies, mainly in situations when the science reflecting simple fields of phenomena carries out the function of methodological tool towards the other science which solves more complicated problems. Thus Physics is the methodological tool towards Chemistry, and Chemistry towards Biology. Sometimes another situation may appear. A more abstract science, e.g. Mathematics, is a methodological tool towards the other sciences (Hellberg and Bílek, 2000).

The function of the interactive medium is not directly, but vicariously methodological. It enables to apply basic empirical and theoretical methods in a faster, more complex way, save their results to memory in long-term periods, and provide information on the history of the studied phenomenon at any time. This is a substantial auxiliary tool allowing improving methodology of gaining new and application of existing pieces of information.

When considering the aspects presented above, computers have the importance in connection to any other basic empirical or theoretical methods, or in mutual relations between them. Above all, they can work as a database of information gained in continuous monitoring, or control processes on all quantitative levels – laboratory (micro-, semi micro-, macro-) instrumentation and operating. This is the main way of ICT implementation in natural science practice. They serve as the tool enabling (Hellberg and Bílek, 2000):

a) numeric operations (similar to high-level calculator);

b) monitoring, continuous assessing and saving data to memory after „live" observations (controlled observations) and real experimenting;

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c) modelling of these procedures – and it works as their simulator; it assumes there exists a mathematical model of the appropriate methodological procedure; the model is the starting point for creating the appropriate simulating programme;

d) a wide range of other possibilities in modelling activities in which the computer is used, especially to create the model, and interpret it;

e) complicated examples, when a large extent of information on the given class of things, objects, matters, phenomena is inserted and computers are used as advisors (experts) in the field – expert and knowledge systems.

The "remote and virtual laboratories" and "remote sensing" (e.g. Lustigová and Zelenda, 1997; Bílek, 1999; Lustig, 2001; Martínez-Jiménes et al., 2003; Woodfield, 2004; Baran et al., 2004, etc.) are coming into focus in the field of ICT supported natural science instruction.

"Remote laboratories" and "remote sensing" are usually understood as a workplace or place where data recordings are presented, and are accessible to remote co-operating persons; as instruments and measuring systems not accessible in other ways (because of time or financial reasons). Mostly continuously collected data are presented there (e.g. meteorological satellites, seismogram data, high-performance spectral instruments, etc.), sometimes the remote user can influence the measuring system configuration and receive data according to his/her requirements. The „virtual laboratory" is an open remote access database of objects useful for both simulated and vicarious real experimenting activities (annotations, manuals, practice sheets, graphs, circuit diagrams, contacts, photographs, animations and simulations). It can be also understood as the use of applets and other simulative and animation tools for presenting the researched object, phenomena or experiment.

These models can be transported from the scientific environment to schools. The "remote and virtual laboratory" in the educational concept works as open, remote accessible database of objects which can be used in students´ and teachers experimental activities. It can be formed by e.g. following blocs (Hellberg a Bílek, 2000):

a) the environment supporting experimental activities with the use of computer measuring systems,

b) the environment for phenomena modelling,

c) the samples of data files of experiments collected under different conditions,

d) the data from research centres, monitoring centres etc.

The main advantage of such an on-line database is its open and nearly unlimited capacity, operativeness in access to consultations, possibility to compare the data, and other, still unsuspected possibilities. The use of ICT, which are very flexible, enables to accommodate students´ different learning styles and preferred strategies. In comparison to the real experiment, the virtual one can be slowed down, divided into phases or stages, some details may be emphasized, unimportant features not relevant to the formed knowledge suppressed, etc.

When using this approach it is necessary to realize that apart from specific functions (originating from natural sciences), computers can also have another function, i.e. the didactic one. But the specific (subject, field) function is always considered to be more important, and then the less important position in the educational process follows. The real experiment has the central position in the hierarchy of methods, as natural sciences are empirical. That is why the computer functions which relate to teachers´ and students´ experimental activities during the instructional process are emphasized (Hellberg and Bílek, 2000). Controlled observations and real experiments supported by ICT are closely connected to another function – controlled observation and real experiment simulations.

Remote and virtual laboratories as part of a virtual learning environment (VLE) are the up-to-date trend in natural science instruction supported by ICT. They bring a new dimension not only to laboratories, but also to everyday life of students, teachers and every other person interested in science education. New possibilities to measure, to control anything from any computer, to receive current data from the opposite part of the world – these are and will bring immense motivation.

Objectives and Structure of the Research Project

For our research project we have proposed three areas of objectives:

1) Analysis of results in research projects fully or partially dealing with effectiveness of blended real and simulative experiment in natural science instruction abroad.
2) Researching the effectiveness in application of selected simulative and animating experiments in early chemistry education (application of pedagogical research methods, especially direct and indirect observation, interview and pedagogical experiment).
3) Researching the influence of pre-concepts, individual learning styles and other pedagogical-psychological phenomena of effective learning on application of simulations and animations in early chemistry instruction.

Methodology of Research

For the three-year period of research project solving we create three phases; each of them corresponds to approximately one-year period.

1. The starting phase will be devoted to **bibliographic search** and **concept activities**, i.e. it will contain analysis of mainly foreign sources presenting research results in interaction of real and virtual environment in natural science education. The results will be partly published in a monograph containing studies of authors participating in the project and other addressed national and international experts; it will be published by the Faculty of Education, University of Hradec Kralove, in edition "Didactics of Science and Technical Subjects"; partly the research concept will be specified according to the analysis results, i.e. preparation and choice of materials suitable for research activities (in the form of school chemical experiments and their simulations, including worksheets) and tools for collecting data empirical research activities. The target group will be formed of basic school pupils (grades 8 and 9).
2. This **information - registration phase** will cover carrying out all empirical research activities with the target group.
3. The final **information – interpretation phase** will consist of interpretation of collected empirical data and specifying criteria and recommendations to implementing virtual and remote experimental activities into early chemistry (natural science) education.

The Chemistry instruction will serve as example of natural science instruction, as it corresponds to the team specialization. This subject provides wide space for application of information technologies supporting empirical (observation, measuring, experiment) and theoretical (modelling) cognitive methods. The technology development is very fast but as for its influence on learning in various stages of pupil's development in the field of knowledge processing, there are only few applicable principles, rules and natural relations. Children's concepts and likely learning styles are of some importance role in this process.

One of the main objectives is to express the role of modern technical equipment and technology in forming so called visual literacy, current and important part of which the work with computed simulations is. Modern technical equipment plays a contradictory role in this type of learning. On one hand various processes and technologies of visualisation (mainly of 3-dimensional objects) lead to using software products strengthening spatial skills, if properly used. On the other hand both TV and computer screens may provide incorrect imaginations and habits, e.g. space less and other virtual experience which do not prove exact, but biased, misrepresented or incorrect forming of spatial skills, understanding weights, forces, energies, solidity, as well as emotions and feelings.

We have outlined the summary of the current situation in the research field of the project, including the concept and schedule proposal, and main research objectives of the project. A recently established laboratory of young scientists (called K-LaMPa – "Hradec Kralove – Laboratory for Young Scientists"),

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which is situated at the Chemistry Department, Faculty of Education, University of Hradec Kralove, will be used for the purpose of the research to support experimental activities of pupils in the Hradec Kralove region.

Pilot Researches and Results

In the first part of the research project various proposals combining a real and virtual experiment were designed and considered by chemistry students and teachers who participated in the course Computer supported school chemical experiment and Chemical educational software. Totally 78 students of the 4th a 5th grades evaluated four combinations below:

- simulation after real experiment for explaining its principle,
- simulation after real experiment for fixation knowledge,
- simulation before real experiment for explaining its principle,
- simulation before real experiment for training the activity.

Acid-base titrations, experiments with galvanic cells, measurements with spectrophotometer and pH-meter were used as examples. Most students preferred running the real experiment before the virtual one, and mainly using the simulation of experiment for explaining its principle. It was interesting that students did not consider the "training" role of simulations to be important for practising work with laboratory apparatus, understanding principles of laboratory procedures etc.

The basic school pupils will undergo a pilot research on laboratory pH measuring supported by real and virtual (simulated) apparatus, i.e. a virtual pH-meter, which is an available simulation on T. Greenbowe Web page (Greenbowe, 2009) – see Figure 1, and a hand pH-meter in real set on the laboratory desk (Figure 2).

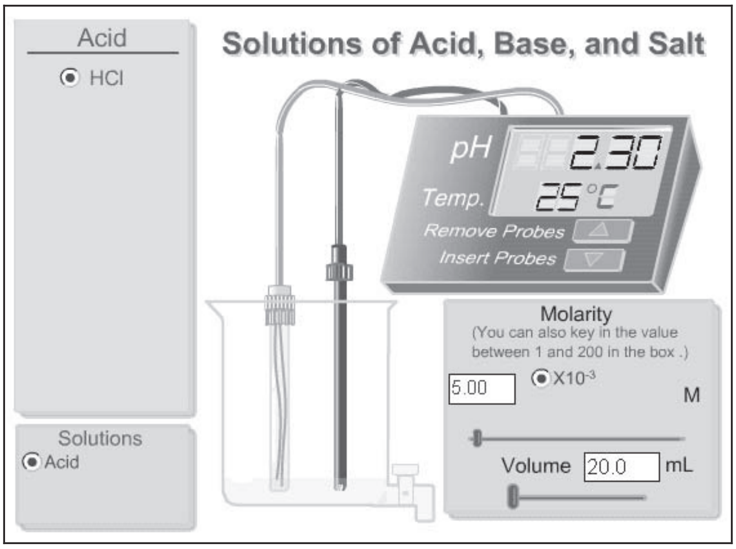

Figure 1. **pH-meter simulation on T. Greenbowe Web page (Greenbowe, 2009).**

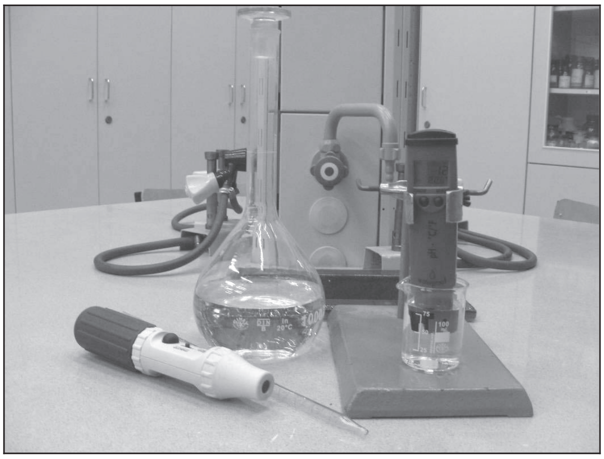

Figure 2. Laboratory arrangements when using real hand pH-meter.

Two as much as identical scenarios were prepared using either real or virtual pH-meter, managed by worksheets containing tasks of three levels:

Level 1: simple pH measuring in three samples of selected chemical matters (hydrochloric acid, sodium hydroxide and sodium chloride) in three different strengths.

Level 2: answers to problematic questions followed by their verifying by measuring changes in parameters of the matters (strength, volume, similar chemical matters), e.g. What pH value will a certain volume of hydrochloric acid solution reach having lower/higher strength than in previous measuring? How will pH sodium hydroxide with strength of 0.06 mol/dm^3 change when its volume increases from 100 ml to 150 ml? What pH value will potassium hydroxide solution reach in comparison to sodium hydroxide solution if the strength is the same? Etc.

Level 3: open task, e.g. Design and describe assignments and results of other tasks which you could do with the provided aids and real or virtual chemicals. You can ask your teacher to provide you with other chemicals and aids for the real experiment, or with advice on other functions of the simulated pH-meter for the virtual experiment.

The following hypotheses were set for this research:

1) No statistically significant differences will appear in pupils´ results of pH-measuring in provided solutions of chemical matters with the real and simulated pH-meter.
2) No statistically significant differences will appear in pupils´ answers to problematic questions dealing with pH-measuring in solutions of concrete chemical matters by the real and virtual pH-meter.
3) Pupils' recommendations on using the laboratory arrangement for other measurements will be more frequent and varied, i.e. more proposals will appear, and the teacher will be asked more questions related to the real environment than to the virtual one.

The presented project is ready for piloting in the K-LaMPa Centre, which is situated in laboratories of the Chemistry Department, Faculty of Education, University of Hradec Kralove, and enables running experimental activities of primary and secondary school pupils and students (Fig. 3). The received results will be presented and discussed on conferences and relating actions. The authors cordially invite proposals on co-operation on this project, i.e. in running both laboratory experiments and their combinations. Materials are available at authors´ address.

Figure 3. From the K-LaMPa Centre.

Conclusions and Discussion

The feasible real experiment should not be in any way eliminated from school laboratory practice. This is the starting point of all approaches to natural science curricula, and it is still in force. The real living environment makes us face more and more items of virtual environment, worlds, mediated by infinite possibilities of computer networks. The mediated perception through virtual images has become (thanks to massive spreading of information technologies) the major cognitive channel of school age pupils. Direct utilization of information from objective existing reality is steadily superseded and replaced by virtual information. How to blend an effective and meaningful application of real, indirect and simulative observation, measuring and experimenting according to didactic principles? Numerous authors (rather intuitively) tend to simple experiments (which do not require demanding material and technical equipment) to be made in the form of real activities; to remote observations and remote experiments to be used to update information and motivate, e.g. in the form of school project and project-oriented instruction; and to virtual experiments to be applied in interpretation of real experiments (simulators of laboratory activities, predicting and verifications of results in experiments) and experiments which cannot be made in schools (dangerous, requiring demanding instruments, unobtainable, etc.). Forming and improving manual skills (measuring by available laboratory instruments, working with laboratory systems, even constructed from common subjects of everyday use, working with safe matters, etc.), which are substantial part of natural science education, cannot be fully replaced by practising through monitor and keyboard. On the other hand it is impossible to avoid indirect observations and working with models and instruments. Researching these fields leads, or not, to proving intuitive estimations, which is important, as well as answering other questions which result from this area of potential assets and threats. The author's department dealt with researching the influence of simulations – simulators of laboratory activities on pupil's successfulness in real experiments (Hellberg, 1983, Vít, 1986, Bílek, 1991), but the results are not ambiguous. There exist other experiments dealing with real measuring and simulations which were made by the Institute of Natural Science Pedagogy (IPN), University of Kiel (e.g. Dahncke and Behrendt, 2001). The positive role of working with simulative experimental devices was presented on the example of calorimetric measuring. It is obvious that nowadays, in the period of creating and applying remote and especially virtual laboratories and their accessibility also in extra-curricular conditions via Web, there is an increasing demand for new researches (mainly in pedagogical and pedagogical-psychological ones) in this field.

The ICT, especially their network systems, do not offer only advantages. They also bring risks and problems to teachers and pupils. Terms and conditions for the use of simulations and other computer support of empirical and theoretical cognitive methods, mainly the support of remote and virtual laboratories, are still in progress according to the growing possibilities of the Internet, Web services and possibilities of measuring, modelling and other means. Virtual universities, virtual classrooms or other ways of remote parts of educational systems in the field of natural science cannot work without the presented methodological components. At technical universities the remote and virtual laboratories have been common and we suppose that their spreading to lower levels of the educational system will not take a long time. In many cases they will be joint projects which should support interest in natural science and technical studies. In our opinion, the necessity to research this field, especially in situations where the initial relation to natural science and technical subjects is formed, is very topical and desirable.

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