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Remote Experiment in Terms of View of Didactics of Education

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REMOTE EXPERIMENT IN TERMS OF VIEW OF DIDACTICS OF EDUCATION

Keywords: Remote experiments; Internet; School experiments; didactics

Abstract

The preparation and use of remote experiments in the education system consists of the solutions of two, at first glance, single and independent issues. The first one, on the part of the provider – the administrator of the remote real experiment, is a solution of technical design for the remote experiment and consequently its implementation. The second one, on the part of the remote experiment user, is a solution of the tasks related to didactics of the application of remote experiment in the different stages of a lesson. To achieve a positive educational effect from the application of remote experiments in education, solution of didactic tasks is as important as solution of technical design of the experiment. The authors in this paper propose a procedure for making solutions, implementation and operation of remote experiments. They come to the conclusion according to which maintaining the long-term functionality and regular innovation of the remote experiment has the nature of the development spiral. They define the essential role of pedagogical research in relation to the application of remote experiments in education. In addition, they refer two examples of technical solution of remote experiments, in which for the control and management, the programmable logic controller (PLC) is used.

Introduction

Real experiments (RE) in natural and technical sciences are integral and inseparable parts of the teaching process. Their fundamental educational aim is to provide a widening of knowledge in the frame of particular topics of the curriculum. The most frequently used method is the verification of the existing laws and dependences between physical quantities or technological parameters.

By performing experimental measurements pupils or students:

- obtain the ability to apply theoretical knowledge in the frame of practical activities,
- improve their practical skills with aids and measuring apparatuses,
- gain laboratory experience,
- confirm and widen their knowledge from the course of previous study.

Laboratory experiments cause interaction between previously obtained knowledge and newly gained experience and so they support what we call a metacognition[1] while hand in hand pupils/students learn to cognize methodology of scientific and research work. They also positively influence our youth in the process of their deciding regarding future professional orientation in the area of natural scientific or technical spheres.

Besides educational influence, practical school experiments also have the edifying function. Thanks to them students improve their:

- relationship towards purposeful research and technical work,
- habits in precise execution of work activities,
- sense of fulfillment after successful experiment,
- cognition of the mutual relation between abstract theoretical thinking and practical activities,
- experience in work in the laboratory and in the team.

Progress in the area of Information and Communication Technologies (ICT) changes the environment of laboratories, their technological configuration, methodology of measurements, the way of recording and evaluation of the obtained data. ICT have become a tool that provides conditions enabling the transfer of real experiments from the real laboratory to any place on the Earth via the Internet. Usage of school experiments enables teachers to perform educational activities while emphasizing individual demands[2]. According to the authors[3], usage of the remote experiments enables higher flexibility that is required in the experiments with real phenomena; and above all, the Internet on-line laboratories enable more effective deployment of the laboratory equipment by students themselves, since thanks to the Internet they can use them from any place and at any time. Such sharing of the created laboratory experiments decreases expenditure needed for building and running the laboratories and on the other side it increases accessibility of the experiments for a higher number of students. Nowadays, it is possible to connect more e-laboratories via the Internet that are placed especially in the university workplaces.

1. Starting Points of the Remote Experiment Application in Education

The creation of a real remote experiment that fulfills demands for its reliable and safe running while meeting methodical objectives is not a simple task. The

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[1] M.P. Clough, *Using the laboratory to enhance student learning*, in Learning Science and Science of Learning, R.W. Bybee, Ed. National Science Teachers Association, Washington, 2002.

[2] D. Grimaldi and S. Rapuano, *Hardware and software to design virtual laboratory for education in instrumentation and measurement*, in Measurement, vol. 42, 2009, pp. 485–493.

[3] R. Pastor, J. Sánchez, and S. Dormido, *An XML-based framework for the Development of Web-based Laboratories focused on Control Systems Education*, in "International Journal of Engineering Education", vol. 19, 2003, pp. 445–454.

challenge and specification of this task requires a close cooperation of real experts – specialists. (fig.1)

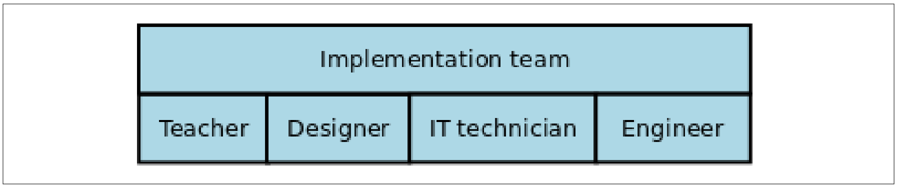

Fig. 1. Implementation team of experts

So that real remote experiments can become an effective teaching aid it is important and needed to keep the valid principles regarding the preparation and running of the remote experiment as may be seen in the developmental spiral (fig. 2).

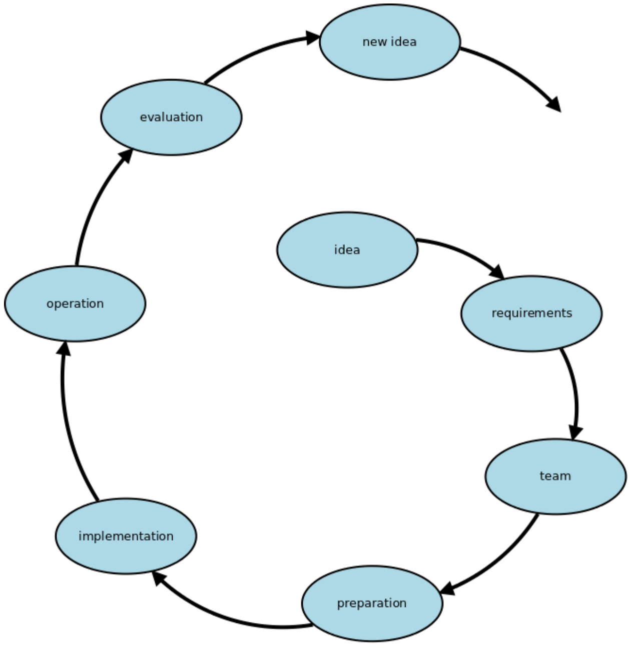

Fig. 2. Developmental spiral of remote experiment

The basic idea comes from a designer – a pedagogue, who specifies a task for the experiment from the particular topic of a curriculum, defines fundamental demands for the creation and running of the experiment from both technological and didactical points of view. Last but not least there is a task regarding the creation of an appropriate work team. The outcome of the cooperation of such a team is the created experiment ready to be verified and consequently offered to users on the Internet. Another important phase in the process of further development of the experiment is the evaluation of its functioning that is closely connected to the design of innovative ideas and their implementation in the next developmental cycle.

To provide a sustainable remote experiment we need to guarantee both its sufficient maintenance and continual innovations where demands from the side of users who in practice are teachers and pupils/students must be taken into consideration.

The crucial demand of teachers regarding remote experiments (RE) is to provide a higher level of fulfillment of educational and edifying aims in teaching process[4].

The design and application of a remote experiment represent two separate troublesome areas. The first one deals with a technical solution and the running of a remote experiment on the side of a provider who is responsible for the:

- design and construction of a remote experiment on a specific theme,
- system of management and control of functionality of particular experiments,
- philosophy of collecting and processing of the observed data,
- hardware and software support of the remote experiment via the Internet.

On the side of a user of a remote experiment the situation is completely different. The most likely, user of the RE is a pedagogue – teacher, who decided to use the RE as an innovative tool in the lessons. Such a user is primarily interested in the didactic side of the experimental topic and how the experiment can help him/her improve the level of education. Technical and programming issues of the RE are usually just secondary from the point of view of users – teachers.

When working with RE we deal with real laboratory equipment that is perceived indirectly on the side of a user. According to[5] one part of students do not perceive remote laboratories as the real ones and that is why we should try to reach the state where the display and controlling of the experiments are as authentic as possible. It must enable accessibility to all the possible settings of the

[4] T. Kozik and M. Šimon, *Preparing and managing the remote experiment ineducation*, in 15th International Conference on Interactive Collaborative Learning and 41st International Conference on Engineering Pedagogy. Villach: ICL, 2012.

[5] Z. Nedic, J. Machotka and A. Nafalski, *Remote laboratories versus virtual and real laboratories*, in Proceedings of the 33rd Annual Frontiers in Education Conference. Boulder. s. T3E.1-T3E.6. 2003.

experiment. Possible faults in the setting of incoming parameters of the experiment cannot be filtered out automatically, but the users must detect them and consequently try to correct them. Outcomes of the measurements should be obtained in the same way as if students take them in direct work with real equipment[6].

2. Social Conditions of Application of Innovative Teaching Supported by Remote Experiment

In the last 20 years there is an obvious decrement in the interest in study of natural scientific and technical disciplines among students of elementary and secondary schools in the SR. Experience of the authors from numerous study stays abroad show that there is similar development visible also in other European countries. It is generally known that subjects like mathematics, physics or chemistry are not very much preferred and favorite among pupils/students at elementary/secondary schools. A really sad fact is that similar opinions are heard also from the graduates and postgraduates of technical universities.

Successful study of these subjects is generally contingent on the adequate level of abstract thinking, and good spatial visualization connected with logical and analytical thinking. These attributes are not automatically given to all people and even among those who have such skills it is needed to intentionally develop and improve them through the educational process.

Thanks to information technologies much scientific knowledge is accessible to wide layers of inhabitants in the early decades of the 21. century. E-technologies and their continual applications seriously influence traditional educational systems. It is a contemporary issue for the pedagogical staff to answer the questions what to teach, how to teach it and when. The philosophy of education itself changes constantly. There is a tendency to divert from the philosophy of education orientated towards a lifelong occupation and consequently the philosophy of education for constantly changing conditions on the Labour Market comes forward.

What we know is that lifelong education is being emphasized more and more in today´s world. Our society starts to realize the meaning and importance of real fulfillment of a term knowledge society or so called learning society in relation to its permanently sustainable development[7].

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[6] A. Ferrero, S. Salicone, C. Bonora and M. Parmigiani, *ReMLab: A Java-Based Remote, Didactic Measurement Laboratory*, in IEEE transactions on instrumentation and measurement, vol. 52, 2003, pp. 710–715.

[7] T. Kozík and J. Depešová, *Technical education in the Slovak Republic in the context of education in the European Union, Technická výchova v Slovenskej republike v kontexte vzdelávania v krajinách Európskej únie*, Nitra: Pedagogická fakulta UKF, 2007, p. 140.

In the abovementioned social-economic environment there are also educational systems of particular countries whose fundamental aim should be the provision of such an educational level of inhabitants that has a potential to create preconditions of its future development.

Specification of teaching technical branches is in the necessity of applying a whole range of creative methods for every particular technical or technological problem. This approach in education represents the very substance of innovative educational forms in which a teacher is in the position of a partner for pupils/students and at the same time he represents a role of authority and personage. The basic role of a teacher in this model of the educational process lies in the activation of learners towards the subject of education thanks to which a needed place for individual activities of learners will be created orientated on the already mentioned attributes (abstract thinking, spatial imagination, logical thinking etc.).

In the history of the development of human societies there had never been recorded such a huge acceleration of updating knowledge as it was in the 20. and at the beginning of 21. century. As a consequence of quick mass widening of the ICT applications, new information regarding advances in science, research and social development have become easily accessible for people practically of all social groups. E-technologies are more and more frequently used in the area of education. Step by step the whole society gets to know the meaning and content of the term knowledge society in connection to the perspective of sustainable industrial growth[8].

In the abovementioned social environment there are acting and developing various educational systems. Specification of teaching technical specializations lies in preferential implementation of creative methods in the process of solving various tasks or problems. Getting familiar with this approach from the very beginning (ideally already at the level of pre-school education) creates positive predispositions for further successful understanding of more complicated technical principles in the course of further study and the elegant mastering of various technically orientated activities in everyday life.

3. Remote Experiments and the Didactic Cycle

The creative approach is the substance of an innovative form of education where a teacher stands in the position of a partner while keeping his authority. So that a pedagogue/teacher can reach the required educational aim, he must be able to attract the attention of learners to the particular topic. And the implemen-

[8] *Ibidem*, p. 140.

tation of experiments (hands-on, remote, simulated) in education is the mean that enables it[9].

In both vocational and pedagogical literature there is no straightforward answer to the question regarding minimal ICT competencies of a pedagogue for the creative application of remote experiments in the teaching process that would enable one to design and create one´s own educational experiments while being supported by e-technologies. There is also one reasoned definition of didactic demands for this type of experiments missing, which should be taken into consideration in the process of their design, construction and running. The teaching process has got its specific attested sequence of activities on the side of a teacher as well as on the side of a learner that have been proven in the course of time. This didactic cycle consists of the[10]:

- formulation of the aims of teaching process and consequently their acquisition by learners,
- reiteration of previously obtained knowledge that is closely connected to the new study content,
- exposition and acquisition of a new study content,
- consolidation of newly received information,
- check of the attained outcomes in the educational process,
- setting tasks for a home preparation.

In every one of these phases a teacher can use different methods[11]:

- motivational (supporting interest in learning),
- expositional (getting acquainted with the new study content),
- fixative (reiteration and consolidation of information),
- diagnostic and classificatory (examination and evaluation).

Teaching supported by information technologies has recently become a favourite way of teaching among pedagogues galore and it is positively accepted by students themselves[12]. This fact itself supports expectation for reaching better educational effect when compared to the traditional forms of education.

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[9] F. Schauer, M. Ozvoldova and F. Lustig, *Real remote physics experiments across Internet - inherent part of Integrated e-Learning*", in Proceedings of iJOE. 2008, pp. 54-57.

[10] I. Turek, *Didactics, Diadaktika*" Iura Edition s.r.o Bratislava (members of group Wolters Kluwer), p. 595. 2008.

[11] E. Petlák, *General Didactics, Všeobecná didaktika*, IRIS Bratislava, 2. wyd., p. 311, 2004.

[12] F. Schauer, M. Ozvoldova and F. Lustig, *Real remote physics…*; L. Domingues, I. Rocha, F. Dourado, M. Alves and E.C. Ferreira , *Virtual laboratories in (bio)chemical engineering education,* in Education for Chemical Engineers, vol. 5, 2010, pp. 22–27; M.P. Clough, *Using the laboratory to enhance student learning*," in Learning Science and Science of Learning, RW. Bybee, Ed. National Science Teachers Association, Washington 2002.

If we take into consideration all the mentioned didactic demands in the process of designing and running RE, then such a system should fulfill the following criteria:

- easy accessibility on the Internet,
- simple orientation on the web site of the experiment,
- easily understandable guide regarding handling the experiment,
- assignment with clear definition of educational aims,
- corresponding theory to the theme of an experiment at the appropriate educational level of a user,
- definition of a way of communication between users and provider of the experiment,
- recommendations for pedagogues regarding the deployment of the experiment in particular stages of a teaching unit (in didactic cycle).

From a technical point of view the experiments should be constructed in such way so that:

- the created experiment is in accordance with theoretical knowledge which it is based upon,
- it is technically resistant against user´s failure in the process of control of the experiment.

It is obvious that the deployment of a gradually widening net of e-laboratories that are used in pedagogical practice is going to be the subject of serious pedagogical research in the nearest future. The issue of development of new universal systems in management and control of remote laboratories that would provide safety and needed economy in the process of their running shall also be one of the topics of the research.

4. Technical Solution of Remote Experiments with Deployment of PLC

Authors in the process of designing remote experiments and constructing remote laboratories have decided for the philosophy of applying the elements of industrial automation. In the process of searching for suitable technical solutions to of managing and handling the experiments in remote laboratories they decided to try to use technical parameters and attributes of PLC. PLC (Programmable Logic Controllers) are used in solutions of automatized tasks at different levels of technical difficulty. When deciding about deployment of PLC, the fundamental and original idea was the creation of a universal system of handling and managing. A system constructed in such way will be exploitable also in teaching the subjects orientated on automation.

The system of remote administration of PLC on the Internet is provided via web server which represents the graphical interface (GUI) between PLC and users. Communication between the web application and PLC itself is provided via OPC server (OLE for Process Control).

In technical experimental tasks from the area of electro engineering we frequently may see a task regarding regulation of revolutions of an electric engine. The authors have decided to use the frequency transducer in their remote experiment. In fig. 3 is displayed overall configuration of the remote experiment for the regulation of revolutions of the 3-phase electric engine by the 3-phase frequency changer.

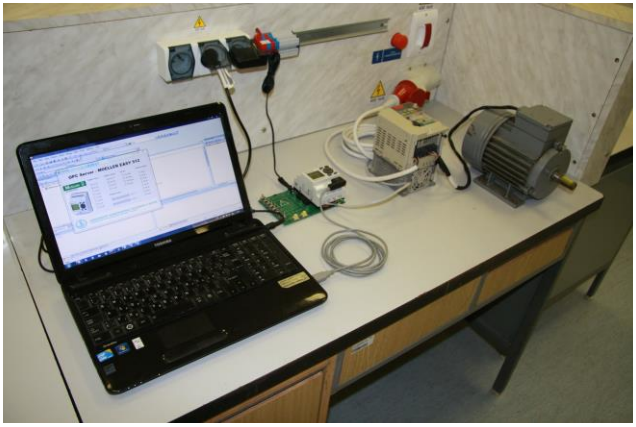

Fig. 3. Configuration of the real experiment regarding regulation of the engine revolutions by a frequency changer

Parameters of the frequency changer are set in a way so that revolutions of the engine can be regulated by a time width of the input impulse. It means that if there is a logical 1 at the A master input of the frequency changer, then the speed of the engine will continuously rise all the time while the logical 1 remains active at this input. B input will react similarly in relation to the decrement of revolutions. In the case that at both inputs (A, B) are logical 0 or 1, revolutions of the engine will not change. In this configuration the PLC made by EATON EASY 512 was used. It is the bitwise combinative automaton managed through OPC server.

In the process of constructing remote experiments in remote laboratories the question of their economic efficiency becomes more and more important. Running the experiments in the remote laboratories is a difficult task from the point of view of the illumination of the workplace. It is required to provide a permanent source of illumination of particular experimental configurations even in such cases when there is nobody logged in on the server.

An interesting decrement in operating expenses can be obtained through the installation of a system that after user´s entry turns the light in the laboratory on and consequently activates particular experimental components. This function can be added into the remote experiment that is operated by programmable logical automaton[13].

A model of a remote experiment simulating the abovementioned processes may be seen in the fig 4.

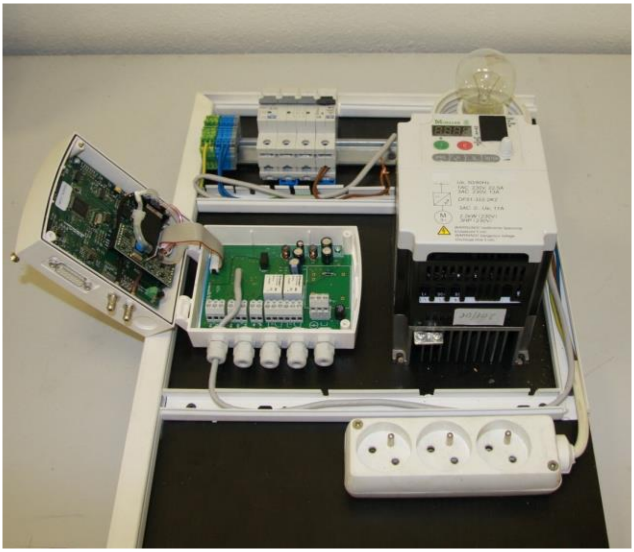

Fig. 4. Model of regulation of illumination of the remote experiment in the real laboratory

Nowadays, it is not a problem to create practically any experimental configuration and consequently to make it accessible for users via the Internet. Still one open problem remains – how the experiment from the point of view of a user can be deployed in education, or in other words, how it will be implemented into the teaching unit so that a teacher can reach the demanded educational goals.

Conclusion

Already nowadays there are obviously visible changes in the educational environment at practically all types and levels of schools as a consequence of

[13] T. Kozik, G. Banesz, D. Lukacova, M. Sebo, V. Tomkova, I. Handlovska, P. Kuna, M. Simon, *Videoconferencing systems in educational applications*, Videokonferenčné systémy v edukačných aplikáciách, Nitra: PF UKF, 2011. p. 175.

implementation of up-to-date applications of the information technologies in education. RE make a good example of their penetration into the teaching process especially in natural scientific and technical areas where there is an emphasis put on the deployment of methods regarding the work with experiments. In parallel, they are a challenge for pedagogical research in the area of searching for the answers to the questions regarding their implementation into the teaching process and the impact on knowledge level and specific skills of postgraduates from natural scientific and technical fields. The already published outcomes regarding deployment of the RE in educational sphere point at their benefit especially in the area of shortening the time needed for practical vocational training of pupils/students. We want to state that deployment of RE in education does not automatically mean total exclusion of real experiments from the teaching practice. Ideally, the RE should be combined with the real experiments[14]. The potential of deployment of remote experiments lies in the individual approach of every teacher, their ability to prepare a good experiment and the overall pedagogical mastership considering innovative principles of teaching and the effective exploitation of educational time.

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