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Elimination of barriers for a broader use of remote experiments in Slovakia

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Elimination of barriers for a broader use of remote experiments in Slovakia

A remote experiment is a real experiment that can be observed and controlled by a computer through the internet. The subject matter of a remote real experiment is a real laboratory experiment, with real laboratory instruments and equipment, at which a student does not solve a physical or technical task in teaching process based on her/his personal presence at the measurement set but s/he observes the equipment, and controls and regulates it through a computer connected on the internet [3]. In this way the use of the mediated teaching experiments – remote real experiments, enables to conduct educational activities based on the students` individual needs [5].

The use of remote real experiments in teaching process is not a new phenomenon either abroad or in Slovakia. However, in Slovakia this kind of experiments has not still become a common teaching tool for science and engineering education and has not been ranked among the conventional ways of teaching.

A main motivation leading teachers to use the remote real experiments in their teaching practice is the fact that to carry out laboratory experiments at school requires having adequate technical equipment and devices of appropriate technical parameters, what is usually considerably costly. Moreover in the view of providing students possibilities of active actions, it is necessary to have the same technical facilities for several groups of students, to enable them to solve the same experimental tasks at the same time [13]. In their talks and discussions at various professional seminars and workshops teachers very often point to a bad state of school facilities including the state of school labs equipment and devices necessary to carry out school (laboratory) experiments. As results from their expressions [6], most of the lower secondary schools rather maintain their existing technical equipment and renew it in a minimal extent, mainly due to the financial aspects. Consequently a lot of demonstrations, measurements, experiments, observations and investigations, which teachers could carry out together with their students in a practical way, stay only at the level of their theoretical description and explanation.

A possible solution of the above-mentioned situation is introducing and providing remote real experiments for educational purposes. For this reason in 2014 Constantine the Philosopher University in Nitra submitted a project entitled *Remote Real Experiments in School Practice* to the Ministry of Education, Science, Research and Sport of the Slovak Republic. In frame of the project following tasks were solved:

- to find out teachers` opinions on the use of the real remote experiments accessible on the Internet,
- to design a set of evaluation criteria for the remote real accessible on the Internet to assess them in terms of their didactic quality,
- to assess the current state regarding remote real experiments available at the internet and to find out topical areas which they are related to,
- to prepare a surveillance catalogue (overview) of the remote laboratories and remote real experiments accessible on the Internet.

Teachers` opinions on the use of the remote real experiments accessible on the Internet were surveyed on a research sample of a questionnaire survey, respondents of which were university teachers. In the particular questionnaire items the respondents expressed their opinions why the higher education institution teachers (involved in technical subjects teaching) do or do not use remote real experiments in their teaching practice, what conditions are necessary for an efficient use of these teaching means, from the view of technical subjects (or STEM) didactics what advantages and benefits application of these means brings for technical subjects (STEM) teaching [11].

Results of the questionnaire survey pointed to some barriers acting against a broader use of the remote experiments, which can be summarized in following points:

- insufficient technical platform for their use at schools, or rather costly platform creation with the relevant technical parameters (technical and related to them financial obstacles),
- technical difficulty and time consuming design of the remote real experiments to be created by teachers,
- franchise costs and fees in the case of commercial software products,
- lack of information for teachers on web sites with open access to remote experiments,
- low teaching level of the available products (underestimated didactic aspects of the offered remote experiments),
- lack of trainings for teachers to be trained in using this teaching tool (almost no offer of the adequate continuing professional development courses).

As the most significant barrier for a broader use of remote experiments the results of the questionnaire survey showed to be a low familiarity of teachers with the work with remote experiments, i.e. weak competences to operate them. On the other hand a very often reason why the teachers do not develop their skills to work with remote experiments is a low informedness on particular experiments which they could utilize in their teaching practice. To solve this problem it was decided to publish the monograph *Remote real experiments in practice* [12] and to create a catalogue of relevant accessible experiments.

To create a system of didactic requirements that would enable an objective assessment of quality of the remote real experiments in terms of their use in education, i.e. from the didactic point of view, various professional publications on this topic were used and considered [11]. The final designed methodology is based predominantly on principles used by Dormido [2], Ferrero [4] and Klementa [7] and following assessment criteria:

- observed experimental process (its particular phenomena) visualization,
- speed of response (access time to the experiment),
- experiment accessibility from the software point of view,
- page navigation,
- comprehensibility of the offered instructions regarding the experiment control and operation,
- introduction (assignment) of the experiment in relation to the stated teaching goals,
- presentation of the theory needed to understand the experiment,
- possibilities to communicate with the experiment provider,
- provision of different instructions and comments designed for the teacher.

The above-mentioned surveillance catalogue of the remote laboratories and remote real experiments accessible on the Internet consists of both descriptions of the experiments as well as their assessments based on the created methodology (http://ki.fpv.ucm.sk/kega/index.html). As to the types of the presented labs of the remote experiments, the labs were classified to four basic categories:

- free accessible,
- accessible after a free registration,
- accessible only within the particular education institution,
- commercial, accessible with an access charge.

Another issue, solved within the project, was the technical realization of the remote real experiments ([8], [9], [10]). From the point of view of their creators and users, this is very often uneconomical as to the financial aspects. To eliminate this barrier it was proposed to use programmable logic controllers (PLC). To prove correctness of the mentioned decision two remote experiments were designed: measurement of the air flow in a tube and automatic regulation of stop-go lights at a crossroad.

To illustrate the described issues and project results thereinafter we present examples of three remote real experiments with the highest evaluation score achieved in accordance with the above-mentioned assessment methodology: Solar Energy Conversion, Alternating Current Rectifier, Wind Tunnel.

Solar Energy Conversion
Link: http://kdt-4.karlov.mff.cuni.cz/index_en.html

This experiment illustrates characteristic curve of the photodiode Tesla 1PP75. The changeable variable which can be set in the experiment is electric voltage across the diode. On the graph (Figure 1) one can see the change of the electric current [mA] flowing through the diode in dependence on the value of the set electric voltage [V]. Additionally, it is possible to find out from the graph when the diode is in a conductive mode. Another changeable parameter is illumination intensity of the light source [%]. If the bulb is switched off, the experiment runs as well. In this case the photodiode responds to the illumination from the background (illumination of the room).

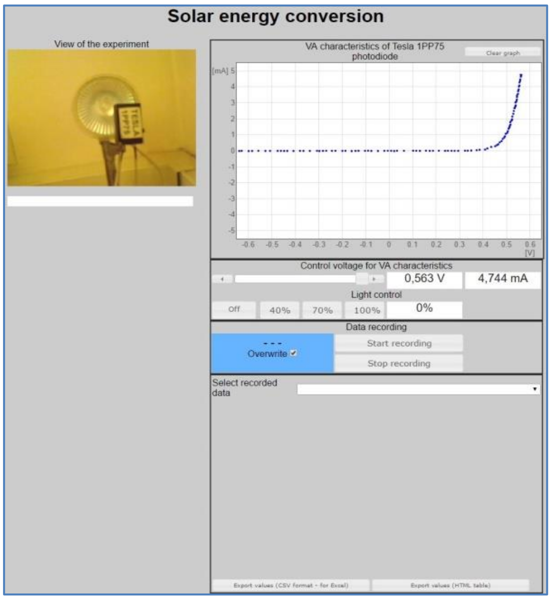

Figure 1 Solar Energy Conversion
(http://kdt-4.karlov.mff.cuni.cz/index_en.html)

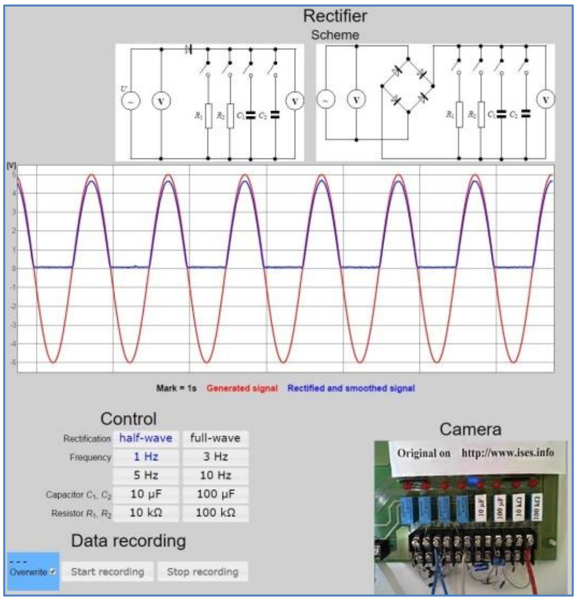

Figure 2 Alternating Current Rectifier
(http://kdt-19.karlov.mff.cuni.cz/index_en.html)

Alternating Current Rectifier
Link: http://kdt-19.karlov.mff.cuni.cz/index_en.html

This experiment shows two ways to convert alternating electric current to direct current: by the use of one rectifier diode (half-wave rectifier) and by the use of four rectifier diodes in Graetz bridge. The ways of the connections are presented on the one hand by the means of the electric schemes and at the same time through a web camera view (Figure 2). First and foremost it is possible to choose/change one of the two given connections (to push a button half-wave for the half-wave rectifier or a button full-wave for the Graetz Bridge connection). Further changeable parameter is frequency of the alternating current: 1 Hz, 3 Hz, 5 Hz or 10 Hz. To smooth the rectified current from the fluctuating one to the constant direct one two resistors R1 a R2 (10 kΩ a 100 kΩ) and two condensers (10 μF a 100 μF) are connected in the both given two connections. Activation of the Graetz diodes, resistors and condensers is indicated through LED diodes. Changes done in the particular connections are illustrated also in a graphical form in the voltage [V] – time [s] (V - t) graph. The graph shows the input electric voltage in red and output electric voltage in blue. The experiment uses the iSES system.

Wind Tunnel
Link: http://137.193.65.97/eng/laboratory.htm

This experiment illustrates the use of a wind tunnel to measure air resistance at the body circumfluence (resistance of air flowing around a car model). Changeable parameters are the car shape (three different car models: BMW 6er Coupe, fire-fighting truck or BMW X5) and air flow velocity (0 – 100 $km.h^{-1}$). By a camera recorded anemometer shows real values of the air flow velocity (Figure 3). To measure the air resistance on the car, a tensometer is used. The value of the air resistance is found out through the electric voltage recorded by a multimeter.

Figure 3 Wind Tunnel
(http://137.193.65.97/eng/laboratory.htm)

Description of the results obtained at the assessment of some selected used didactic criteria put on the remote real experiment design for the use of the experiments in teaching processes is summarized in Table 1.

Experiment	Solar Energy Conversion	Alternating Current Rectifier	Wind Tunnel
Required criterion			
Visualization of the observed experimental process	*real connection*	*real connection*	*real connection*
Speed of response	*experiment starts immediately*	*experiment starts immediately*	experiment starts with a short time-delay
Experiment accessibility from the software point of view	*no need to install any additional software supports*	*no need to install any additional software supports*	*no need to install any additional software supports*
page navigation	*page menu clearly comprehensible*	*page menu clearly comprehensible*	*page menu clearly comprehensible*
comprehensibility of the offered instructions regarding the experiment control and operation	*information understandable also due to the presented processed theoretical knowledge related to the experiment issue*	information incomprehensible, some information on the experiment	*information understandable also due to the presented processed theoretical knowledge related to the experiment issue*
introduction of the experiment in relation to the stated teaching goals	teaching goals undefined, instead of that motivation of students included	teaching goals undefined, instead of that motivation of students included	teaching goals undefined
presentation of the theory needed to understand the experiment	*theoretical knowledge to the observed experiment elaborated on an appropriate level*	without any presentation of theoretical knowledge to the observed experiment	without any presentation of theoretical knowledge to the observed experiment
possibilities to communicate with the experiment provider	communication with the experiment provider undefined	communication with the experiment provider undefined	communication with the experiment provider undefined
provision of different instructions and comments designed for the teacher	regulations and recommendations regarding inclusion of the experiment into the teaching process missing	regulations and recommendations regarding inclusion of the experiment into the teaching process missing	regulations and recommendations regarding inclusion of the experiment into the teaching process missing
Total assessment score*	**6**	**4**	**4**

Table 1 Fulfilment of the selected didactic criteria in case of the particular remote real experiments

* Total assessment score of the given experiment expresses number of the didactic criteria which it fulfils (see the items in italic).

From the view of the didactic assessment none of the evaluated experiments can be specified to be at an adequate quality level. The quantitative way of the assessment is based on allocation 1 point to the evaluated experiment for each fulfilled assessment criterion. This means that if an experiment fulfils all stated didactic criteria, it can achieve the total assessment score of 9 points. Experiments with the total assessment score of 8 – 9 points are considered to be experiments of a high didactic quality, those with the total score of 5 – 7 points are labeled as experiments achieving a standard evaluation. Score below 5 points means experiments with a low didactic standard (quality).

The highest rank is recorded in case of the Solar Energy Conversion experiment (total score 6 points). The main insufficiency of the experiments is "underflow" of the didactic criterion focused on teaching goals. Also suggestions and methodological instructions on the use of the experiment in teaching are missing. As Šebo mentions [14], such instructions could be developed e.g. by means of a discuss forum at some of the social nets. Another weakness of the experiment is failure of communication with the experiment provider. There is no contact offered although currently there are different possibilities how to ensure technical support and consulting services.

The Alternating Current Rectifier experiment achieved in the didactic assessment 4 points, what is neither a standard value. Basic information on the experiment offered on the web site is incomplete and in relation to some factors is missing completely (this regards mainly an introduction into the experiment issue theory and main principles of the experiment). Same to the previous experiment teaching goals are missing here, too. On the other hand a plus of this experiment is inclusion of motivation information devoted to the user. Due to the missing theory to use and control the experiment correctly a teacher`s explanation is necessary. Also same to the previous experiment no communication with the experiment provider and no instructions how to use the experiment are provided.

The third experiment, Wind Tunnel, is in our opinion from the technical application point of view the most interesting experiment. But from the didactic aspects alike the Alternating Current Rectifier experiment it did not achieved even a standard evaluation. The use of this experiment is limited due to the fact that if another user is working with the system, the system switches off the first at the 120 s after the lock in of the second user. Maximal waiting time is 120 s, i.e. all activities, which the experimenter plans to carry out, must be done in this time duration. The experiment web sites do not offer any information and instructions related to the experiment theory, its teaching goals or didactic use.

The use of the remote real experiments in teaching practice in the Central Europe region is considerably limited. The research results [12] point to the fact that only 35 % of the surveyed respondents have some basic information and knowledge on the remote experiments. And what is even more alarming from the given 35 % only 14 % use these means in their teaching practice. The created catalogue should help to improve this state on the side of the teachers. But on the other hand at the same time it can be very useful to attract students to use this kind of experiments in their informal education (additional education activities, such as home preparation, self-study etc., [1]).

Bibliographic Information

1. Clough, M. P. 2002. Using the laboratory to enhance student learning. *Learning Science and Science of Learning*, NSTA Yearbook, National Science Teachers Association, Washington, DC, pp. 85-97
2. Dormido, S. 2004. Control learning: present and future. *Annual Reviews in Control*, vol. 28, no. 1, pp. 115-136
3. Dostál, J. 2015. Inquiry – Based Instruction and teachers Competences for its Realization. *Journal of Technology and Information Education*, vol.7, no. 1, pp. 7-34
4. Ferrero, S. - Salicone, C. – Bonora - Parmigiani, M. 2003. ReMLab: A Java - based remote, didactic measurement laboratory. *IEEE Transactions on Instrumentation and Measurement*, vol. 52, no. 3, pp. 710-715
5. Grimaldi, D. - Rapuano, S. 2009. Hardware and software to design virtual laboratory for education in instrumentation and measurement. *Measurement*, vol. 42, no. 4, pp. 485-493
6. Hašková, A. – Manduľáková, S. – Van Merode, D. 2017. Problematic Aspects of Technology Education in Slovakia. *Communications: scientific letters of the University of Žilina*, vol. 19, no. 1, pp. 75 – 80
7. Klementa, M. 2011. *Přístup k hodnocení elektronických studijních opor určených pro realizaci výuky formou e-learningu*. Litovel, Velfel Ladislav
8. Kozík, T. – Šimon, M. –Arras, P. – Kuna, P. 2015. Remote experiments, from internet to intranet. *Edukacja - Technika - Informatyka : wybrane problemy edukacji technicznej i zawodowej*, vol. 13, no. 3, pp. 328-332
9. Kozík, T. – Šimon, M. – Arras, P. – Ölvecký, M. - Kuna, P. 2014. *Remotely controlled experiments*. Nitra,UKF
10. Kozík, T. – Šimon, M. – Kuna, P. – Arras, P. – Tabunschyk Gallina. 2015. Remote Experiment at Universities. IDAACS'2015 : The crossing point of Intelligent Data Acquisition & Advanced Computing Systems and East & West Scientists. Proceedings of the 2015 IEEE 8th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications. Warsaw, Piscataway, IEEE, 2015, pp. 929-934
11. Lukáčová, D. – Bánesz, G. – Hašková, A. 2015. Quality Assessment of Remote Real Experiments and their Use in Practice. *Application of Information and Communication Technologies - AICT2015*, 9th IEEE International Conference Proceedings, pp. 491–495. Baku, Designing and Publishing Department of Qafqaz University, IEEE Catalog Number CFP1556H-ART
12. Lukáčová, D. et al. 2016. *Vzdialené reálne experimenty v praxi* . Nitra, UKF
13. Ma, J. - Nickerson, J. V. 2006. Hands-On, simulated, and remote laboratories: A comparative literature review. *ACM Computer Surveys*, vol. 38, no. 3, pp. 1–24
14. Šebo, M. 2013. Support for non-technical education students through social networks. *Edukacja - Technika – Informatyka*, vol. 4, no. 2, pp. 330-342