Real Remote Mass-Spring Laboratory Experiments across Internet – Inherent Part of Integrated E-Learning of Oscillations

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Abstract—**The paper presents the application of Integrated e-Learning exemplified on the thematic block "Oscillations". The goal of the course of Physics in the chapter of Oscillations is to show the oscillatory movement as a basis of nearly all natural phenomena. The unifying model for all real world systems then may be the mass-spring system established on the mechanical oscillator. The three constituting components of Integrated e-Learning, based on our definition and interpretation of Integrated e-Learning are illustrated: the remote (or hands on, class) experiments, e- simulations and e- textbooks for the unit Oscillations. The new method of Integrated e-learning, very substantial for prospective physics teachers, was verified at Trnava University in cooperation with Charles University in Prague. First experiences with utilization of real remote experiments of driven and damped oscillations, corresponding applets and e-textbook „Multimedia university physics" in teaching process are presented, reflecting the necessity for the new physics course for university students, especially for future teachers. New interactive simulation of oscillations in the system mass-spring with data outputs and transfer is introduced for the first time.**

Index Terms— **Driven oscillations, e-simulations with data output and transfer, e-textbook, Integrated e-Learning, remote Internet experiments.**

I. INTRODUCTION

Offering a set of important theoretical knowledge and practical skills, a basic course in Physics has always been a basement of technical creativity and critical thinking development in natural sciences and engineering universities. The aim of the basic courses of Physics in naturals sciences and technical oriented universities is to build up a complex physical platform outcome for comprehension of real systems and processes, so that students are able to get an insight into things and actions. Students entering universities show absence of such insight and comprehension and minimum interest in viewing the world via "physical eyes". This is surely due to incomplete physical picture and absence of principles of top contemporary inventions offered by secondary school Physics. It could also reflect the results of the attitudes to natural sciences in this period. Also another reason for this could be that most of freshmen in university studies often lack the prerequisites for even the standard introductory courses, especially in the physics sciences.

The most of the physics courses generally available are almost entirely descriptive. A great deal of material is presented, for which most of the students have neither the background nor the time to absorb. Such courses often reinforce a tendency to perceive physics as an inert body of information to be memorized, not as an active process of inquiry in which teachers and students can participate [1]. The understanding of the nature of science should be an important objective in a physics course. Students should be able to distinguish observations from interferences and to do the reasoning necessary to proceed from observations and assumptions to logically valid conclusions. Students, especially future teacher, must understand what is considered evidence in science, what is meant by an explanation, and what the difference is between naming and explaining. The natural science can only be taught via scientific methods of work, through direct observation and direct experience. And it is the aim of Integrated e-Learning (INTe-L) [2, 3], a new strategy of education of physics based on the method sciences use for the cognition of real world, which the latest Information communication technologies (ICT) have made possible and which, as we hope, may also improve the unfavorable situation in physics education in secondary schools and universities.

Our motivation for the experimental work in the direction of INTe-L came from the recent paper of Wieman et al. [4], supporting and calling for the change in the educational methodology, further the new approach called e-LTR (eLearning, eTeaching, eResearch) using the remote experiments [5, 6] introduced by Thomsen and his co-workers and last but not least the possibility to use advanced technologies for the radical changes in the methods and forms of learning and teaching processes.

The paper presents the development of a qualitatively new form of education "Integrated e- Learning" presented in general terms in [3], here exemplified on the teaching unit of Oscillations as the results of the combined effort of several universities in the Czech and Slovak Republic, its utilizations and the first experience with this new teaching technology of physics education. New interactive simulation of oscillations in the system mass-spring with data outputs and transfer is introduced for the first time.

II. INTEGRATED E-LEARNING OF OSCILLATIONS

The strategy of education may be both traditional, based on the accumulation of basic models, laws, cumulatively speaking „the rules“ of the branch. The other, more compatible one is the strategy, similar to that used in the scientific method of cognition of real world [4]. The main features of this method are observations, search for proper information, its processing and storing, organization and planning of work, data and results presentation etc.

As we declare in our paper [2, 3] INTe-L is a new strategy of the cognition of real word in physics teaching based on the following definition: *INTe-L is the interactive strategy of teaching and learning based on the observation of the real world phenomena by the real e-experiment, e-simulations based on the principal features of the physic laws and e-teaching tools as interactive e-textbooks, manuals and instructions providing information and theoretical background for the understanding and quantification of observed phenomena.* The implementation of such a scheme into the teaching of physics is very demanding, attainable only with a decisive support of the latest ICT. Further breakthrough of the ICT in the development of real laboratories was conditioned by the introduction and sophistication of the Internet and its corresponding services that enabled the building of the laboratories under the scheme server – client, so called remote real experiments (RRE) across the Internet in e-laboratories. We would like to illustrate this approach on the example of real remote mass-spring laboratory experiment across Internet as a part of INTe-L of Oscillations.

A. *Oscillations - motivation*

As we have mentioned previously the instructional methodology in INTe-L should be laboratory – based direct experience. So the starting point in this new strategy is an experiment – real hands on or real remote one via Internet at the beginning of the lecture and later in student’s laboratory during laboratory exercises. Very interesting and effective teaching method is Physics by inquiry, developed by Mac Dermott and co-workers [7], we have applied as guided inquiry during or after students observations, drawing inferences, identifying assumption and conditions of experiments, formulating, testing and modifying hypotheses with the goal deep students thinking about problem, resp. more complex problems and their own understanding utilized later in student’s project works.

Oscillations of individual oscillators or continuous media constitute one of the most important parts of the Physics, describing all sorts of motion in the real world [8]. The goal of the basic course of Physics in the chapter of Oscillations is to show the oscillatory movement as a basis of nearly all natural phenomena. As an example we may mention the oscillations of an atom and its constituent particles, the oscillations due to the thermal motion in any real matter, through the periodic motion of any old mechanically driven clock hanging on the wall, up to the movement of planets. The unifying model for all these real world systems is the mass-spring system constituting the mechanical oscillator.

Let us try to explain the basic steps in the INTe-L method exemplified on the teaching unit of Oscillations based on the three constituting components: e-experiment, e-interactive simulations and e-interactive textbook.

B. *Experiments - Oscillations*

In the practical teaching process the starting point of the lecture is the real experiment with pendulum and remote experiment of the oscillations available across the Internet(http://kdt-17.karlov.mff.cuni.cz/pruzina_en.html), enabling the study of both damped and driven oscillations and such phenomena as the resonance and energy transfer. The schematical representation of the classical experiment Driven oscillator with the mass and spring using the system ISES (Inteligent School Experimental System, see: http://www.ises.info/default_a.htm) is in Fig. 1. The experiment provides the possibility of controlling the frequency of the electromagnetic generator producing the external periodic driving force on the weight and collecting the data of the instantaneous deflection (Fig. 2).

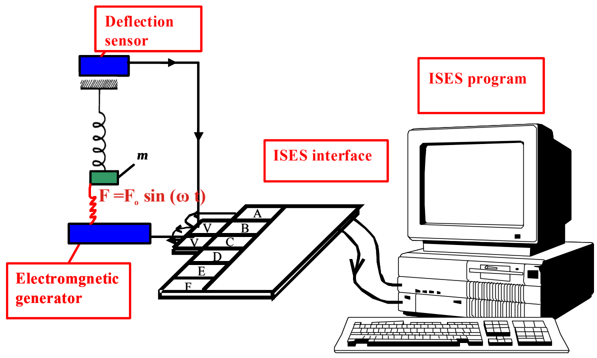

Figure 1. The schematic representation of the remote experiment Driven oscillator with mass and spring using the system ISES. The oscillator consists of the spring and the weight, the external force is exerted by the electromagnetic generator with the variable frequency, all controlled by ISES, the instantaneous deflection is detected by the deflection sensor.

The transferred data give information about frequency and instantaneous value of the driving force and the deflection giving both amplitude of the driven oscillations and their corresponding phase. The usage of the experiment is manifold, determining the own frequency of the oscillator, its damping, the resonance, the amplitude and phase transfer functions (see Fig. 3) and e.g. the energy transfer from the source of the driving force to the oscillator. If used in the student’s laboratory, the students are encouraged to process the acquired data and evaluate the requested quantities of the model oscillator and discuss the obtained results and critically assess the errors of the measurements. Such experiments may be also with advantage used for self study of students, during examinations and may be very useful for the part time – students, where laboratories are not a standard. The distribution by days of the accesses on the web page “Driven oscillator “during monitoring period (X.2006 – VII. 2007) can be seen in the table 1.

C. *Interactive e-simulations of Oscillations*

The next step in teaching the Unit Oscillations by the strategy of INTe-L is to exploit the simulation applets in form of e-simulations for the dynamical animations and for delivering the required information for the support of real world measurements by real remote experiments.

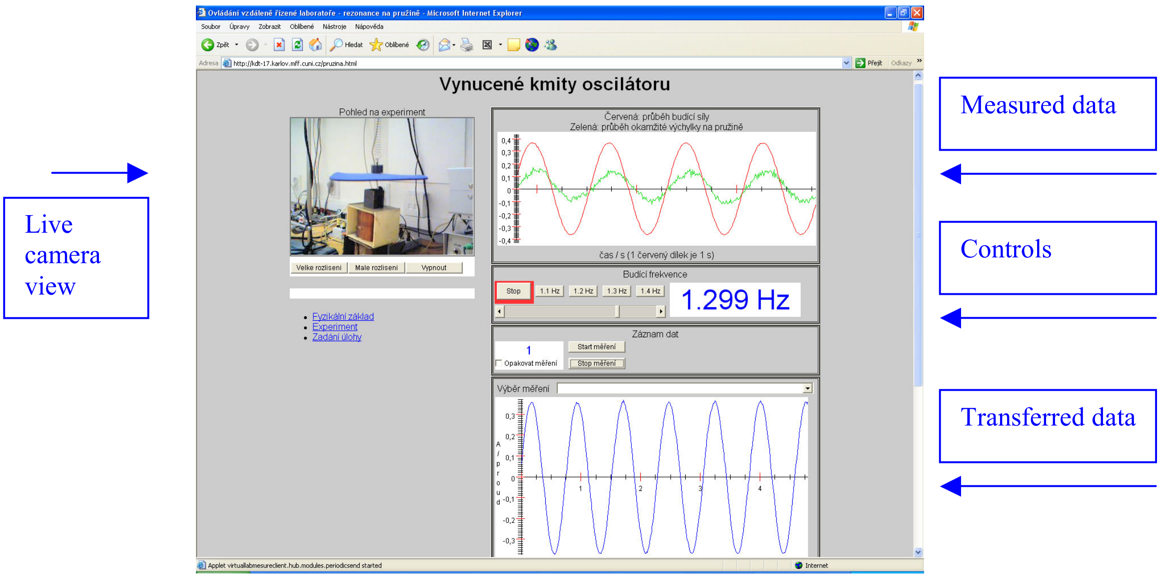

Figure 2. The web page of the real remote experiment Driven oscillator with frequency controls, life web camera view and graph of the measured data (upper plate: red - driving force, green - instantaneous defection, bellow: transferred data – here the driving force, the second part of the transferred data is hidden).

TABLE I.
STATISTICS OF ONLINE ACCESSES OF THE REMOTE EXPERIMENT "DRIVEN OSCILLATOR"

Day	Total number of online accesses from the start of monitoring (X. 2006- VII. 2007)	
	Absolute No.	*Relative in %*
MONDAY	93	16,32
Thusday	101	17,72
Wednesday	111	19,47
Thursday	122	21,40
Friday	67	11,75
Saturday	36	6,32
Sunday	40	7,02
Σ	**570**	100
Arithmetic mean	81	14,21

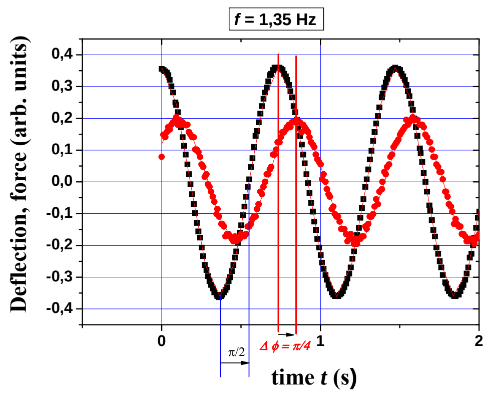

Figure 3. Time dependence of the external force (black points) and instantaneous deflection (red points) of the spring and mass mechanical oscillator measured by ISES system for the external force with below resonance frequency f=1,35 Hz, the phase shift $\Delta\Phi = \pi/4$ is also depicted. The red lines are the least squares fit.

In our case the Driven oscillator animations which can be found on Internet, were used. Here we have used very instructive www page PhET [9] built by the Colorado University, especially system mass spring (Fig. 4) with kinematic, dynamic and energetic displays of the phenomena. For this purpose there are three springs with several masses to be attached (also with the unknown values of the mass) with adjustable spring stiffness and dissipation forces and different gravitational environments.

We have also utilized simulation compiled by Walter Fendt (http://www.walter-fendt.de/ph14e/resonance.htm) [10] (Fig. 5) with nearly identical observables to that of the above mentioned remote real experiment. The applet provides the simple schematic dynamic view of the oscillator; its driving force (red) and oscillator deflection (blue) and their corresponding time representations. The adjustable parameters are spring stiffness, mass of the weight and attenuation with driving force frequency. Very important point of the Fend´s simulation is the possibility to observe the changes of the phase shift above and under the resonance frequency, the same observables as in the real remote experiment, as can be seen in Fig. 3.

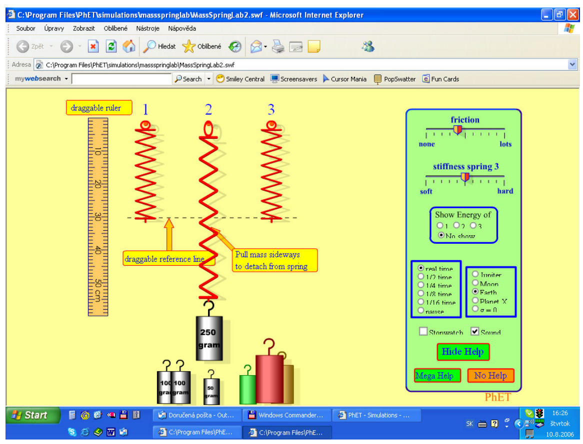

Figure 4. The front page of PHYSLET simulation of oscillations in the system masse spring from the Colorado university (http://phet.colorado.edu/web-pages/index.html)

For our purpose we have concentrated on the extension of the applets in the direction of the calculated data outputs in order to create the computational and modelling environment for the comparison of the real world experiment and model data. As our latest accomplishment, we present here for the first time a new simulation for oscillations, which makes it possible and offer the transfer of the calculated model data to a PC client, as depicted in Fig. 6 [11].

D. *Interactive e-textbook - block Oscillations*

The lesson then continues using the necessary theoretical framework, presented by the teacher, and using the data collected during the experimentation both by real experiment and simulation. For this purpose the e-textbook is used, (e- Physics or Multimedia university textbook of Physics), covering the whole theory for basic bachelor physics course, solved problems and exercises, glossary for quick orientation in the theory covered, multiple-choice tests with immediate evaluation of the acquired knowledge compiled by the team of Slovak physics teacher and continuously upgraded [12,13].

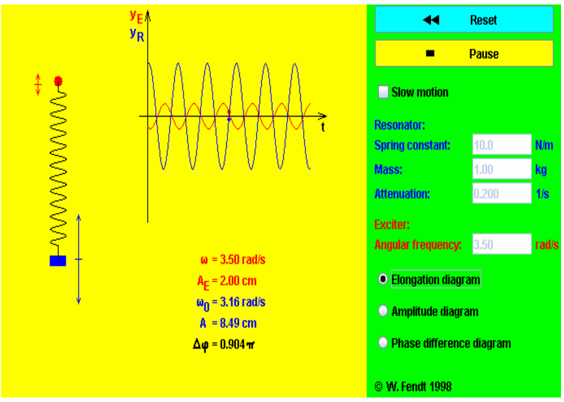

Figure 5. The front page of interactive simulation of driven oscillations in the system mass spring (http://www.walter-fendt.de/ph14e/resonance.htm).

Electronic textbooks and various sorts of tests can be used as a supplement and an enhancement of classical study books. Animations, videos and numerical experiments make study more effective and attractive. Incorporated testing programs enable students to test themselves before sitting for an exam. In connection with Internet such a testing program enables teachers to see how students mastered the given subject matter. The student can utilize them for more detailed study of the theory of observed phenomena. The major advantage, appreciated by students, is availability across the Internet and its lucidity. Students are encouraged to use throughout their study of physics in seminaries, laboratory work and preparation for examinations.

III. DISCUSSION

The pedagogical impact of real hands on or real remote and virtual laboratories, demonstrated by Java applets, on the teaching process is potentially large in the motivation and demonstration phases of lectures and seminaries, when the experiments and applets are used for the introduction.

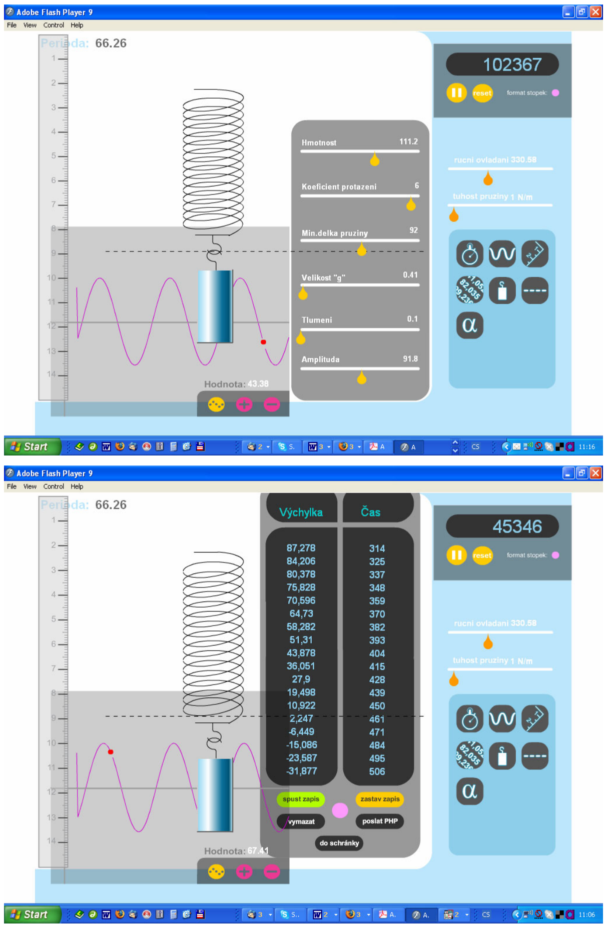

Figure 6. a) Page of interactive simulation of oscillations in the system mass spring [11], b) View of the simulation with data outputs and transfer

The main purpose of simulations is the comparison of the observed and model data and the discussion of the possible differences. Part of the teaching unit is the discussion. Students are encouraged to discuss the main terms, quantities and phenomena as natural frequencies, dissipative influences, energy considerations, resonance, transfer of energy from the source to the oscillator etc., with examples of oscillations in other phenomena in the Nature. The students are encouraged to find examples of the energy transfer in the Nature phenomena and in the technique.

The theory is then provided by e-textbook for explaining the observable phenomena. Electronic textbooks and tests can be used as a supplement and enhancement of classical lecture. Animations and numerical experiments make self-access more effective and attractive. Interactive self-tests with randomly generated questions with immediate evaluation are very popular with students. Self-tests enable students to check their knowledge before, during or after lessons and also before exams, which satisfies both, students and teachers.

At the end of the lecture the students are given the homework in the form of the project, which constituted the part of the final examination. Both real world experiments and applets were then frequently used as a starting point during examination and problem solving method. That method turned out to be very fruitful in suppressing students stress during examinations. The disadvantage of the virtual laboratories is the fact of the potential remoteness of the virtual laboratories from the real world phenomena and laws, as we can see it from computer toys and plays. This trend is absolutely prohibitive for the schooling of natural sciences and engineering [14].

These initial pedagogical experiments with the Remote experimentation in teaching process [15 - 18] and with INTe-L [19] has been realised and experiences gained at the Faculty of Pedagogy, University of Trnava, Slovakia and at the Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava during basic bachelor course of Physics. Standard Research by our group on students conceptual understanding of oscillations has been started.

IV. CONCLUSIONS

Natural science experiments, especially in Physics, play an indispensable role in the curricula. Standard e-learning has not applied up till now experiments into on-line teaching and learning processes. The absence of experiments in all forms of education brings the loss of motivation and of deep understanding of real world phenomena.

The new method to teach more attractive physics course via INTe-L with utilization of remote real experiments and interactive applets and simulations has been suggested and demonstrated on important part of physics – on oscillations.

The main conclusions may be formulated as follows:

- INTe-L is a non-traditional method which provides a mechanism for motivation of students in physics education in particular and science and engineering in general and it represents the new generation of e-learning.
- ICT supported education via real remote experiments together with interactive applets may increase the students interest in natural science and technical disciplines and real world phenomena.
- Assessment of the first two years of application of INTe-L used both in present and part-time form of study indicates that the methods is successful in meeting goals in accordance with M. Planck`s claim [20]:

  "The ultimate and the highest goal of education is not a knowledge and a skill but a practical activity. However, in as much as a skill precedes any practical activity, it is a knowledge and a comprehension which are the necessary prerequisite for a skill".
- It is premature to draw finite conclusions of the project of INTe-L due to its relatively short duration. In spite of this we can conclude, that the participating students and instructors find education via INTe-L as a highly progressive, effective, affordable, helpful and attractive way of education. Students confirmed via questionnaire that this form of study is helpful for them.
- Prepared English version of round clock accessible Internet e- Laboratory will serve not only for Slovakia and Czech Republic, but will be available globally for education in natural and material science.
- The remote real experiments may be also with advantage be used for self-study of students, during examinations and may be very useful for the part time students, where laboratories are not available.
- The human factor, provided by high-level teachers counseling and feedback is another factor influencing the success of INTe-L method.

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REFERENCES

[1] C. L. Mc Dermott, P. S. Shaffer and C. P. Constantinous, *"Preparing teachers to teach physics and physical science by inquir,"* Phys. Educ. 35, vol. 6, 2000, pp. 411-416.

[2] M. Ožvoldová, F. Schauer, P. Čerňanský, J. Krepmapský and F. Lustig, *"Integrated e-Learning – New Strategy of Integrated Teaching of Natural Sciences"*, to be published in Europ.J..Phys.

[3] F. Schauer, M. Ozvoldova, F. Lustig, *"Real Remote Physics Experiments across Internet– Inherent Part of Integrated E-Learning,"* Proceeding of ICL 07,Villach , Kassel University Press, 2007, Austria, ISBN 3-89958-195-4.

[4] C. Wieman and K. Perkins, *"Transforming Physics Education,"* Physics Today, Physics Today, V 58, pp. 36-41, 2005.

[5] S. Jeschke, O. Pfeiffer, R. Seiler and C.Thomsen,*"eVolution: eLTR- Technologies and thier Impact on Traditional Universities*, in Proceeding EDUCA online 2005, ISWE, Berlin 2005.

[6] S. Jeschke, O. Pfeiffer, R. Seiler and C. Thomsen: *"e-Volution an deutschen Universitäten: Chancen und Herausforderungen durch eLearning*, eTeaching & eResearch, Medien in der Wissenschaft, Bd.34, Auf zu neuen Ufern, ISBN 3-83091557-8.

[7] L. Mc Dermott and at al., Physics by Inquiry, Vol. I, II., John Wiley 1996, USA.

[8] L. G. Baker, J. A. Blackburn, *„The Pendulum a case study in physics,"* Oxford University Press, 2006.

[9] http://phet.colorado.edu/new/simulations/sims.php?sim=Masses_and_Springs

[10] W. Fendt, http://www.walter-fendt.de/ph14e/

[11] F. Schauer, F. Lustig, M. Dekar, *"New type of Interactive Applets with Data Output"*, to be published.

[12] M. Ozvoldova et all., *"Multimedia university textbook of Physics*, Part I, CD ROM, Trnava University press 2007, ISBN 978-80-8082-127-2.

[13] M. Ozvoldova at. al., *"e–Physics,"* Slovak University of Technology, 2005 http://kf- lin.elf.stuba.sk/~ballo/fyzika_online.

[14] S. Jeschke,. T. Richter, H. Scheel, R. Seiler, C. Thomsen, *"The Experiment in eLearning Magnetism in Virtual and Remote Experiments.*" in Proc. ICL 2005, Villach, 28.-30. 09. 2005, Kassel Uni. Press, 2005.

[15] M. Ozvoldova., F. Schauer , F. Lustig, *"Internet Remote Physics Experiments in a Student Laboratory"*, Innovations 2006, World Innovations in Engineering Education and Research, iNEER Special Volume 2006, pp. 287-295, 2006, ISBN 0-9741252-5-3, 2006..

[16] F. Schauer, F. Lustig, M. Ozvoldova, *„Remote Material Science Internet Experiments Exemplified on Solid State Photovoltaic Cell Characterization"*, Journal of Materials Science Education, Vol. 29 (3-4), pp. 193-200 , 2007, Denton, TX 76203-5310, USA; http://www.unt.edu/ICME/. ISSN: 0738-7989.

[17] M. Ozvoldova, P. Cernansky, F.. Lustig,, F. Schauer, *„Internet Remote Physics Experiments in Student's Laboratory*, "in Proceedings of the International Conference on Engineering Education, Silesian University of Technology, Gliwice, Poland, V 2, pp.794 –799, 2005.

[18] M. Ozvoldova, P. Cernansky Lustig, F.. Schauer, *" Experience with Remote Experiments in Student´s Laboratory,"* Proc. 4th Intern. Conf. Physics Teach. Eng. Educ., PTEE 2005 Brno, CZ CD pp. 4, ISBN 80-903063-6-5, 2005.

[19] F. Schauer, M. Ozvoldova, F. Lustig,, *"Prof. M.Lánsky vision fulfillment: e-research as a missing link in the interdisciplinary cybernetisation of teaching process,"*, in Proc. Intern. Conf. Education in the mirror of time, Nitra, September 2006, Univerzita Konštantína Filozofa, Nitra, 2006, ISBN 80-8050-995-6.

[20] L. Bulavin, V. P. Privalko, Y.F. Zabashta, *"Strategies for the Development of Physical Thinking in the Teaching of Materials Science,"* Journal of Materials Education V 27, (1-2), pp. 33-42 , 2005.

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