PHYSICS LABS FOR INTEGRATED E-LEARNING: CLASSICAL REAL, REAL REMOTE AND VIRTUAL

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Abstract: The paper introduces the integration of three ICT and computer oriented laboratories, namely traditional computer based laboratory, remote real laboratory across the Internet and virtual laboratory. We present the system composed of the system ISES (Intelligent School Experimental System), remote real experiments across the Internet with software ISES WEB Control kit and examples from virtual laboratory from the Colorado University – PhET. This system of laboratories served for our experimental studies in the direction of Integrated e-Learning.

Key words: Real laboratory, real remote laboratory, virtual laboratory, Integrated e-Learning, Internet, ISES

1 Introduction

The physics teaching strategy of education based on the classical stereotype , i.e lecture – seminary – laboratory exercise and on the accumulation of basic models, laws, cumulatively speaking „the rules“ of the branch undergoes a crisis. [1] [2]. The other, more compatible one, is the strategy, similar to that used in the scientific method of cognition of real world [3] or the alternative method of e-LTR [1]. The main features of these methods are observations, search for proper information, its processing and storing, organization and planning of work, data and results presentation etc. In this method of education the experiment and experimentation plays a decisive role [4] In turn, in experimental laboratories a silent revolution has taken place due to the massive invasion of personal computers (PC) and information and communication technologies (ICT) [5]. Experimental working places for the teaching purposes provide real experiments using nowadays omnipotent computer for the data collection, processing and evaluation. The second, fast developing area of the physics experimentation in teaching are remote e-laboratories. Many real remote e-laboratories across the Internet have been published that provide experiments on real world objects, supplying the client with the view of the experiment, interactive environment for the experiment control and resulting data for evaluation [6]. The third and new area to be named are the virtual e-laboratories [7], where simulations create the virtual reflection of the real word objects and their characterisation, going to the least details as are mistakes and errors and noise influence. In the physics community the vivid discussion is taking place about the place and applicability of all these new forms of experimental work in teaching [4] [5] [7].

The present paper wants to contribute to the discussion about new forms of experimental work in physics education in a constructive way, giving the experience based on the recently introduced new form and technique of education, Integrated e- Learning [8] (INTe-L), and show on the example of the teaching unit Oscillations, how real experiment, real remote experiment and virtual experiment may be with advantage combined with the impressive pedagogical gain. We choose the topic of the oscillator in its forced version, as we consider understanding of its properties central in the understanding of many phenomena in micro and macro world, from atomic to planetary motion.

2 Real physics laboratory with the computer

The first computers in laboratories, some two decades ago, served exclusively for the collecting of the data and their simple processing. Later, many measuring software and hardware were built with bringing new qualities in the physics experiment. As the example may serve the system ISES (Intelligent School Experimental System), whose first version came into existence in 1991 [9] and since then constantly upgraded till contemporary form [10]. The system is now composed of an interface (12 bit Analog Digital–Digital Analog (ADDA) PCI card with sample and hold, maximum sampling frequency of 100 kHz, 4 analogue inputs, 2 analogue outputs, 4 binary outputs) a set of variable modules and sensing elements, and a service graphic and evaluation program [11].

The schematical representation of the classical experiment Forced oscillation with the mass and spring using the system ISES is in Fig. 1. The experiment provides the possibility of controlling the frequency of the electromagnetic generator producing the external periodic force on the weight, collecting the data of the instantaneous deflection. From these data, the time dependence of the force and deflection for fixed frequency of the external force (example is in Fig. 2) a lot of information on the oscillator can be derived like amplitude and phase characteristics and its properties and behaviour like its own frequency, damping and quality factor, resonance frequency, energy transfer from the generator of the external force.

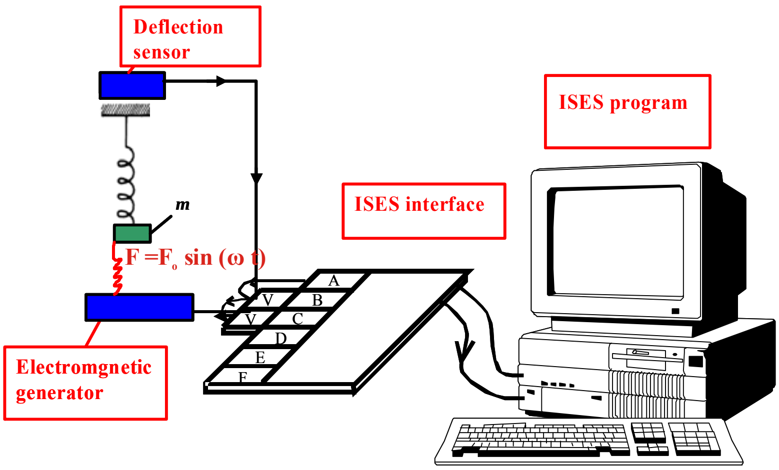

Fig. 1 The schematic representation of the classical experiment Forced oscillations with mass and spring using the system ISES. The oscillator consists of the spring and the weight, the external force is exerted by the electromagnetic generator with the variable frequency, all controlled by ISES, the instantaneous deflection is detected by the deflection sensor, the data are depicted and processed by ISES software.

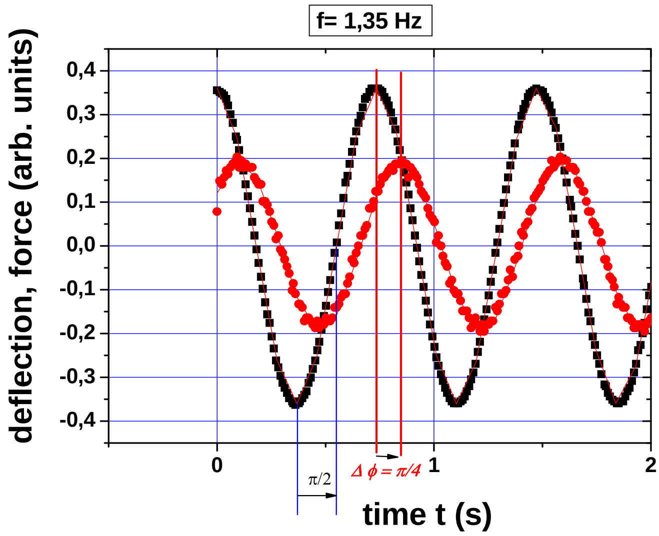

Fig. 2 Time dependence of the external force (black points) and instantaneous deflection (red points) of the spring and mass mechanical oscillator measured by ISES system for the external force with below resonance frequency f =1,35 Hz, the phase shift $\Delta\Phi = \pi/4$ is also depicted. The red lines are the least squares fit

The arrival of computer oriented experiments marked the breakdown in physics experiments. The enormous advantage of a computer oriented experiment is obvious and rests mainly in the availability of the experimental data and the possibility to process and evaluate it for meaningful study and discussion. Their disadvantage rests in the limited possibility to use such experiment in other forms of the teaching, especially in lectures, examinations, and discussions with students - in all cases outside of laboratories. It is also not available outside the campus of the University. The overall experience and present state of the ISES system will be reported elsewhere [12].

3 Remote real e-laboratory

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. First remote experiment, using the ISES and the common web browser and active Java, was built in 2001. In this system, the experiment is first built using standard ISES hardware. Then, using the software package ISES WEB Control kit (software compiled in 2001 and refined since, available on demand [13]) the server of the remote experiment is devised, enabling the transfer of the view of the layout and function of the experiment and providing the corresponding data transfer to the client. It should be stressed that this procedure of creating the server for the remote experiment is relatively simple, as it is based on copying and paste principle, adding only parameters of the experiment. The function of the server – client scheme of the remote experiment is straightforward. On the server side the web pages are generated using Java applets and sent to the client. These web pages create in the client computer control keys and bars for the control of outputs, applets for measuring and digital displaying of input values, applets for graphic displaying of input values, applets for the transmission of measured values into the client computer, applets for the image transmission from a WEB camera, etc.

In Fig. 3 are several examples of modular Java applets from ISES WEB Control kit as building tools and blocks for remote experiments construction: display (a), control slide (b) and graph for data presentation (c). The kit consists up to now of 18 applets with great flexibility for the user.

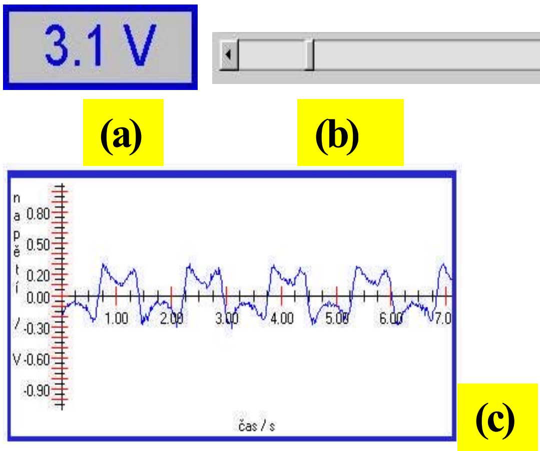

Fig. 3 Examples of modular Java applets from ISES WEB Control kit [13] as building tools and blocks for remote experiments construction depicting: (a) display, (b) control slide, (c) graph for data presentation.

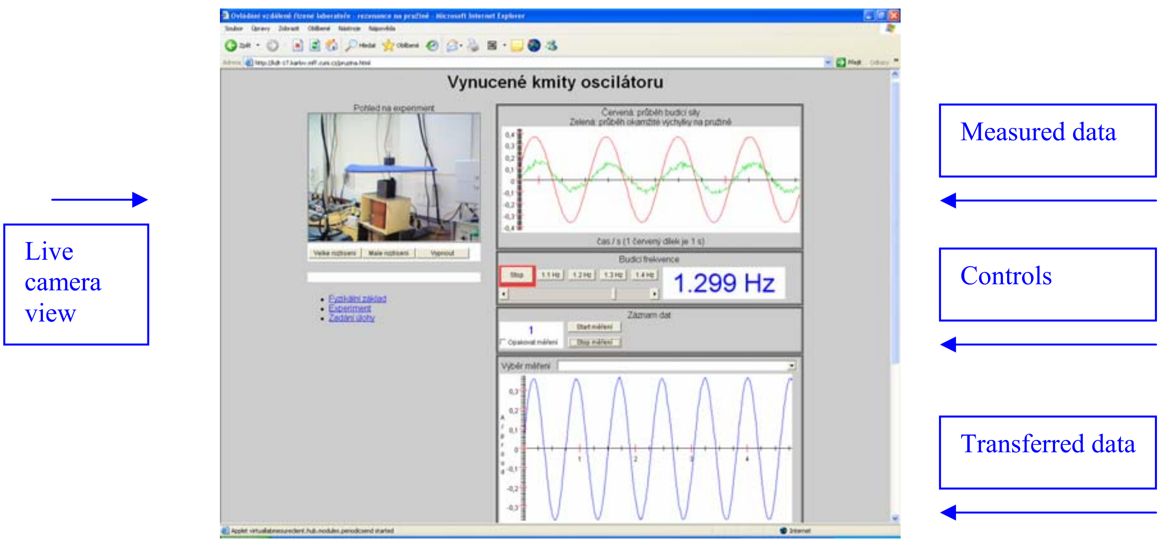

Fig. 4 The web page of the real remote experiment Forced oscillator with frequency controls, life web camera view and graph of the measured data (upper plate: red - driving force, green - instantaneous deflection, bellow: transferred data – here the driving force, the second part of the transferred data is hidden).

In Fig. 4, there is the web page of the remote experiment Forced oscillator (http://kdt-17.karlov.mff.cuni.cz), enabling the study of both damped and forced oscillations and such phenomena as the resonance. The transferred data give information about frequency and instantaneous value of the driving force and the instantaneous deflection giving both amplitude of the forced 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 and e.g. the energy transfer from the source of the driving force to the oscillator.

Generally speaking the advantage of remote real e-laboratory is enormous, as in general exhibits all the features of the real physics experiments with the computer, with some added quality, given by the possibility to use it independently on the laboratory. Thus the way is opened for the introduction of such experiments in lectures, seminaries, examinations, self study of students independently round the clock, distant students and disabled. The reservation system compiling and the tracing of the student's activities during the measurements systems are being compiled at present. The overall experience with and the present state of the ISES system based remote laboratories will be reported elsewhere [14].

4. Virtual e-laboratory

For the purpose of the INTe-L we used during this study predominantly the simulation of Forced oscillations in Fig. 5, providing the same sets of the data as depicted in Fig. 2 or Fig. 4, compiled by Walter Fendt [15] from the University of Magdeburg. The Java applet (Fig. 5) provides the simple schematic dynamic view of the oscillator, its driving force (red) and weight deflection (blue) and their corresponding time representations in the graph. The adjustable parameters are spring stiffness, mass of the weight and attenuation with driving force frequency.

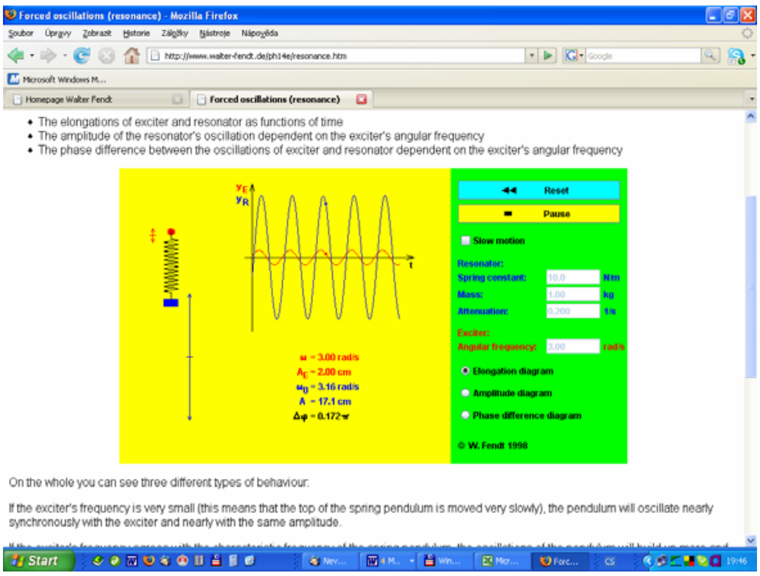

Fig. 5 Example of the Simulation. Forced oscillation (http://www.walter-fendt.de/ph14e/resonance.htm)

As the example of the very suitable virtual laboratory we use also the interactive simulations and applets from very instructive www page of the Colorado University - PhET with plenty of applets, covering the usual scope of physics [16]. In Fig. 6 there is a instructive Java applet Mass and springs with kinematic, dynamic and energetic display of the data. For this purpose there are three springs with several masses to attach (also with the unknown values of the mass) with adjustable stiffness and dissipation forces and different gravitational environments.

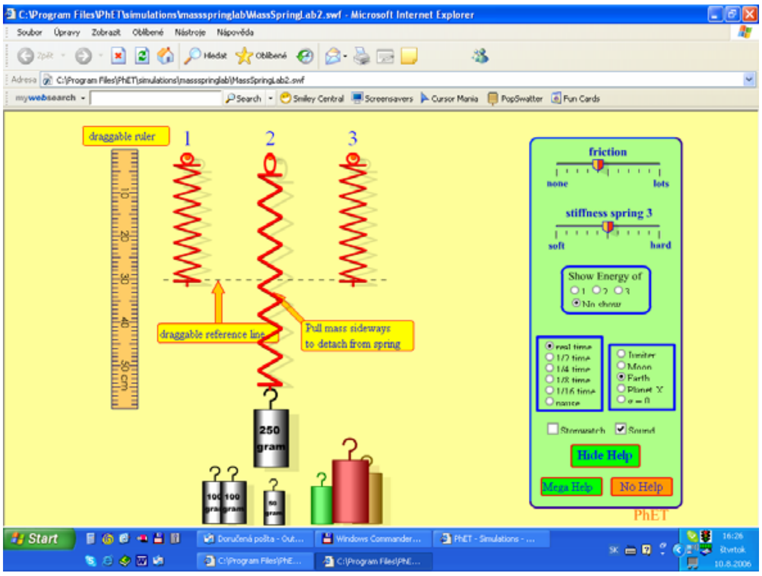

Fig.6 Example of the Simulation - Masses and springs from the Colorado university (http://phet.colorado.edu/web-pages/index.html)

The pedagogical impact of virtual laboratories on the teaching process is potentially large in the motivation and demonstration phases of lectures and seminaries, when the applets are used for the introduction to the topic. For our purpose we concentrate 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 real world and modelling data. 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 [7].

5. Conclusions - Real, Remote real and Virtual Laboratories for Integrated e-Learning

The INTe-L, as a new strategy for the physics education, where the experiment and experimentation plays a decisive role, calls for new types of experimental e- laboratories [4]. The INTe-L is based on the methods of the cognition of real world and thus on the methods, sciences have built as their working method. Their characteristic features are observation of phenomena of the real world, search for relevant information and their sorting and storing, organization and planning of work, data and results presentation and conclusions generalization and drawing. For the teaching process based on the cognition process the active approach, motivation and involved active discovering are decisive, the strict elucidation of all encountered problems and strict fulfilment of the study plan are of less importance.

The crucial question in INTe-L is the experiment. The question arises, which form of experiment or their combination, we choose as a starting point of the study a unit of Oscillations and Waves, to arose the interest and curiosity and general interest in the topic or phenomenon in question. As many studies show [17] the choice of modern, more interesting and simple representations are obligatory, as the susceptibility of the students to grasp the phenomena from their mathematical formulation and graphical representation is rather decreasing. The contemporary possibilities in e-laboratories are manifold, providing real physics laboratory with the computer, real remote e- laboratories and virtual e- laboratories.

In our three years experience of the formulating the goals and plan of the INTe-L, we concentrated on the teaching unit Oscillations and Waves [18]. As the previous experience shows, the real physics experiment or demonstration, even with the computer, is, with some stipulations, the most effective, especially in less populated groups. The main disadvantage is very time consuming in the phase of preparation, technical background of the working place and professor skill. The real remote experiment seems to be the best means in all phases of teaching process, both lectures, seminaries, projects, self study and discussions and examinations. It is surprising, how the experiment with suitable chosen parameters and data transfer may be used on “spiral” principle and on different levels of teaching process.

So, in the units Oscillations we started the lecture usually with the motivation experiments of the mathematical pendulum, mass and spring oscillator and electromagnetic oscillator, stressing their unity and discussing the significance of Oscillations in real world phenomena. Then we used the applets of Walter Fendt [19], PhEt [20] or with advantage the CD with Java applets by [21] or the e-textbooks applets [22] and presented the graphical time presentations of the oscillatory movement both not damped, damped and forced and its parameters. To our surprisal we have discovered the virtual e-experiments, both Java and Flash, are the best means for motivation and concept formulation. We have also successfully used the applets for the projects, testing if the physics background of the applet is working, complying with the physics (and thus with real world) laws and finding the potential deviations. The virtual e-experiments served for arousing discussion and questions both from students and teachers, e.g. about the role of gravity, what are the main parameters of each type of oscillations, energy issues and the relation to damping. The last and the most decisive step in the experimental part of the lecture was the remote real e-experiment Forced oscillator [23], where both qualitative and the quantitative measurements with the data transfer are possible. At this stage the students were ready and motivated for the explanation of the observed phenomena and formulation of the dynamic equations of motion and their solutions, with the possibility of their discussion on the basis of the experiment. At the seminaries the detailed examination of all these phenomena continued to greater detail with the solving of the computational examples. The experimental work of the students then continued in several ways measuring the more complex oscillators, examining and studying the remote real experiments and also studying in more details the e-experiments on oscillations in virtual laboratories. The students were then led to produce the written reports of their projects as the outputs of their activities. Some of the students were invited to speak and presented their results during the lessons in the more organized way, some students took part in the faulty competition for the best students scientific activity of the year under supervision of the teachers of the department. The students could deepen their interest in the INTe-L in accompanying subjects PC oriented laboratory work using ISES, simulations and applets from physics and physics phenomena of the real world.

The main conclusions from the tree years trial with the INTe-L are positive. All the three forms of the e-laboratory merged with advantage as a main and decisive block of INTe-L. The students are much more motivated to examine topics in question, with the stimuli for the exploration of real world phenomena. Besides, students acquire new skills both in experimental techniques, but also in ICT and data processing and their presentations.

All these advantages that bring the new forms of e-laboratories are also supplemented by the possibility for the students of the department to study both concurrently and also for self study for examinations independently on any planning and technical means of the department in their hostels, flats and at home. A special benefit brings all the presented to the distant students of the department. It also brings enormous possibility for insemination of knowledge and e-teaching globally and to those, hitherto discredited from the University schooling for different reasons. This topic deserves special attention in future.

It is fair to mention that all these new forms of education, acquiring the form of blended education, call for reformulating the goals and objectives of syllabi, need the deep support of the University authorities in the direction of new syllabi and education organization, including the infrastructure, the teachers preparation and last not by least the Accreditation commissions understanding and approval for these new and pioneering approaches.

6. Acknowledgment

The authors acknowledge the support of the following projects: Grant of the Ministry of Education of the Czech Republic project "E-laboratory of remote interactive physics experiments", 2007 and Grant of the Ministry of Education of the Slovak Republic KEGA, project N 3/4128/06 „E-laboratórium interaktívnych experimentov ako pokračovanie projektu multimediálnej formy výuky fyziky na univerzitách SR" 2006-2008.

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