Easy to Build Remote Laboratory with Data Transfer using ISES – Internet School Experimental System

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Abstract
The present state of information communication technology made it possible to devise and run computer based e-laboratories accessible to any user with the connection to the Internet, equipped with very simple technical means and making full use of web services. Thus, the way is opened to a new strategy of education of physics with strongly global features, based on experiment and experimentation. We named this strategy Integrated e-Learning and remote experiment across the Internet is the foundation for this strategy. We present both pedagogical and technical reasoning for the remote experiments and bring the outlines of the simple system based on the server-client approach and on the web services and Java applets. We give here the outlines of the prospective remote laboratory system with data transfer using Internet School Experimental System (ISES) as hardware and ISES WEB Control kit as software. This approach enables the simple construction of remote experiments without building any hardware and virtually no programming, working with paste and copy approach of pre built typical blocks as camera view, controls, graphs, displays etc. We set up and operate at present 7 experiments, running round o clock, with more than 12 000 connections since 2005 and give the near outlook for their building. The experiments are widely used in practical teaching on both secondary and university level of teaching of physics. The recording of the detailed steps the experimentator takes during the measurement enable a detailed study of psychological aspects of running experiments. The system is prepared for the starting the network of universities covering the basic set of physics experiments In conclusion we summarize the achieved results and experiences with remote experiment built on the ISES hardware system.

1. Introduction

Many students perceive physics as a difficult subject, dealing with the abstract laws and models not describing the real world and so without much of help for their future carriers in both engineering and natural sciences. The physics teaching strategy of education based on the classical stereotype, i.e. lecture – seminary – laboratory exercise based on the accumulation of basic models, laws, cumulatively speaking „the rules“ of the branch undergoes a crisis [1]. The other, more compatible strategy to the present state of the society is that used in the scientific method of cognition of real world [2] or the method of e-LTR (e-Learning, e-Teaching and e-Research) [3]. 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]. Traditional laboratory work courses do not comply with these trends; therefore it is necessary to redefine the learning targets and to reconsider the learning methods. The project work based on the theory of constructivism [5] and blended learning [6] will play a decisive role in laboratories and the idea that project laboratories will be the typical learning environment for physics and engineering students for the next generation is very probable [7]. In experimental laboratories a silent revolution has taken place due to the massive invasion of personal computers and information communication technologies (ICT). Experimental working places for the teaching purposes provide real experiments using nowadays omnipotent computer for data collection, processing and evaluation. The second, fast developing area of the physics experimentation in teaching is remote e-laboratories with remote experiments (RE). 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. Recently, two European activities arose interest in Remote physics laboratories. The project Pearl “ Practical Experimentation by Accessible Remote Learning “ [8] and the project “Remotely Controlled Laboratory” [9]. The gathered experience, the inventory of the state of the art and corresponding references in Europe and United States are to be found there.

In the presented paper we want to add to those activities in a constructive way. We know, from our own long lasting experience, once the University or the Department and/or their teachers decide to build the RE, the main obstacle is often not the financial requirements of the RE, but the technical and know how of the ICT and the corresponding knowledge with the client-server communication and its establishing.

With the following paper we intend to offer the remedy to this situation and provide help with available hardware and software solutions enabling easy building of both computer based real experiments and their straightforward transformation to the real RE across the Internet. It is based on the scalable building set for the construction of natural science experiments, including physics, - ISES (Internet School Experimental System) [10] and ready for use software for easy and simple creation of remote experiments - ISES WEB Control [11]. Further we bring the overview of the two decades lasting activities in real physics experiments with computer and the present state of the e-laboratory of remote experiments with the data transfer using only the web services with common web browser and active Java support on the side of the remote experimentator. The potential and future possibilities of the ISES systems in connection to the RE are also discussed.

2. Reasoning for remote laboratories

The general consensus among the academic staff and the authorities of the universities exists about the weight and importance of laboratory work in science and engineering in general, and in physics in particular. On the contrary, in a real university life, due to manifold reasons, including the need for new instrumentation, new techniques and methods, and resulting costs requirements, the quality and the role (expressed in teaching hours) of the laboratories start to diminish. Besides, the laboratory work is usually only loosely bound to the time schedule of the lectures and seminaries and, at majority of universities, consists of the lists of experiments with the more or less given recipes, the strict objectives and goals to be achieved by the student within the planned teaching hours. It is then a common habit to have a fixed prepared laboratory working places with experiments for the whole term with students "circulating " individual experiments in an arbitrary way. In this way the access of the students to the laboratories for their independent and self study work without tutor is not accounted for by the planning. The same goes for the students of distant education and students, who, for variety of reasons, are excluded from the laboratory work.

The general and the most decisive criterion for the introduction of the remote laboratories in our case was the trend to draw students more into practical experimental work and to remove the barriers for the possibility for independent laboratory work. The provision of remotely controlled real experiments accessible over the Internet can potentially positively address all these issues.

- The remote real experiments in most cases work in round o clock regime. Students and those interested may choose optimal for them time and work at their most suitable speed. If the instructor presence is required, the reservation system for the experiment is needed.
- The access to the costly and potentially safety risk experiments is feasible.
- The introduction of the students in a natural way into the real contemporary world of science and technique, with the team work mediated by computers and web and organized on distance and so building corresponding skills.
- The university premises do not limit the access to the RE, but a computer and the Internet mediate them. The group of distant students may profit from RE. At the present scheme of organization, they work in laboratories in blocks covering more then one laboratory experiments, completely independent of lectures. RE positively influences the very populated group of people who, for different reasons, are excluded from the laboratory work.
- The remote experiments support the idea of globalisation and delivery of experiments to underdeveloped countries.

When RE are introduced, the provisions for the high quality educationally effective interface design, instructions for the experiment, questions and problems connected to the experiment, the further reading texts, the possibility and the way of the communication with the help and the instructor. These all are of paramount importance. Students should concentrate during the measurement and subsequent data processing on the examined phenomena and not on the instrumentation and its function. Also, they should from the very beginning of the work with the RE know what to measure and what to observe and thus the communication web page on their computer should be as simple and self explanatory as possible, without unnecessary details and formulas. The centre of gravity in RE should be in data processing and evaluation after their transfer to the client (experimentator) computer.

3. Pedagogical issues

In searching for the pedagogical reasons to introduce the remote laboratories it is valuable to summarize the skills and benefits of the laboratory work that may be acquired. [12,13]. All these skills and benefits should be taken account when building a remote experiments. On top of this, without the claim of being exhaustive, that the present students should learn and make full use of the advantages, the ICT and Internet brings to the laboratory work. In majority of progressive university laboratories the computer found its way into experiment in various ways, from data collecting (functioning and replacing e.g. analogue and digital oscilloscopes), through their filtering from noise to the simple processing and exporting to the graphical processors for presentation. Our own experience and the golden rule in the introducing the computers into student laboratory is the claim for the computer to remove the routine work, not encroaching the borders of the physics principles and laws of the examined phenomenon. The Internet opens in itself the possibility for the search for information and supporting material, enables the comparison of his/her results with others.

The above given potentialities and assets give us the reasons for the introduction of RE, let us enumerate the most important.

1. To substitute "recipe labs" [14] by research laboratories

Laboratory classes in traditional laboratories typically involve students performing teacher-structured laboratory exercises or experiments. Each step of a procedure is carefully prescribed and students are expected to follow the procedures exactly. Usually, little is left to the student's own thought or ingenuity. This requires little student engagement with the content, and as it is commented in [15], "students can be successful in their laboratory class even with little understanding of what they are actually doing". In [16] the authors suggested that the recipe lab "omits the stages of planning and design" and it encourages 'data processing' rather than 'data interpretation'. In [17] the authors developed this further by commenting on the various steps a research scientist would take before actually getting to the practical aspect of the experiment by asking: What questions are we trying to answer? What observations would provide an answer to the questions? How can we best create conditions for making the desired observations? How will we process and evaluate the observations? What will we do next?

RE provide more scope for skills development and understanding of concepts and of the experimental process. The students get experience of the whole scientific process in a relevant and stimulating format. Furthermore, they seem to enjoy the experience of working by the method of **trials and errors** and the method of **hypothesis formulations and their proving or disapproving** as the most idea generating methods in the scientific method of work; at the same time this is the main objection against introduction of virtual e- laboratories [8].

2. Project work by RE

Once we have introduced the research laboratories using RE, we can also start to think about project education [18]. The problem solving students encounter in their projects with RE help to learn a set of important concepts, ideas, skills and techniques that will be required in subsequent subjects and their future carriers. This form of education constitutes an enormous change; students must be willing to take charge of their own learning and to cope positively with the attitudinal shifts that occur when they experience change. The enormous advantage of this approach is the possibility to work at any time, suitable for students from any destination they choose and at the most matching rate.

3. Skills students acquire

The question of additional acquired skills is very obvious in RE work On the one hand students are forced to measure independently and, on the other hand, they can easily share experience with RE. On top of this, the tutor, or other sources of information on the RE, is easily available. This forces students to exchange information, knowledge and know how in the team work. This supports awareness in himself as the planning of work, necessity of selecting appropriate techniques and procedures and understanding of errors is necessary. Further, the main feature of project work forces students to analyse and evaluate the obtained data. The project work using RE strengthens the possibility to measure and observe events of the real world and its peculiarities and thus serves as introduction and generation of interest in general science issues and learning of presentation of the gained results.

The additional gained skills in ICT and in the Internet operating are quite important and obvious, but above all the endeavour of the university teachers to struggle with the deeply seated and broadly exercised by students notion about the Internet as the ICT environment suitable for chatting, playing and surfing, but not appropriate for serious, especially scientific work.

To optimise pedagogical and educational goals of RE a constant feedback of its effectiveness and operation should be provided. The statistics of the visits of individual experiments with the detailed recording of the activities split into individual steps and corresponding times spent are imperative for the pedagogical research and constant improvement of the both hardware and software of RE, similar as the pedagogical research on the efficiency of applets [19].

4. Technological aspects of remote real experiments – ISES and ISES web control

The present state of the ICT in the area of measurements, data collection and transfer using the web services is rather complicated and not clearly arranged for the physics teacher to build the remote real physics experiment. Missing standards lead to many individual solutions, and therefore to unnecessary hurdles for hosts and users [9].

To build the remote real physics experiments requires as the first step to set up the computer controlled experiment. In our laboratory, the friendly in use hardware and software for easy building of physics experiments - Internet School Experimental System (ISES) - has been constructed [20]. It forms the basis of our approach to the simple and prospective building of remote experiments. Its detailed description and philosophy is reported elsewhere [20]. Here we will mention only few simple facts important in relation to the RE building. ISES is an open system working under Windows operating system with all its advantages (OLE and multitasking).The system is composed of the interface card, the set of variable modules and sensing elements, and the service graphical and evaluation software (see figure1).

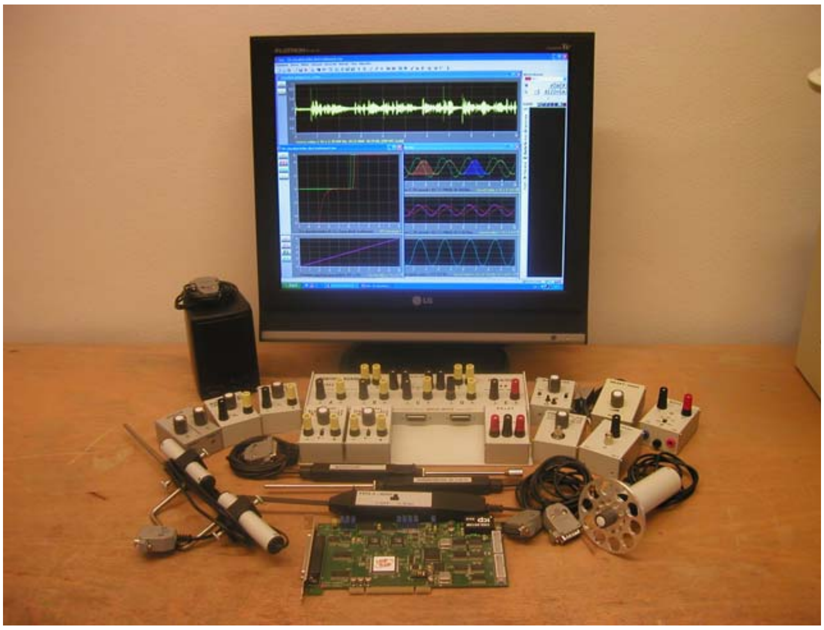


Figure 1. ISES-Internet School Experimental System [20]

Once the computer oriented experiment using ISES system is built, the second step in the building of the real RE across the Internet is needed, i.e. the establishing of the classical server-client connection with the data transfer from the server to the client and in the reversed direction for the control of the experiment by the client (experimentator). For this purpose, we built the software kit ISES WEB Control [23] for the easy transformation of the computer oriented experiment based on the ISES system to the RE (with server-client approach), using only the web services, web pages and Java support on the client side based on the copy-paste principle of the prefabricated building blocks with only very limited knowledge of the rules of web pages creation using suitable editor at hand. The schematical representation of the RE "Natural and driven oscillations " using ISES hardware and ISES WEB Control software is in figure. 2

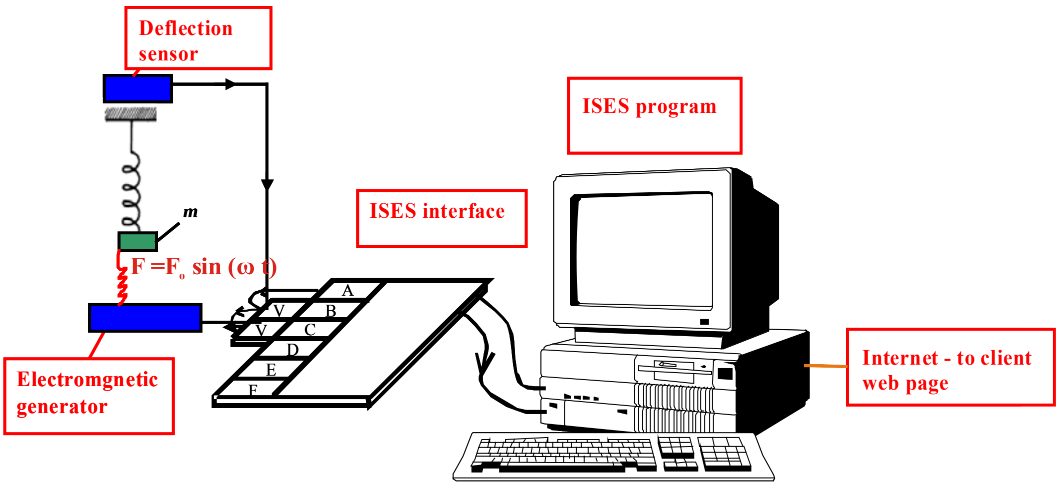


Figure 2. The schematic representation of the server of the remote experiment "Natural and driven oscillations " with mass and spring using the system ISES.

In figure 3 there are the examples of the typical prefabricated controls for the set up of client web page. The present ISES WEB Control kit consists of 15 typical Java applets with great flexibility and adjustable parameters enabling to build web pages for controlling the majority of physics experiments on the client side and in figure 4 is the example of the control web page for the RE “Natural and driven oscillations ” (with life web camera view, frequency controls, and graph of the measured data - upper plate: red - driving force, green - instantaneous deflection). In figure 5 there is the data transfer to the client computer for further plotting, processing and evaluation.

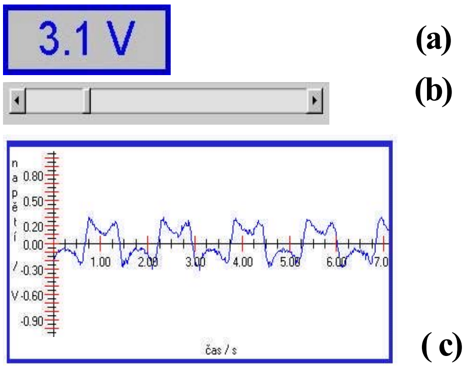


Figure 3. Examples of modular Java applets from ISES WEB Control kit [23] as building tools and blocks for remote experiments web control pages (a) display, (b) control slide, (c) graph for data

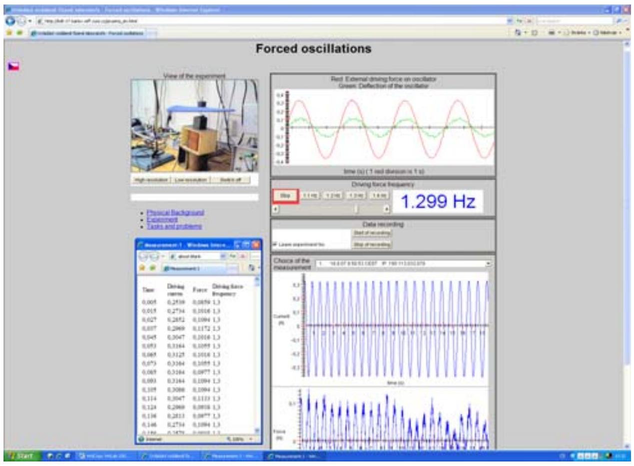
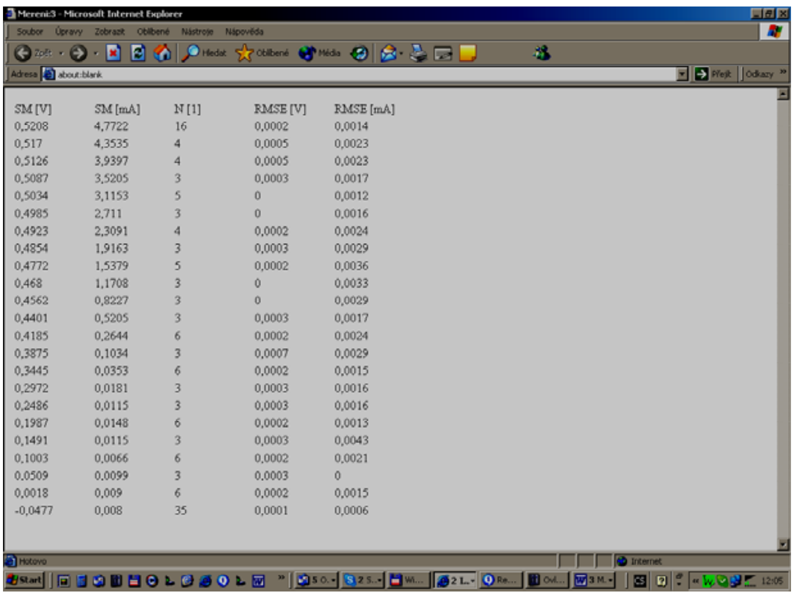


Figure 4. The web page on the client computer of the real remote experiment “Natural and driven oscillations” with life web camera view, frequency controls, and graph of the measured data (upper plate: red - driving force, green - instantaneous deflection).



SM [V]	SM [mA]	N [1]	RMSE [V]	RMSE [mA]
0,5208	4,7722	16	0,0002	0,0014
0,517	4,3535	4	0,0005	0,0023
0,5126	3,9397	4	0,0005	0,0023
0,5087	3,5205	3	0,0003	0,0017
0,5034	3,1153	5	0	0,0012
0,4985	2,711	3	0	0,0016
0,4923	2,3091	4	0,0002	0,0024
0,4854	1,9163	3	0,0003	0,0029
0,4772	1,5379	5	0,0002	0,0036
0,468	1,1708	3	0	0,0033
0,4562	0,8227	3	0	0,0029
0,4401	0,5205	3	0,0003	0,0017
0,4185	0,2644	6	0,0002	0,0024
0,3875	0,1034	3	0,0007	0,0029
0,3445	0,0353	6	0,0002	0,0015
0,2972	0,0181	3	0,0003	0,0016
0,2486	0,0115	3	0,0003	0,0016
0,1987	0,0148	6	0,0002	0,0013
0,1491	0,0115	3	0,0003	0,0043
0,1003	0,0066	6	0,0002	0,0021
0,0509	0,0099	3	0,0003	0
0,0018	0,009	6	0,0002	0,0015
-0,0477	0,008	35	0,0001	0,0006

Figure 5. Example of the transfer of the measured data in the remote experiment “Solar energy conversion” [25].

5. Discussion - past, present and outlook for the remote experiments using ISES

The present state of the remote experiments in our e-laboratory project is accessible via our new webb pages (see www.ises.info): Water level control , Meteorological station in Prague , Electromagnetic induction , Natural and driven oscillations , Difraction on microobjects , Solar energy conversion and Heisenberg uncertainty principle . In following we want to state the reasons why exactly these pilot individual experiments have been chosen, we give the variable parameters and the outputs and the hints for the operation and also give some of the leading didactical aims for each of the experiment. All the detailed instructions (Motivation, Introduction , Physical background, Experimental Setup, Experiment and Assignments) are given in each experiment on the web site (www.ises.info). We would next only comment on the specifics of each experiment.

It should be stressed that the leading idea for the choice of the experiments was the effort of having one introductory experiment, one experiment with the features of manual control, one experiment with the features of the data logger and then the experiments, covering step by step the basic course of Physics at Universities. We insisted from the very beginning of our activities in remote experiments to master the data transfer to the remote experimentator to enable their further processing. We realized at the early stages of the building of the e-laboratory that the suitability of any classical experiment for RE differs in a wide range due to their steady or dynamic character, the level of the observed signals and the number of parameters to study the phenomenon in question. We on purpose evade the complicated and sophisticated instrumentation for RE building, because we tried to persuade the teachers to build similar experiments by themselves for their work.

Water level control

The introductory remote experiment "Water level control" is the experiment with the manual control of the type on/off. It controls the water level interactively and manually from the www page without data transfer to the user. The controls are "Run Experiment", "Pump control", "Start-Stop“,“ Overflow checking“ and "Enable-Disable". Further, the messages "Probe 1 status " and "Probe 2 status" signals the height of the water level. The tasks and questions are oriented on the coloured water pumping dynamics and monitoring.

Meteorological station in Prague

The experiment “Meteorological station in Prague” is the remote laboratory experiment, monitoring the temperature, the pressure and the intensity of sunshine at the Faculty of Mathematics and Physics, Charles University in Prague at Klarov. The built experiment shows the possibility to monitor different physical variables with simple technical hardware and software across the Internet. It is a typical task of a remote sensing, where the selected variables are only sampled at certain time intervals, measured and stored without any remote control of the process. The experiment is running since 2002. More users may be connected to this experiment at a time. The task is accessible round o clock and it is free to access without any password or registration. The tasks and questions are oriented on the evaluation of the quantities related to the weather and environment, its presentation, evaluation and its relation to human mood and body fitness.

Electromagnetic induction

The phenomenon is presented in the remote experiment using the rotating coil in the homogeneous magnetic field. The goal of the experiment is to show the phenomenon and how it compiles with the Faraday's law of electromagnetic induction. The only parameter is the voltage for the driving motor influencing the frequency of the rotation of the coil, the collected data are the voltage picked up from the coil. The tasks and questions are oriented on the Faraday's theory .

Natural and driven oscillations

The experiment from mechanics, covers the oscillations, the important part of the physics course, forming the basis of many phenomena and technical applications, ranging from UV absorption in atmosphere, in telecommunications or in molecular, atomic or nuclear physics. The remote experiment " Natural and driven oscillations" is built as a simple mechanical oscillator with the mass and spring , externally driven by the electromagnetic generator of variable frequency. The parameter is the driving force frequency and the data transferred are the instantaneous driving force and the deflection. The wide range of tasks and questions are oriented on the study of the natural oscillations and their damping, the amplitude and phase characteristics, the resonance phenomena and the energy transfer.

Difraction on microobjects

The experiment from the physical optics shows the diffraction phenomena on microobjects and how they change with the dimensions of the microobjects and wavelengths of the coherent sources of light. The variable parameters are the microobject dimension and the laser wavelength. The transferred data is the spatial distribution of the diffraction intensity. The goal and task are to determine the geometrical dimensions with their corresponding errors and the impact of the errors of the individual quantities, entering the calculation of the resulting quantity.

Solar energy conversion

This remote experiment may be used the chapters Circuits, Solid state and Environment, with stressing the respective teaching goals. It consists of the solar cell illuminated with the light source of variable light intensity and voltage applied on the cell. The *I-U* characteristics in dark and under illumination give great deal of information, ranging from the equivalent circuit, solar to electric energy transformation efficiency and fill factor, optimum load for maximum power transfer, etc. The transferred data are the averaged *I-U* characteristics, the number of the measurements and the corresponding mean square deviations.

Heisenberg uncertainty principle

This remote experiment from the Quantum theory is using the hardware of the experiment Diffraction on microobjects and differs only in instructions and assignments. The goal is to verify the validity of the crucial for the microworld the Heisenberg principle of uncertainty using the diffraction probability distribution of photons on a screen after the passage of a slit and/or to find the approximate value of the Planck's constant.

We have recorded till now (February 2008) over 12 000 accesses to all RE. The number has been recently fast rising, what confirm the numbers of users (visitors), since in the mid year 2007 there were about 7000 accesses compared to the present 12 000.

Table 1 Number of connections to remote experiments

Total Number of online connections to RE from start of monitoring till Fabruary 2008						
Water level IV /2004	Meteorology in Prague XII /2005	Electromag. induction X/2006	Natur.driven oscillations X /2006	Solar energy conversion X /2006	Diffraction microobj. VI /2007	Σ
3573	2401	2748	1282	1515	862	**12 381**

The next important step in the development of the remote experiments and studying their impact on the psychology of the experimentators were the pedagogical and psychological aspects of RE. We started the systematic recording on the server side of detailed steps, the experimentator on the client side takes during the measurements, with the time intervals spent in each step. To give the more specific insight, which activities are collected, in Table 2 there are summarized the types of activities recorded in the experiment "Diffraction on microobjects" in time scale. The scope of the data is enormous and this

Table 2 Activities recorded in the experiment "Diffraction on microobjects"

Activity No	Activity
1	User connection
2	Auto measurement start
3	Manual measurement
4	Wider slit on
5	Narrow slit on
6	Green laser on
7	Red laser on
8	Start recording data
9	Stop recording data
10	Data transfer
11	User disconnected

material is currently evaluated for the assessment of the pedagogical impact of the experiment and its psychological improvements.

As the last and recent step of our activities was the remote scientific experiment in solid state, exemplified on the characterization of photovoltaic solid state cell [25].

To add to the general characteristic of the e-laboratory of remote experiments in Prague, the access to any experiment is at present granted to any interested without any checking or registration. The laboratory is operated round o clock, constantly supervised as to the state of the experiments and improved. All the experiments bring the view of the experiment using life camera enable the choice of the measured and transferred data to the client – experimentator for their processing (with the exception of " Water level control").

The near future of our activities in the direction of ISES and ISES web control and building of the remote laboratories is distributed among the Charles University in Prague, Tomas Bata University in Zlin in the Czech Republic and several universities in Slovakia, with the centre in the Trnava University in Trnava. The main goal of the emerging e-laboratory network is to cover the university syllabus of basic physics course by experiments in the direction of Integrated e-Learning [26].

We have envisaged and started building of new remote experiments:

- “ Standing waves in the resonator “,
- “ Driven mathematical pendulum ”,
- “ Oscillations in RCL circuits”,
- “ Magnetic field generation and mapping”,
- “ Electrochemical sources of energy” [28],
- “ Free fall in gasses and liquids”.

6. Conclusions

The remote real laboratories are a new phenomenon in the teaching of engineering and natural sciences subjects, where the method of classical teaching of “the rules“ is still prevailing. The new strategy, based on practical observations and personal involvement in discovery of the real world phenomena is urgently needed. If it were the strategy of blended [6] or project [18] learning stemming from the more general strategy of constructivism [5] [28] or other stream of new ideas, it is not obvious. We propose the idea of Integrated e-Learning [26], based on the scientific method of work, where observation and its rationale play the crucial role. It is complying with the truism of A. Einstein “Truth is what stands the test of experience” [27]. The idea of remote real experiments strongly supports these strivings for new teaching methods and so it is worth both of further development and of removing all the obstacles preventing its worldwide acknowledgment. We try with our results to contribute to this trend by devising the system ISES and ISES WEB CONTROL, bringing the possibility for unification in the field of remote real experiments across the Internet.

On top of this, from the experience of the last two decades in the field, we may draw following conclusions.

- The remote real experiments - interactive, real time, with data outputs - bring the possibility to make the study of many engineering and science subjects more interesting and idea generating, ushering the students to the involved elucidation of the real world phenomena,
- With the real remote experiments we intend to step in favour of the real experiments against the idea of the virtual world and virtual measurements, the indistinguishable of the real and virtual “measurements” [8], stripped of the possibilities of the hypothesis formulations and their proving or disapproving,
- We hope to attract young people, used to exploit the Internet for the casual playing, chatting and communication purposes, for real work with the planned goals and aimed and involved output and to persuade them about the information strength of the remote experiments and the Internet,
- Finally, we hope to bring the practical experimental work by remote real experiments to those, hitherto not participating on the laboratory work for different reasons – distant students, disabled, handicapped, and those from underdeveloped countries, who can not afford to enter the real laboratories,

- For all these reasons we suggest to build the network of e-laboratories, accessible without any preconditions, serving worldwide for the popularisation and advance of the physics education.

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