Integrated e-Learning with remote experiments for engineering education in the era of networking

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Abstract

Information communication technologies have made it possible to introduce Integrated e-Learning (INTe-L) as a new strategy of education of physics for engineering education based on the method sciences used for the cognition of the Real world. It is based on the e-laboratory with remote experiments across the Internet, e-simulations and e-textbook. Its main features are the observations of real world phenomena, possibly materialized in data and their evaluation, search for relevant information, its classification and storing. Only then come the explanation and the mathematical formalism of generalized laws and their consequences. The indispensable quality of this method is the active part the student has to take in the teaching process both in lessons, seminars and laboratory exercises, but also his/her substantially increased activity in form of projects, search for information, presentations etc. In the paper, the INTe-L strategy is presented and general and pedagogical reasons for its introduction are given. The experience with INTe-L on teaching units Electromagnetic Induction, Oscillations, Photovoltaics and Electrochemistry is presented and discussed. We present the outlines of the existing and planned remote laboratory system with data transfer using Internet School Experimental System (ISES) as hardware and ISES WEB Control kit as software . For this purpose, the LMS system Moodle turned out to be a highly effective means of organization of physics courses.

Keywords: Integrated e-Learning, e-laboratories, e-remote experiments, e-simulations, e- textbooks, e-laboratory studio

1. Introduction

The physics teaching methods at secondary schools and universities face a critical stage of their development. The traditional way of delivering physics is used in the overwhelming majority of physics courses and has familiar characteristics. Most of the class time involves the teacher lecturing to students; assignments are typically homework problems with short quantitative answers. Seminars and especially laboratory work are more or less "recipes" style usually only loosely bound to the time schedule of the lectures and examinations are largely based on written exams containing theory and a little of problem solving [1]. Over the past couple of decades, physics education researchers have studied the effectiveness of such practices including extensive conceptual understanding, transfer of information and ideas from teacher to student in a traditional physics lecture, and beliefs about physics and problem solving in physics. [2] [3]. For reviews with useful citations, see references [1]. The definitive conclusion is that no matter what is the quality of the teacher, typical students in a traditionally taught course are learning mechanically, memorizing facts and recipes for problem solving, and are not gaining a true understanding. Equally alarming is that in spite of the best efforts of teachers, typical students are also learning that physics is boring and irrelevant to understanding the world around them [1].

In all new emerging teaching technologies, the nearly unanimous opinion prevails about their most decisive feature - to remove the barriers to student's independent and exploratory work in all sorts of laboratories in elucidation of the real world [1] [4] [5]. The main possibility,

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without any dissenting voices for this trend, was to bring about the change in the physics laboratories in the direction of substituting the "recipe labs" [6] with research laboratories. It is very instructive in this respect to consult the still valid document, American Association of Physics Teachers (1977) [7], which formulated five goals the physics laboratory should achieve:

1. "The Art of Experimentation: The introductory laboratory should engage each student in significant experiences with experimental processes, including some experience designing investigation.

2. "Experimental and Analytical Skills: The laboratory should help the student develop a broad array of basic skills and tools of experimental physics and data analysis.

Computers, when used as flexible tools in the hands of students for the collection, analysis, and graphical display of data, can accelerate the rate at which students can acquire data, abstract, and generalize from real experience with natural phenomena. The digital computer is an important tool for an inquiry-based course in physics because it has become the most universal tool of inquiry in scientific research. However, computer simulations should not be used as substitutes for direct experience with physics apparatus.

3. "Conceptual Learning: The laboratory should help students master basic physics concepts. The use of computers with laboratory interfaces allows real-time recording and graphing of physical quantities. The qualitative use of real-time graphing in microcomputer-based laboratories (MBL) has increased interest in using the laboratory to enhance conceptual understanding. The combination of two factors — laboratory course design based on an understanding of the preconceptions that students bring to the study of physics from their past experience, and the continuing development of MBL and other laboratory technology — has the potential to significantly improve the effectiveness of laboratory instruction.

4. "Understanding the Basis of Knowledge in Physics: The laboratory should help students understand the role of direct observation in physics and to distinguish between inferences based on theory and the outcomes of experiments.

5."Developing Collaborative Learning Skills: The laboratory should help students develop collaborative learning skills that are vital to success in many lifelong endeavours."

Since 1977 till today, the Information Communication Technology (ICT) and computers have invaded all aspects of physics teaching. The present state of ICT development is characterized by reaching the level of the quantitative increase of parameters that are bringing about very deep qualitative changes. In an editorial to the recent issue of Eur. J. Phys. devoted to student undergraduate laboratory and project work, D. Schumacher [8] brings examples of the invasion of computers in contemporary laboratory work including project labs, modelling tools, interactive screen experiments, remotely controlled labs, etc., Schumacher closes with the plausible statement "One can well imagine that project labs will be the typical learning environment for physics students in the future" [8].

The present discussion about new teaching methods in physics is no longer directed towards fundamental changes in learning processes due to the new ICT, but how to introduce the new techniques into everyday teaching practice by establishing the resources of e-learning, curricula, etc.

With this paper, we intend to contribute to this discussion, introducing the new technology and strategy of physics education based on ideas and the sciences used for their study of the real world – i.e. exploratory, discovery and ICT, the Integrated e-Learning (INTe-L). First, we want to give the motivation and pedagogical reasoning for INTe-L, how its components - remote e-experiments, e- simulations and e-textbooks contribute to its goals, and present the first pedagogical experiences with INTe-L through examples of teaching units in Electromagnetic induction, Oscillations and Photovoltaics.

2. Integrated e-Learning (INTe-L)

Motivations and pedagogical reasoning for INTe-L The first motivation of our work was very practical - the decreasing level of physics education and the reduced popularity of physics subjects among students. Physics is one of the most formidable subjects encompassing primary and secondary schools to technical universities with a logical consequence of decreasing level of physics knowledge [2] and hours for physics education. This trend has been in progress for some two decades. The most probable cause for this state is the way physics is presented to the younger generation.

The second motivation and inspiration for INTe-L came from the paper of Wieman et al. [1], supporting and calling for the change in educational technology, while seeing the remedy at hand in the existence of simulations. For this purpose, Colorado University started a very instructive Internet site PhET [9] with many applets, covering the usual scope of physic topics.

Thomsen and his co-workers introduced a new approach called e-LTR (eLearning, eTeaching, eResearch) using remote experiments [4]. Introducing eResearch, based on the e - laboratory, which is composed of remote Internet mediated experiments, filled the missing link of e-Learning [4].

The third motivation came from our own work over the last two decades on computer-oriented experiments and remote experiments. We have realized that the existence of the computer oriented experiments based on the hardware and software system ISES [10] and remote experiments built on the same system [11] enabled the introduction of a new strategy of education allowed by these new teaching tools.

Let us discuss the possibilities. The traditional strategy of physics education, which may be called "teaching of the rules," is based on teaching of the physics laws, their mathematical formulations for ideal and idealistic conditions, and consequences, and explanation of observed phenomena. Lectures, seminars and laboratory exercises are subordinate to this scheme, leading to the rather rigid structure of the roles of both the teacher and the student, leaving little space for independent and exploratory work of students. The manifestations of this are the recipes in both the seminars and laboratory exercises, where the deviations from the prescribed "trajectory" is not rewarded but often penalized. This requires little student engagement with the content, and as has been noted [12], "Students can be successful in their laboratory class even with little understanding of what they are actually doing". Hunter et al. [13] suggested that the recipe lab "omits the stages of planning and design" and it encourages data processing rather than data interpretation. Examinations as the only feedback about the success of physics education, are then concentrated on the memorization and mechanical enumeration of the basic laws and emerging concepts and much less on the creativity of the students.

The complementary strategy of education is actually copied from the method, scientists use in their cognitive work. We may call it "teaching of research“. The evolution diagram is quite different from the first mentioned strategy, as it is based on observations of phenomena of the real world, with the processing and interpretation of ensuing data and their presentation, searching for relevant information, and its classifying and storing. Only then come the explanation and the mathematic formulation of generalized laws and their consequences. The teachers are not bound by strict rules of the teaching unit; some problems may be left for the students' independent and project work. This teaching approach requires active participation of students, whose involvement may be strengthened by simplified models of dynamical animations which simulate real phenomena. Indispensable to this approach is project work, public presentations and defence of achieved results.

We introduce Integrated e-Learning with the following definition: INTe-L is the interactive strategy of teaching and learning based on the observation of real world phenomena by real e-experiments and e-simulations, on the principal features of the physic laws. It includes e-teaching tools as interactive e-textbooks and manuals and instructions which provide 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 decisive support of ICT, as now remote Internet experiments in e-laboratories are available for real world phenomena observations [14]; Java or Flash applets in form of e-simulations [9] for the dynamical animations; and for the required information and theory supplied by e-textbooks [15] [16]. With this in mind, we suggest and already have started to practice the INTe-L and want to present the first results of the combined effort of several universities in the Czech and Slovak Republics.

3. Components of INTe-L

The constituting components of INTe-L are, based on our definition and interpretation of INTe-L, as follows.

Remote e-Experiments. This component includes remote (or hands-on) experiments. The technical achievements of ICT enable to build now Internet e-laboratories – comprising the set of real interactive experiments, globally distributed, accessible from any Internet-connected computer, using the common web services (as web browser) [11] [14]. This educational technology, until recently not available, enables the introduction of the complex study of real world phenomena based on data collection, their processing and evaluation, and comparison with the models (see our e-laboratory on **www.ises.info**).

e-Simulations.The e-simulations and modelling using both Internet-available and home made Java or Flash applets [17]. They serve for the demonstration and explanation of observed phenomena and functioning of the concomitant physics laws. Surprisingly, the vast majority of applet simulations do not provide data output, which are needed for comparison of real experiments and models. For the multipurpose simulation applets, we try to provide the data outputs to support (or contradict) the measured data with the model.

e- Textbooks. The e-textbook covers theory, solved problems and exercises, glossary for quick orientation of the theory covered, multiple-choice tests with immediate evaluation of the acquired knowledge [15]. Recently, the INTe-L course in Mechanics using LMS (Learning Management System) MOODLE was introduced using the general scheme of INTe-L, i.e. e-remote laboratory (www.ises.info), e-simulations and e-textbooks [16].

We intend to demonstrate the first experiments in teaching physics using INTe-L on three teaching units from quite different parts of the physics course, namely Electromagnetic Induction, Oscillations, Photovoltaics and Electrochemistry. The details about the remote experiments, their philosophy and their ICT are published elsewhere [11]. We give here only short introductory information. The experiments are running on the server-client scheme, using normal web pages and web browser and Java support, no extra hardware or software is necessary on the client (student) side. The experiments are unique in available data transfer using the standard web page; the students can choose the range and the time interval of the wanted data for subsequent processing and evaluation.

Examples of teaching blocks with INTe-L

Teaching Unit Electromagnetic Induction The teaching unit examines the connection of time varying magnetic and electric fields into one entity of electromagnetic field, with the focus on the time varying magnetic fields and the ensuing consequences. The central focus of this unit is Faraday's law of electromagnetic induction.

Remote experiment - Faraday's law (http://kdt-20.karlov.mff.cuni.cz/ovladani_2_en.html)
The start of the lecture in teaching the Electromagnetic induction unit is the introduction of the remote experiment as an observation of real world phenomenon, loaded with noise and other real world phenomena. To demonstrate Faraday's law by remote experiment [21] (Fig. 1),

the coil is rotating in the homogeneous magnetic field (view in left top panel) at the constant but arbitrary variable frequency (see controls for changing the frequency of rotation and corresponding driving voltage for the motor). The resulting instantaneous electromotive voltage (right top panel) is transferred to the web page of the experiment. The collected data (left bottom panel) and the corresponding time representation (right bottom panel). The web page is supplemented by the text, providing the necessary theory and resources.

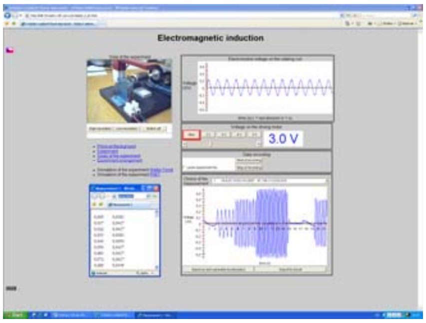

Fig. 1 Web page of the remote experiment Faraday's law withcontrols, output data and the graph of the outpuvoltage and live view of the experiment by the camera (see www.ises.info and experiment)

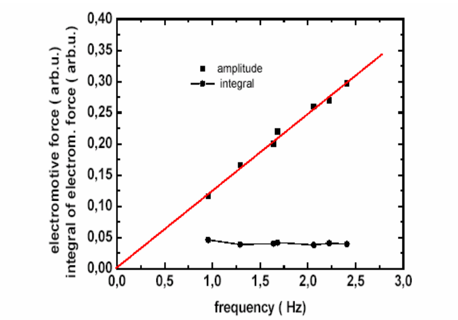

Fig. 2 Dependence of the amplitude of the output voltage on the frequency of the rotation (Red) and the Integral (Black)

$$\int_0^{T/2} |\varepsilon| dt = \int_0^{T/2} NBS\,\omega \sin(\omega t)\,dt = 2NBS = konst$$

by students, is availability across the Internet and its lucid presentation of materials. We press

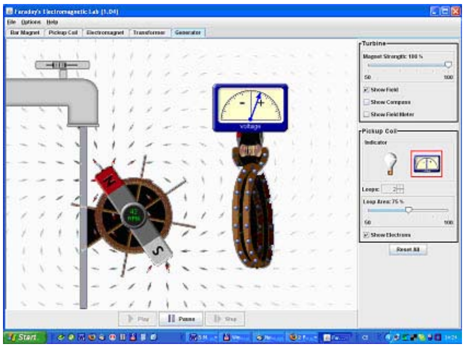

Fig. 3 Faraday's Law in Action in the Colorado Applet Simulation [9]

It is worth mentioning that the experiment may be used in different phases of the lecture (motivation, discussion, phenomenon evaluation etc.). It may also be introduced in a computational lesson and laboratory exercise and also for student project work (see the sample of the evaluation from the project work in Fig. 2), self study, and preparation for examination (with advantage during the examinations) [18].

e-Simulation - Faraday's law. The e- simulation of the phenomenon comes next in the lecture. For this purpose, we use the sophisticated and very useful applets provided by the PhET - Colorado University project (Fig.3) [9]. Using the simulations, we present the model of the above demonstrated real world experiment. Here the students may qualitatively observe and study the influence of variable parameters of the setup.

E-Textbooks. The lesson then continues using the necessary theoretical framework presentation by the teacher including using the data collected during the presentation. For this purpose the e-textbook is used, which is one compiled by a team of Slovak physics teachers and covering the basic physics course [19]. Students are encouraged to use the e-textbook throughout their study of physics in seminars, laboratory work, and preparation for examinations. The major advantage, appreciated

on the students to examine and verify the validity of the physics laws in "action" in their seminars and project work.

Teaching Unit Oscillations. Oscillations of oscillators constitute one of the most important parts of physics. 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. The unifying model for all real world systems then may be the mass-spring system constituting the driven mechanical oscillator.

Remote experiment – Oscillations

(http://kdt-17.karlov.mff.cuni.cz/pruzina_en.html)

In our illustration of Integrated e- Learning in the practical teaching process the starting point of the lecture is the remote experiment of the forced oscillations available across the Internet [20] (Fig. 4 and Fig. 5). These data give

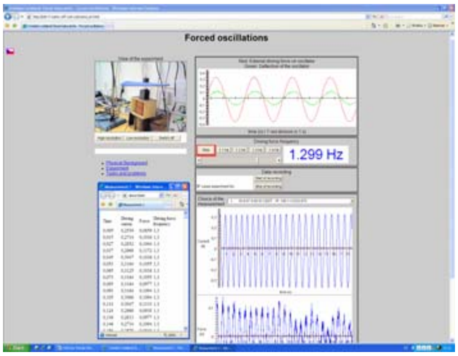

Fig. 4 Web page of the Remote Experiment Oscillations with Live Web Camera View (top left), Graph of the Time Representations and Controls (see experiment live)

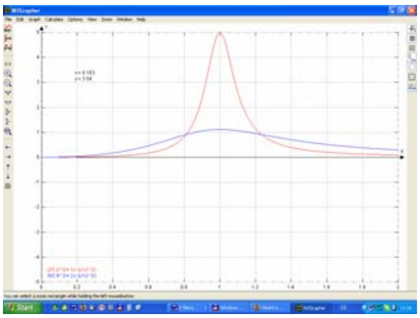

Fig. 5 Energy Transfer from the Driving Force Generator to the Oscillator vs.Frequency of the Driving Force with Damping as Parameter (Blue-Higher, Red-Lower)

information about frequency, the 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. If used in the student's laboratory, the students are encouraged to process the ac
the model oscillator, discuss the obtained results, and critically assess the errors of the measurements. Fig. 6 depicts the energy transferred from the driving force generator to the oscillator, as a function of the frequency of the driving force, damping being the parameter. The students are encouraged to find examples of the energy transfer in the natural phenomena and in technique. Such experiments may also be used advantageously for self-study of students, during examinations and may be very useful for part time students, where laboratories are not standard.

E-Simulation - Oscillations

(http://www.walter-fendt.de/ph14e/resonance.htm). In this simulation nearly identical observations to that of the above-presented remote experiment may be carried out. Forced oscillations in Fig. 6, provide the same sets of the data as depicted in Fig. 4, and were compiled by Walter Fendt [22] from the University of Magdeburg. The Java applet (Fig. 6) provides the simple

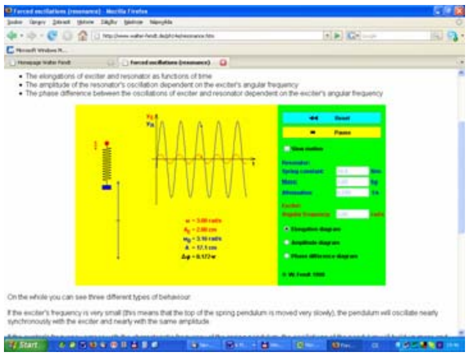

Fig. 6 Example of the Simulation - Forced Oscillations; See [22]

schematic dynamic view of the oscillator; its driving force (red) and weight deflection (blue) and the corresponding time representations in the graph. The adjustable parameters are spring stiffness, mass of the weight and attenuation with driving force frequency. Schematic view of the oscillator; its driving force (red) and weight deflection (blue) and the corresponding time representations in the graph. The adjustable parameters are spring stiffness, mass of the weight and attenuation with driving force frequency.

As the third example, we present the remote experiment Photovoltaic (PV) cell It has at present a strong environmental justification. This unit serves as an example of the possibility to teach by INTe-L also more abstract, scientific in nature, and theory oriented topics from material science and solid state physics.

Remote Experiment–Photovoltaic Cell (http://kdt-4.karlov.mff.cuni.cz/vacharakteristika_2_en.html) characterization in Fig. 7 and Fig. 8. This is a popular real-world experiment interesting both from the physical and environmental views.

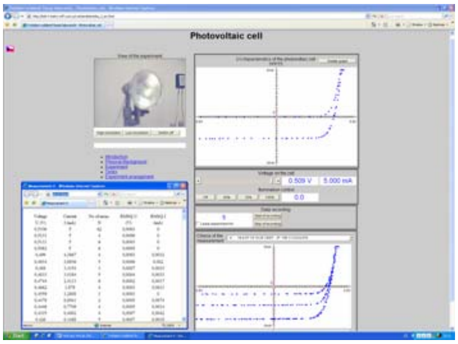

Fig. 7 Web Page of the Remote Experiment Photovoltaic Cell Characterization with Controls, Live Web Camera Picture and Graph of the *I-U* Characteristics (see live experiment)

We have recently devised the more sophisticated version of this experiment as an example of the possibility to use remote experiments in Material Science [23]. The students were encouraged to study the quality factor of the dark current I-U characteristic of the photovoltaic

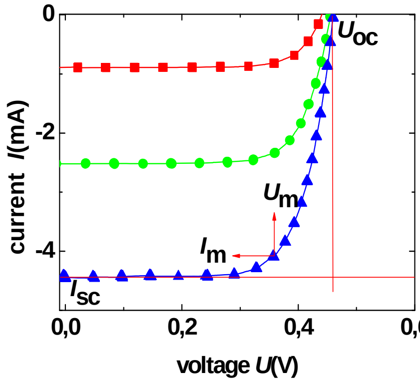

Fig. 8 *I-U* Characteristics of the Cell for Illumination with Three Relative Light Intensities: *L* (Triangles), 0.7 *L* (Circles) and 0.4 *L* (Squares)

cell and fill factor of the illuminated device that is decisive for the efficiency of the radiation to electrical energy transformation. The measurements are straightforward; the focus is then on the data evaluation. The extra variable parameter is the intensity of light of the PV element. The students faced no problems with data transfer, but had to cope with some problems as to the physical phenomena involved and data evaluation.

E-Simulation - Photovoltaic Cell . We use for this unit the excellent applet from the Australia National University in Canberra which provides support solar radiation data for the solar cell devise and its energy output Fig. 9. [24].

Remote experiment - Electrochemical cell (www.remotelab2@truni.sk)The schematical representation of the experiment is in Fig. 10 and www page in Fig.11 It consists of the two reaction chambers with variable concentration of electrolytes, connected by the membrane and two metal electrodes. Sever new ISES components were devised - titration pump, electromagnetic valve and stirring device. The principle of the experiment is simple – changing the concentration of the electrolyte, the validity of the Nernst equation is tested by the measuring the electromotive force of the cell, combined with the conductometric and pH data [29].

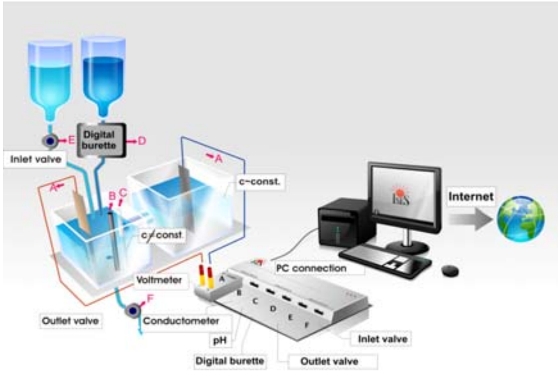

Fig. 10. The schematical diagram of the remote interactive experiment "Electrochemical cell" in the Department of Physics, Faculty of Pedagogy of Trnava University in Trnava.

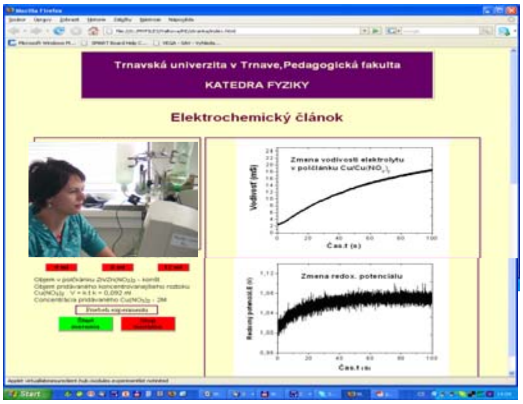

Fig. 11. WWW page of the remote experiment "Electrochemical cell".

4. Other component parts of INTe-L

All units of INTe-L were delivered within the basic course of physics to the students of Informatics. The course was implemented in the LMS system Moodle, whose frontpage is in Fig.12 . In Fig. 13 and Fig. 14 are examples of INTe-L of a lecture and a seminary. We keep to a rule to minimize the number of experiments and simulations, but try to keep them in all forms of classes, i.e. lectures and seminaries.

It is premature to try to summarize the impact and the effectiveness of the newly applied strategy of physics education. As we found, the prerequisites for the application of INTe-L are the carefully prepared supporting materials, cooperative interplay of all teachers in lecture, seminars and laboratory exercise, and perfect function of all the ICT. We used during the course the standard COLLES (Constructivist On-Line Learning Environment Survey).

Discussion of benefits of INTe-L Among the teachers of physics exists the prevailing opinion for the necessity of physics teaching strategy change. In their recent paper on the physics education transformation, C. Wieman and K. Perkins [1] ask the general question "Is there a way to teach physics that does not produce such dismal results for the typical student?" They give the positive answer by using the tools of physics in their teaching; instructors can move students from mindless memorization to understanding and appreciation. Many educators solve this problem by different approaches, many of them by increasing the role of laboratories - either real computer oriented [25], real e-laboratories across the Internet [14] or virtual laboratories and simulations [17].

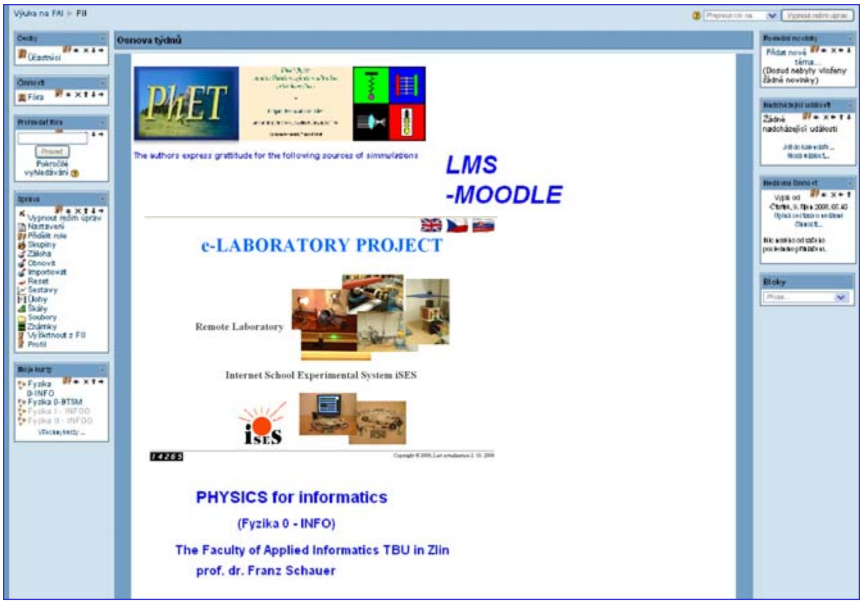

Fig. 12 The Frontpage of the LMS Moodle for the Course Delivered in Integrated -Learning

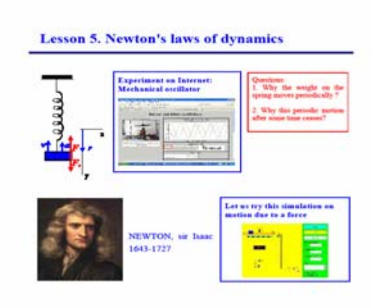

Fig. 13 Example of INTe-L: Lecture on Newton's Laws

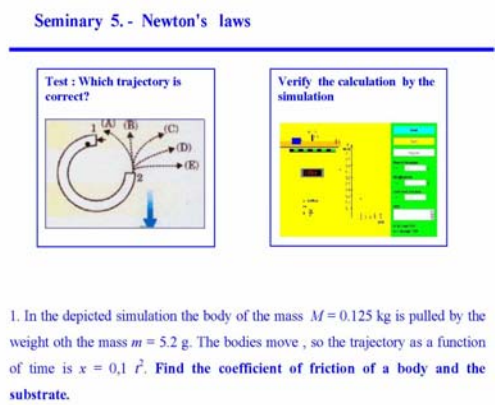

Fig. 14 Example of INTe-L: Seminary on Newton's Laws

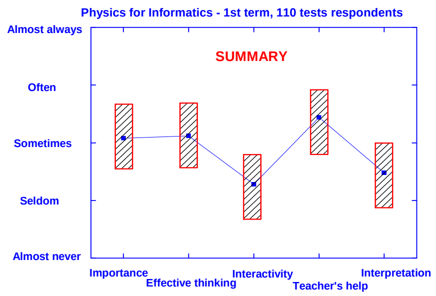

Fig. 15 Results of Standard COLLES Inquiry on MOODLE Course Based on INTE-L Teaching Strategy

We also adhere to the opinion that laboratories and simulations can deeply change the education in physics, but new strategies, including these new teaching tools, are needed. For that reason, we suggest the method of Integrated e-Learning and the question arises, if INTe-L solves the present difficulties in physics teaching and complies with the findings, what do physics education researchers bring to the effectiveness of education process [26]. The prospective methods of teaching, including INTe-L, should comply with the general piece of knowledge coming from cognitive research that:

1. Students should be provided with a suitable organizational structure, based on his/her prior thinking and experience and starting from their own research results. We should not simply be pouring facts on them and not addressing the simple questions "what", but rather "why". On top of this, previous knowledge must be carefully checked and examined and possible misconceptions dispelled. The ultimate goal in this respect should be active thinking, active exploratory work, guided by the active role of the teacher, and conditioned by the double-sided interaction of student – teacher.

2. The traditional teaching of “the rules” brings excessive amounts of new material that is far more than a typical person can process or learn. The more cognitive load the brain is given, the less effectively it can process anything and at the same time it is blocked from processing and mastering new ideas. This is one of the most well established and widely violated principles in education, including by many education researchers in their presentations. Any new method that should bring remedy to the situation and maximize learning should minimize the cognitive load by minimizing the amount of presented material. Presentations should be well organized structures and make the link to the already known ideas of the audience.

3. The third important criterion concerns the students and public beliefs about physics education and the importance of physics for society. If the belief about the purely abstract nature of physics and its not addressing the problems of the real world prevail, it deeply influences the approach towards the physics as a subject and the necessity of its mastery.

How does the INTe-L address these three criteria? The first above mentioned criterion is met byINTe-L from its starting point, observations, irrespective if it is traditional computer based laboratory, remote real e-laboratory across the Internet or virtual e-laboratory [27]. The real experiments strongly support the examination of the real world. On the other hand, the virtual laboratories or simulations support an interactive approach, employ dynamic feedback, follow a constructivist approach, provide a creative workplace, make explicit otherwise inaccessible models or phenomena, and inspires students productively [28].

The cognitive load in INTe-L is limited by supporting the individual comprehension processes offering manifold accesses to knowledge and being individually adaptive, offering significant advantages in the individual rates of teaching progress. Traditional teaching scenarios cannot satisfy this requirement, particularly because of cognitive capacity issues. INTe-L environments meet these needs. The possibility of making abstract objects and concepts tangible by application to real and virtual laboratories demonstrates this qualitative change in education and addresses the diminishing of the cognitive load of students [4].

In the fulfilment of the third criterion, INTe-L brings, the qualities and skills the students acquire studying physics courses for their future study and professional careers. We tried to cope with this problem in a separate paper [27]. In practical teaching it means assigning problems that are graded strictly on a final number, or that can be done by plugging the correct numbers into a given procedure or formula. This approach can teach students that solving physics problems is only about memorization and coming up with a correct number—reasoning and seeing if the answer makes sense are irrelevant. The good news is that courses that make rather modest changes to explicitly address student beliefs have avoided the usual negative shifts. Those changes include introducing the physics ideas in terms of real-world situations or devices with which the students are familiar; recasting homework and exam problems into a form in which the answer is of some obvious utility rather than an abstract number; and making reasoning, sense-making, and reflecting explicit parts of in-class activities, homework, and exams [1].

The easier access of majorities and disabled to the physics education is also contributing, including globalisation features. Technolo-

Our ultimate goal is to prepare the basic physics course curriculum with the above mentioned scheme, using the remote e-experiments, e-simulations and e-textbook. For this, the corresponding set of remote experiments is prepared [29]: “Standing waves in the resonator“, “Mathematical forced oscillations”, “Oscillations in RCL circuits”, “Magnetic field generation and mapping”, “Electrochemical sources of energy”, “Free fall in gasses and liquids” to those already functioning “Controlling of the liquid level“, “Monitoring the environment in Prague“, “The electromagnetic induction“, “The forced mechanical oscillator”, “Diffraction of microobjects”, “Heisenberg principle of uncertainty”, and “Characterization of the photovoltaic device”. The great advantage is the support of the University authorities and the Accreditation commission for these activities. The infrastructure of the teaching process must be changed accordingly. The whole potential offered by the INTe-L will be realized only if it is embedded in the existing academic structure.

gies are a prerequisite for the continuous integration of internationalized studies: transparency of course content forms the basis for the international recognition of academic achievements, eases the formulation of rules of acknowledgement for studies in foreign countries, making a stay abroad considerably easier to manage and realize. Geographical proximity, previously a prerequisite for intensive cooperation, is diminishing in impact.

Application of new media and new technologies has resulted in a significant impact on research. Today ICT is the technical foundation to access scientific sources and data. Interdisciplinary questions are getting more important and the possibility for interdisciplinary communication and cooperation plays a significant role.

Suggestion for future research. The examination of the effectiveness of INTe-L is under way. For this purpose we apply standard pedagogical methods of inquiry and questionnaire, the log-in protocols in remote experiments, and the records of remote experiments measurements.

5. Conclusions

Our long lasting activities in the computer based laboratory system software and hardware system ISES exploitation [25], remote e-laboratories building using ISES [29], together with the stimulating activities on transformation of physics education elsewhere [1] [4] gave rise to our incentives to devise and suggest the strategy of education INTe-L that may positively influence teaching of physics.

In general, INTe-L complies with the general criteria physics education researchers suggest for the effectiveness of education process:

1. suitable organizational structure, based on his/her prior thinking and experience;

2. it reduces the cognitive load by supporting the individual comprehension processes offering manifold accesses to knowledge and being individually adaptive; and

3. it positively addresses the students and public believes about physics education and physics importance of physics for society.

The INTe-L, as a new strategy of education, calls for deep changes in the University life as the infrastructure of the teaching process must be changed accordingly as the exploitation of the whole potential offered by the INTe-L may be employed only if it is embedded in the academic structure.

Acknowledgements

The authors acknowledge the support of the following projects: grant KEGA, project N 3/4128/06: "E- laboratory of interactive experiments as a continuation of the project of multimedia education at the Slovak Universities" and VEGA No 1/0332/08: "Globally available natural sciences experiments as a constituent part of Integrated e-Learning"

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Author's Biography

Franz Schauer received the M.S. degree in Electronics from the Brno University of Technology in 1963 and his Ph.D. degree in Solid State Physics from Prague University of Technology in 1978. In 1982 he was appointed Associate Professor and in 1988 Professor in Condensed Matter Physics at the Technical Academy in Brno.

In 1993-2002 he was with the Faculty of Chemistry, Brno University of Technology and since then he has been with the Polymer Centre of the Faculty of Technology and Faculty of Informatics, Tomas Bata University in Zlin. His main activities are molecular electronics, computer assisted experiments, and e-learning in physics teaching.

Integrated e-Learning for Freshmen of Engineering Education

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Abstract

Presentation gives practical application of Integrated e-Learning (INTe-L) a new strategy of education, based on recent massive progress in Information communication technologies, and exclusively on the exploratory function of physics along the lines sciences use. Here a special function play globally shared remote experimentation of real world via Internet and virtual interactive simulations. We demonstrate on the chapter Mechanics, as a part of the introductory course of physics for freshmen, the utilisation of the INTe-L strategy. The first experience with application for students of the Faculty of Applied Informatics, Tomas Bata University in Zlin and the Faculty of Education, Trnava University are presented, where the subject matter is delivered by Learning Management System - LMS (Moodle) - in successions that start by a remote or virtual experiment, with subsequent questions on observed phenomena, followed by the corresponding theory. The level of acquired knowledge is feed backed by the randomly generated tests and exercises.

Keywords: Integrated e-Learning, Innovation oriented distance education, freshmen education, remote and virtual laboratories

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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.

Max Planck

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1. Introduction

The state of the art of education in all levels shows that contemporaneous students neither like nor understand natural science, especially physics. 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], [2]. The main features of new methods have to be observations, search for proper information, its processing and storing, organization and planning of work, data and results presentation etc. In these methods of education the experiment and experimentation plays a decisive role. Allow me to quote a few words from private communication, concerning the present state of teaching and learning basic course of physic at technical universities "*They become worse since the engineers appreciation of experimental physics is very low. With the introduction of bachelor degrees they have halved the work load in physics. But the problems of understanding remain. The knowledge from school physics is only partly useful with some knowledge about quantum physics, but hardly any student being able to explain what the torsional moment is. And these students are to build our future cars?*"

How to change this situation? It is almost spread over many European countries. I hope that the situation is better in China due to the

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very good school system and higher motivation. Is it not so?

Any physics teacher would like to have his/her student more active, more involved in his/her developing knowledge. But what is very important is the level of understanding of real phenomena based in real life situations. How can the teacher do it in practice, when he works with a large number of students with quite different level and a large amount of subject matter to cover? It could be achieved via the new forms and methods of education based on solving real problems with ingenuity, using their knowledge, abilities and competences. It means, as the first step, it is necessary to open the students´ mind for understanding of physics laws via real experimentation and real situations, perhaps very important in his /her future engineering profession.

Up till now the vast majority of e-learning teaching tools present theoretical concepts of the respective science branch in form of mathematically formulated laws, models, simulations, applets or animations, exercises, graphs and presentations. Virtually no e-textbook presents real remote experiments with virtual experiments form unified body of information [3],[4],[5], if yeas, so only simulations in limited scope [6], [7].

With the progress in information technologies the chance to grasp real objects by application of remote experiments (RE) has emerged. Tompkins in Sanford constructed the physics remote experiment in magnetism [8], the team of authors from Prague experiments for basics physics course [9]. The advantage of this approach, forming integrated combination of e-Learning, e-Teaching and e-Research (e-LTR) [10] is manifold.

A 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, e.g.: The project Pearl "Practical Experimentation by Accessible Remote Learning [11] and the project "Remotely Controlled Laboratory" [12] E-laboratory project [13], [14] and others. The gathered experience, the inventory of the state of the art and corresponding references in Europe and United States are to be found there.

The general and the most decisive criterion for the introduction of the remote and virtual 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 paper presents the new technology and strategy of physics education based on ideas of the Integrated e-Learning (INTe-L) on the example of a new course of Mechanics.

The goal of basic course of Physics for future engineers is to provide a quantitative understanding of certain basic phenomena that occur in real word and to explain the behaviour of various physical systems using relatively few fundamental laws and their applications in technical majors an future career.

It is known that, physics is a science based on the experimental observations and mathematical analyses. The maim objective behind such experiments analyses is to develop the theories that explain the phenomenon being studied and to relate these theories to others established theories. The bridge between the theory and experiment are analytical procedures that require expressing observed phenomena in the language of mathematics. That is for the most of the freshmen like a quarry stone.

We hope that we have found more simple and more interesting way, how to understand better physics and master the Introduction course of Physics. On that way it is decisive the quality of the student's good will to do experimentation work with real, remote or virtual experiments and to think about their outcomes.

2. Integrated e-learning strategy

First, we want to give the definition, motivation and pedagogical reasoning for INTe-L.and these ideas depict on practical examples from the Mechanics.

INTe-L definition. As we declare in our paper [2] the Integrated e-Learning (INTe-L) as the higher generation of e-Learning, 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 and sophistication of the Internet and its corresponding services remote experiments across the Internet in e-laboratories.

INTe-L – motivation. The first motivation of our work was very practical - the decreasing results of physics education resulting partially from the decreasing popularity of physics among students. Physics is one of the most formidable subjects encompassing primary and secondary schools to technical universities with a logical consequence of decreasing level of physics knowledge [15]. This trend has been in progress for some two decades. The most probable cause for this state is the way physics is presented to the young generation.

The second motivation and inspiration for INTe-L came from the paper of Wieman et al. [1], calling for the change in educational technology, while seeing the remedy at hand in the existence of computer simulations. For this purpose, Colorado University started a very instructive Internet site PhET with many simulation applets, covering the usual scope of physic curricula [16].

INTe-L – reasoning. The traditional strategy of physics education, which may be called "teaching of the rules," is based on teaching of the physics laws, their mathematical formulations for ideal conditions and explanation of observed phenomena. Lectures, seminars and laboratory exercises are subordinate to this scheme, leading to the rather rigid structure of the roles of both the teacher and the student, leaving a little space for an independent and exploratory work of students. The manifestations of this are the recipes in both the seminars and laboratory exercises, where the deviations from the prescribed "trajectory" is not rewarded but often penalized. This requires little student engagement with the content, and as has been noted [17], "Students can be successful in their laboratory class even with little understanding of what they are actually doing". Hunter et al. [18] suggested that the recipe lab "omits the stages of planning and design" and it encourages data processing rather than data interpretation. Examinations as the only feedback about the success of physics education, are then concentrated on the memorization and mechanical enumeration of the basic laws and emerging concepts and much less on the creativity of the students.

The third motivation came from our own work on computer-oriented experiments and remote experiments. We have realized that the existence of the computer oriented experiments based on the hardware and software system ISES [9], [14] and remote experiments built on the same system [19] enabled the introduction of a new strategy of education.

INTe-L – components. From our definition of INTe-L arise, that it consist of tree components. We shall discuss them individually and later in individual chosen case studies.

a) INTe-L remote e-experiments. The first Inte-L component includes remote (or hands-on) experiments. The technical achievements of ICT enable to build now Internet e-laboratories – comprising the set of real interactive experiments, globally distributed, accessible from any Internet-connected computer, using the common web services (as web browser). This educational technology, until recently not available, enables the introduction of the complex study of real world phenomena based on data collection, their processing and evaluation, and comparison with the models.

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. Some of them we have mention above [11], [12], [19] (see Fig. 1).

It is known that many others universities have built up their own remote laboratories, which serve only for their own students (e. g. UTC Sydney and MIT in USA). It would be nice, useful and convenient time for building e-hyper laboratory on the Internet with the global connectivity.

Fig. 1. Real Remote Laboratory Project

b) *INTe-L e-Simulations.* The e-simulations and modelling using both Internet-available and home made Java or Flash applets. They serve for the demonstration and explanation of observed phenomena and functioning of the concomitant physics laws. As a father of the new PhET technology (Physics Education Technology) can be consider the Nobel laureate Carl Wieman, distinguished professor of physics at the University of Colorado at Boulder, who has launched a new science education project using part of his Nobel Prize money [20] (Fig. 2). The project was focussed on interactive "virtual" physics experiments created using Java Applets, a type of computer code that allows users to manipulate virtual objects on the computer screen. The computer programs are available worldwide on the Internet. Applets can convey the way a scientist looks at the world. Applets makes it possible to share the mental pictures which have been developed for how things work. They also make the learning much more active. Thestudent adjusts the conditions in the applet and they can discover many ideas on their own by seeing what happens as a result of their adjustments. PhET have employed a computer experts to create the applets and an education experts who will

Fig. 2. PhET Project http://phet.colorado.edu/

design learning units that guide students in their use and measure the learning effectiveness. Carl Wieman, laureate Oersted Award 2007 for notable contributions to the teaching of physics, said [18] " *It is clear that the current physics education system is failing in the creation of a technically literate public and workforce. The nice thing about applets is that they can be an effective tool to help a very wide range of students. PhET applets can be aimed at high school students, science- and nonscience-oriented undergraduate college students and the general public. It will concentrate on the concepts that are covered in many physics courses and that also are relevant to people's lives" For example, applets will be used to demonstrate what is happening about oscillation or RLC circuits, as electricity flows through wires and light bulbs, how radio waves are generated and detected, what happens in a microwave oven, and to illustrate the greenhouse effect in the atmosphere and how it warms the Earth and many others, together about 65 applets,* (see Fig. 3).

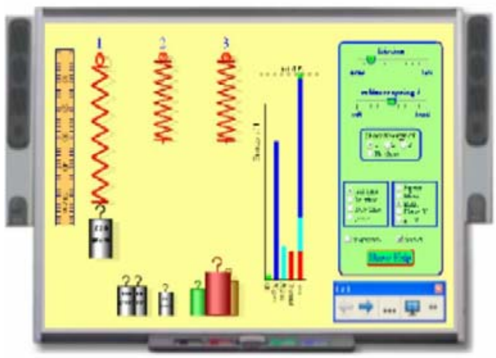

Fig. 3. Applet Mass Spring Laboratory http://phet.colorado.edu/sims/mass-spring-lab/mass-spring-lab_en.html

Except these resourses our students are familiar with Fendt´s applets [21] and many others on the Internet [22], [23], [24], [25], [26].

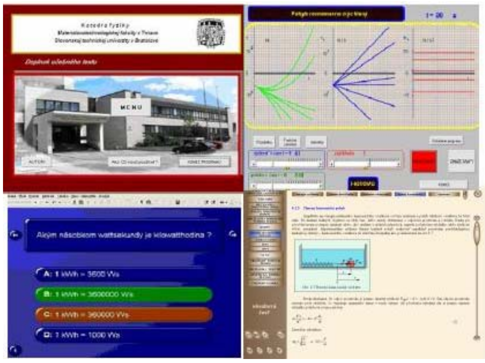

Fig. 4. E-textbooks used in INTe-L strategy ofEducations [6],[7].

In project work our students also have to solve very interesting interactive illustrations, explorations, and problems for Introductory Physics prepared by W. Christiana and M. Belloni [27]. For the multipurpose simulation applets, we try to provide the data outputs to support (or contradict) the measured data with the model . So first, after familiarising with the applet, students verify the physical consistency of the model. Surprisingly, the vast majority of applet simulations do not provide data output, which are needed for comparison of real experiments and models. For that reason the new interactive simulation of oscillations in the system mass-spring with data outputs and transfer was realized [28].

c) INTe-L e- Textbooks. For our students are available the e-textbooks, which cover theory, solved problems and exercises, glossary for quick orientation of the theory covered, multiple-choice tests with immediate evaluation of the acquired knowledge [5], [6], [7]. In Fig. 4 can be seen the title pages of e-textbooks. Recently, the INTe-L course in Mechanics using LMS (Learning Management System) MOODLE was introduced using the general scheme of INTe-L, i.e. e-remote laboratory (www.ises.info), e-simulations and e-textbooks [29]. Of course students can utilize many others e-sources on the Internet as e.g. the free encyclopaedia Wikipedia or Multimedia Physics studios [30].

Now, after the motivation and pedagogical reasoning for INTe-L we would like to show how its components - remote e-experiments, e-simulations and e- textbooks contribute to its goals. Before we present the pedagogical experiences with INTe-L by typical examples of teaching units in Mechanics, let me write a few word about the technology of computer oriented experiments.

3. Technological aspects of computer aided hands on and remote real experiments – ISES and ISES web control

Teaching of Mechanics is usually a starting point of any university basic course, where the support of experiments is important and where remote experiments are generally missing.

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 physics. In our course we would like to change this situation We found the way to attract the student's attention – it is the exploitation of both real and virtual experiments. The presence of computers and IT means – that was absolutely necessary.

Internet School Experimental System - ISES. In our laboratories, the friendly in use hardware and software for easy building of physics experiments - Internet School Experimental System (ISES) - has been constructed [31]. It forms the basis of our approach to the simple and prospective building of real hands on and remote experiments. Its detailed description and philosophy is reported elsewhere [31]. 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 different modules and sensing elements, an the graphical and data processing software (see Fig. 5).

Fig. 5. ISES-Internet School Experimental System

ISES Hardware. The computer interface card, with the inputs and outputs and plug-in slots for modules, provides an easy way of interfacing to virtually any PC compatible computer. The card is the 12-bit analog-digital digital-analog, time of conversion - 0.010 ms, DMA, and universal control board and a set of sensors (about 40 for physics, chemistry and biology etc.). The system offers the possibility of simultaneous measuring and data displaying for 8 input channels and process control via two analogue and four binary output channels. The analogue output channels work as programmable voltage sources (DC, AC with 8 kinds of default signals, manual controlling or user defined signals). Maximum sampling frequency (100 kHz) enables studying of sounds or other high frequency signals.

The ISES modules are easily interchangeable, the computer, provided with the automatic calibration, automatically senses their presence and adjusted range. The system is equipped with such modules as e.g.: voltage (±5 mV ÷ 10 V), current (±0.5 mA ÷ 1 A), resistance, capacitance, temperature (-20 ^{o}C ÷ +120 ^{o}C, microphone, deviation sensing unit, adjustable preamplifier, light stop, current booster, relay switch, pressure meter, and many others. For chemistry the electromagnet valve for liquids and digital biretta have been developed recently. The service program enables the measurement of simultaneously 10 different channels (8 analogous inputs and 2 analogous outputs) and to use 4 binary output channels. All these modules are fully programmable, using the programming panel.

ISES Software. The data in ISES system is depicted both in analog or digital form, on variable number of panels, with depicted quantities either those measured by modules or their combinations (addition, subtraction, product, quotient etc.). The software provides data processing (integration, differentiation, fitting, approximation etc.). The data export for another graphical processor is straightforward.

ISES WEB Control kit. 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 [31].

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 Fig. 7.

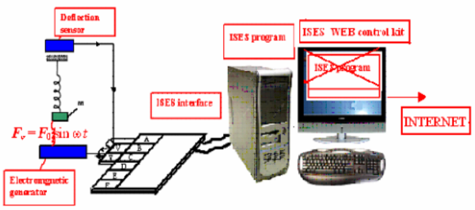

Fig. 7. The schematic arrangement of the PC (hands on) experiment scanned by ISES system and its transformation to remote experiment. The oscillator consists of the spring and the weight, the external force is exerted by the electromagnetic generator with the variable frequency, the instantaneous deflection is detected by the deflection sensor.

4. Mechanics via INTe-L

Mechanics, as is well known, is the first part of basics course of Physics on technical oriented universities. We realized however, that for students perhaps the most difficult. The main goal for teacher in the first term of their physics study is to attract the students interest into active role via experimentation. To achieve this we used the inclination of students to chat, play games and communicate across Internet and use computers in general for leisure. This was also tone leading idea for INTe-L as a new strategy of education. Let us demonstrate this approach on introductory parts of Mechanics through three individual case studies**: A body moving on horizontal plane, Free fall of a body and Mathematical pendulum.** In each, we shall concentrate our attention on three aspects of experiment: **kinematics, dynamics and energy.**

Case study 1: A body moving on horizontal plane and incline plane. Aim: To study one dimensional motion of a body in a plane via hands on computer aided experiment.

a) Kinematics aspects of hands on experiment and the simulations. Student has to realize and explain the motion of an object on a plane. Schematic representation of the computer based arrangement is shown (Fig. 8). It is based on the ISES system, sonar transmitter

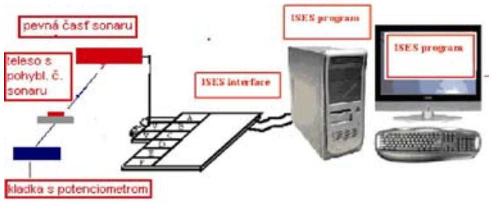

Fig. 8. Schematic arrangement of the experiment with: stationary part of ISES sonar, an moving object with moving part of sonar, frictionless pulley supported by ISES potentiometer.

Fig. 9. The ISSES components. Rigid and movable parts of sonar (left), ISES panel (right).

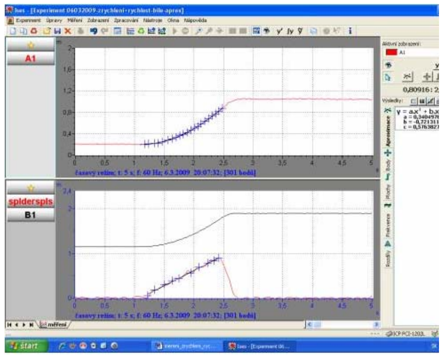

Fig. 10. Results of the measurements: dispalacement vs. time, velocity vs. time measured by two different ISES devices (sonar and potentiometer).

attached to a moving body (Fig. 9) and recording the instantaneous position of a moving body (see Fig. 10).

Student along the lines of INTe-L is encouraged to try to reproduce the same or similar experiment later with the utilization of a virtual experiment (e.g that on the Fig. 11) or others on Internet) with the aim to strengthen his/her acquired knowledge.

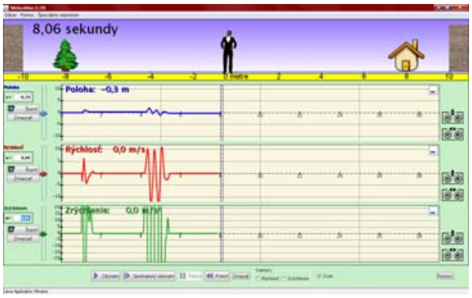

Fig. 11. Applet Moving man
http://phet.colorado.edu

From the observed graph (Fig.10 and Fig. 11 the student could be able to:

- construct a graph (position – time $x = x(t)$, velocity-time $v = v(t)$),
- create a table of measured data,
- discuss the classification of the motions,
- explain how to gain the instantaneous velocity from displacement vs. time graph and how to proceed in the evaluation of the acceleration $a = a(t)$,
- understand the meaning of the slope of the tangent to the curve at the point,
- use the language of calculus to discuss motion,
- write position , velocity and acceleration as a functions of time in analytical formulation,
- describe in words with illustrations what the derivative and integral functions are, etc.

Kinematics aspect – theory - e-textbook. Kinematics approach allowed students to express instantaneous position $x = x(t)$, velocity $v = v(t)$ and acceleration $a = a(t)$ as a function of time analytically in the language of math (by an equation) or by a graph. Student should be able to know and understand when can be used a set of equations for position and velocity

$x(t) = x_0 + v_0 t$, $v(t) = v_0$,

for $v(t) = v_0(t_0)$ with constant velocity, and eq.

for position $x(t) = x_0 + v_0 t + \frac{at^2}{2}$,

velocity and acceleration

$v(t) = v_0 + at$, $a(t) = a_o$.

for motion on a straight line with constant acceleration.

b) Dynamics aspects of a body moving on horizontal plane and incline plane. *Aim:* To study the concept of forces acting an a body moving on a plane using Newton´s laws.

As no suitable remote experiment has benn until now available on Internet, we can use again the same hands on experimental arrangement depict in Fig. 8. The free body diagram in Fig. 9 represents the acting external forces .We can formulate, using the Newton´s second law

$$\sum_i \boldsymbol{F}_i = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} \qquad (1)$$

or in our case of constant mass m, $\boldsymbol{F} = m\boldsymbol{a}$. where $\boldsymbol{a}$ is the acceleration of a body, m is its

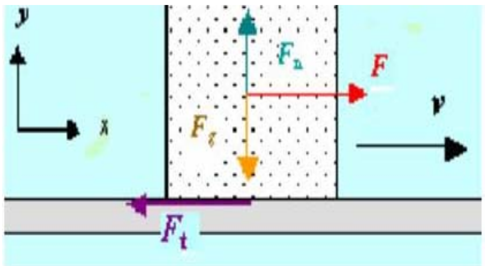

Fig . 12. The free-body diagram that represents the external forces acting on the body (block). $\boldsymbol{F}_g$ – the force of gravity, $\boldsymbol{F}_n$ - the normal force, $\boldsymbol{F}_t$ the force of friction between a block and a rough surface, $\boldsymbol{F}$ - the applied pull force.

mass, and $\boldsymbol{F}$ represent resultant force, the vector sum of all external forces acting on a body.

The students then continue to study motion of an object on an incline. The free-body diagram that represents the external forces acting on the body on an incline can be seen from Fig. 13. Vector equation expressing Newton´s second law is then

$$\boldsymbol{F}_g + \boldsymbol{F}_n + \boldsymbol{F}_t = m\boldsymbol{a}$$

and for x and y components

$$F_{gx} + F_{tx} + F_{nx} = ma_x$$

$$F_{gy} + F_{ty} + F_{ny} = ma_y .$$

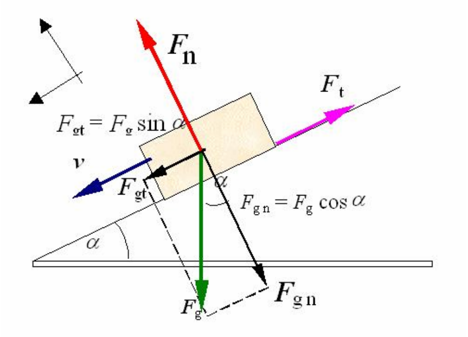

Fig. 13. The external forces acting on a body on a rough incline are: $\boldsymbol{F}_g$ - the weight of a body, $\boldsymbol{F}_n$ – the normal force and the force of friction $\boldsymbol{F}_t$.

or

$$F_g \sin(\alpha) - F_t = ma$$

$$F_g \cos(\alpha) + F_n = 0 .$$

With the utilization of equation for magnitude of the force of friction $F_t = \mu F_n$, the acceleration of a body on the inclined plane is

$$a = g\sin(\alpha) - g\mu\cos(\alpha).$$

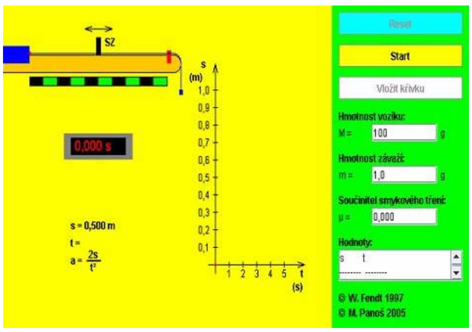

Fig.14. Simulation by Walter Fend [32].

Dynamic aspects of simulation – physlets. We recommended the students to work with Fend simulation [32] (Fig. 14) and also to find other similar simulations on the Internet with the identical topic and utilize them in the project work.

Second Newton law applied for the two objects with the masses *m* and *m*'

$$\boldsymbol{F}'_g + \boldsymbol{F}_g + \boldsymbol{F}_n + \boldsymbol{F}_t = (m + m')\boldsymbol{a}$$

where $\boldsymbol{F}_g'$ and $\boldsymbol{F}_g$ are the weight of the body with mass *m*' and *m*, $\boldsymbol{F}_n$ – the normal force and the force of friction $\boldsymbol{F}_t$. This equation in components form gives

$$F'_g - F_t = (m + m')\, a$$

$$F_g + F_n = 0.$$

$$a = \frac{F'_g - F_g\mu}{m' + m} = \frac{g(m - m'\mu)}{m' + m}.$$

where μ is the coefficient of the friction between a body and the surface and g is acceleration due to the gravity. What can the student acquire? The knowledge how to :

- Select a coordination system.
- Isolate the object of interest whose motion is being analysed.
- Draw a free body diagram and label all external forces acting on the body,
- Apply Newton´s laws.
- Resolve all forces into *x* and *y* components.
- Find the algebraic sum of the components in both the *x* and *y* directions.
- For equilibrium conditions to use the equations $\Sigma F_x = 0$ and $\Sigma F_y = 0$, (remember to keep track the signs of various force components,
- Applied knowledge for two objects connected by a string passing over a frictionless pulley, and others.

c) Energy aspects of the real or remote experimentation: A body moving on horizontal plane and incline plane. *Aim:* To study the concept of forces acting an a body moving on a surface and its connection with energy, and measuring of the coefficient of the friction between a body and a surface.

As no suitable remote experiment until now has been available, we can use again the same experimental arrangement depict in Fig. 8.or the arrangement for an object on an inclined plane Fig. 13. with demonstration of the external forces acting on a body on a rough incline. (We hope, soon to setup such remote experiment)

The same simulation with the incline we can find on the http://phet.colorado.edu/index.php (Fig.15) or the students can verify his/her theoretical knowledge and observe the motion under the change of variable parameters: angle, coefficient of friction, the mass of the body.

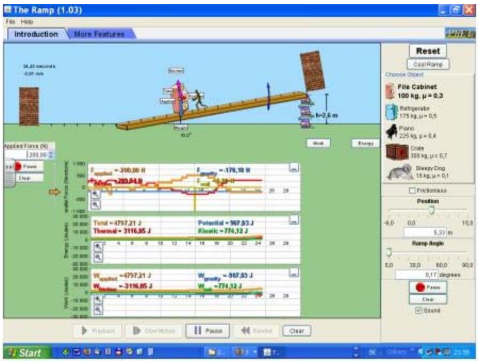

Fig. 15. Applet: Inclined plane from PhET [33].

Energy aspects in e-textbook. For deeper insight into basic concepts students have to open Multimedia university textbook with randomly generated self tests, and a lot of solved problems [7]. There can they find the theory and the discussion about kinetic, and potential energy and also the work exerted by the conservative forces (gravitational force) and also of the nonconservative forces (the force of friction). Students are tought how the work done by all the forces equals the increase of the kinetic energy. The students are required to verify the conditions under which the law of conservation of mechanical energy is conserved. The students has to verify during experimentation the basic facts as:

- When a body slides over rough surface (plane or incline), the force of friction $\boldsymbol{F}_t$ is opposite to the motion,
- Force of friction, $\boldsymbol{F}_t$ is proportional to the normal force
- The magnitude of the friction is $F_t = \mu_k F_n$. Here, μ_k is the coefficient the friction.
- Relations between the kinetic, potential and total mechanical energy.
- Relations between energy and the work.
- Conservation of mechanical energy.

Case study 2: Free fall of a body. *Aim:* To study one dimensional motion of a body in the field of the Earth.

The free fall is very well known from mechanics it is well known that free fall motion resulting from gravitation field that is unimpeded by a medium that would provide a frictional retarding force.

a) Kinematics aspects of Free fall of a body. In the Earth´s gravitational field near the surface of the Earth, the free fall with the constant acceleration, known as the acceleration of free fall g takes place with corresponding time dependence of the path

$$y = \frac{1}{2} g t^2 .$$

We would like to illustrate the INTe-L approach with utilization of real hands on experiment Free fall with schematic arrangement in Fig.16. The view of the experiment are in Fig. 17 and Fig. 18.

Fig. 16. Schematic arrangement of the experiment Free fall.

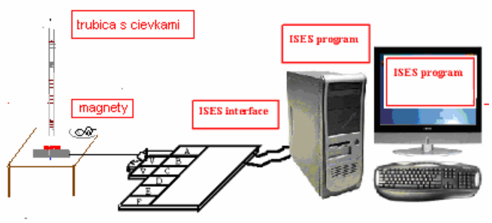

Fig. 17. Experimental apparatus for the experiment Free fall recorded with ISES system.. Experimental apparatus for the experiment Free fall recorded with ISES system.

Fig.18. Detail of the hands on experiment Free fall.

To transform the hands on experiment to the remote one, the most demanding task was to lift the magnet to its starting position. For this purpose we devised and use an electromagnetic vessel lifted by the screw, driven by the step motor, depicted in Fig.19, down, (also see Fig. 19 up).

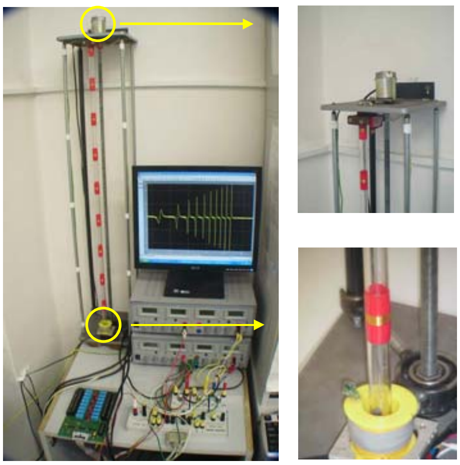

Fig. 19. The remote experiment free fall. The total arrangement (left), nad two important details: The magnetic vessel lifted by the screw (down), the step motor driving the screw (up).

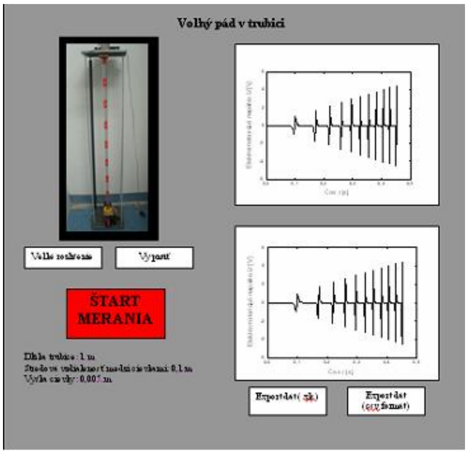

Fig. 20. The WWW page of the remote experiment with life camera view, signal recorded and velocity-time.

To plan and programme the experiment the detailed time and logic scheme of experiment is needed, serving for the proper functioning of the experiment. To this purpose serves the standard flow chart, resulting in the corresponding programme and the web page of the experiment, soon available on http://remotelab4.truni.sk.

Typical signal of the free fall in the air, recorded by the ISES system, is shown in Fig. 21. The position-time graph for a falling magnet in the glass tube with evenly distributed 10 coils is in Fig. 22.

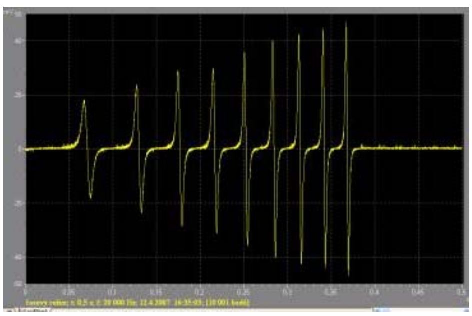

Fig. 21. Typical signal of the free fall in the air recorded by the ISES system.

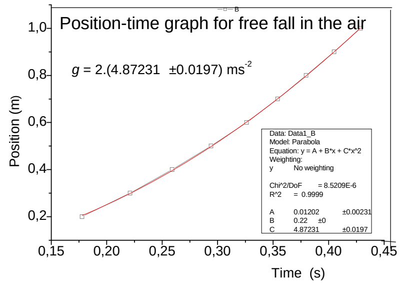

Fig. 22. Time dependence of the falling magnet position with the determined *g*.

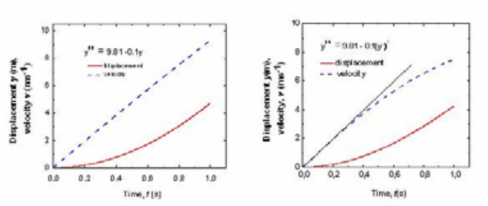

Fig. 24 The modelling results of the eq. (1) and (2) – time dependencies of the displacement y (t) and velocities v (t); the deviation from the constant acceleration (from linearly increasing velocity) is visible on the right panel

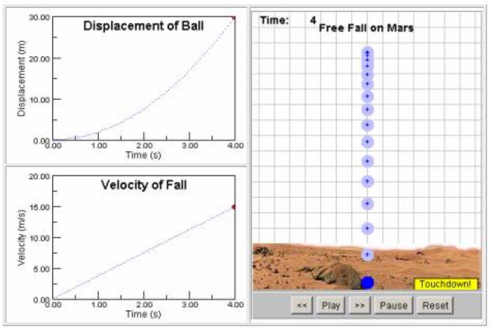

Fig. 23. Simulation Free fall on Mars [34].

Kinematics aspects of simulations Free fall of a body. Would you like to compare free fall on Mars or Moon? You can start the simulation http://www2.swgc.mun.ca/physics/physlets/mars_fall.html on (Fig. 23) or other on the Internet [34].

b) Dynamic aspects – Forces acting on the freely falling object. Before we started the transformation of the hands on experiment to the remote one, the detailed evaluation of the data of the experiment systematically produced the differences between the results of other experiments on the free fall, caused by the presence of the dissipative forces. We decided to introduce these dissipative forces during the experiment artificially, control and measure them. The tube of the experiment enables both to eliminate and enhance the friction forces in a controlled manner, changing the density of the gas in the tube. This is accomplished by both the rotary pump and controlled gas pressurising of the tube. In future the liquids, introduced to the tube, may serve for experimentation in viscous media.

The theory of the free fall in dissipative media is starting from the differential equation. (assuming the positive direction for *y* is chosen to be upward) with the general solution for the motion in low pressure gasses (neglecting the

$$m\frac{d^2y}{dt^2} = mg - k_1 v$$

buoyancy force) with the solution for velocity time dependence

$$m\frac{d^2y}{dt^2} = mg - k_2 v$$

$$v(t) = \frac{mg}{k_1}\left(1 - e^{-\frac{k_1 t}{m}}\right)$$

and for the motion in viscose medium.

$$m\frac{d^2y}{dt^2} = mg - k_2 v^2$$

$$v(t) = -\sqrt{\frac{k_2}{mg}}\,\mathrm{tgh}\left(\frac{k_2 g}{m}t\right)$$

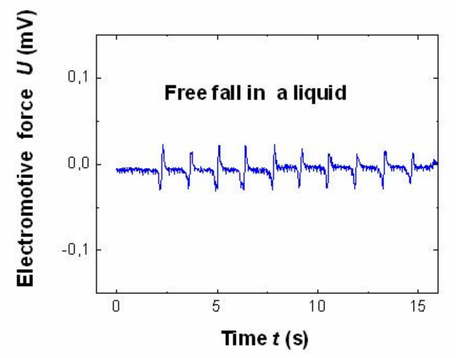

Fig.25 Typical signal of the free fall in the liquid recorded by the ISES system

where m is the falling body mass, t is the time and v is the velocity, k_1 and k_2 are the corresponding coefficients of dynamical friction. Electromotive force time-graph for free fall in liquid shows that magnet is falling don with constant acceleration due to the resultant of acting forces.

Dynamics aspects in e-study material. The interesting physical simulation with the theory of the permanent magnet motion in a coil can be found on the . http://www.meet-physics.net/AFco-angles/elec magnet/induccion/faraday/faraday.htm. We are planning to continue our work with the applications. The experiment was with the success used in both the Mechanics [36] and as the Faraday law.

c) Energy aspects – Forces acting on the freely falling object. Let us consider the total mechanical energy: - the concept of kinetic energy and potential weigt energy. Instantaneous velocity can be determined from the position time dependence. The result is linear time velocity dependence. From the slope of the this graph we can determined the value of the acceleration due to the gravity. Potential gravitational energy of a freely falling object decreases while its kinetic energy increases as the mechanical energy should be constant. These observations confirmed, that if the only acting force on a system is conservative, total mechanical energy is conserved. What can we say about examined system?

Case study 3 – Oscillatory motion. *Aim:* In third case study we shall look at general study of curvilinear motion in two dimensions.

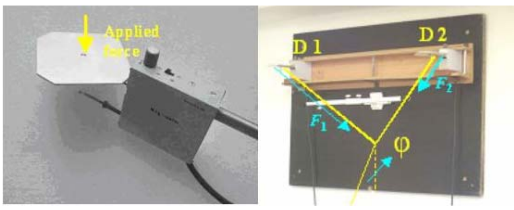

Fig. 26. ISES dynamometer module (right), board with two dynamometers (D1 and D2) for reconstruction of instantaneous deflection φ(t) of the pendulum (down).

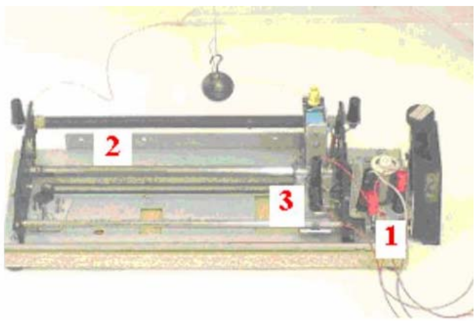

Fig. 28. The unit for remote experiment giving the pendulum the initial deflection of the preselected value with step motor controlled motion

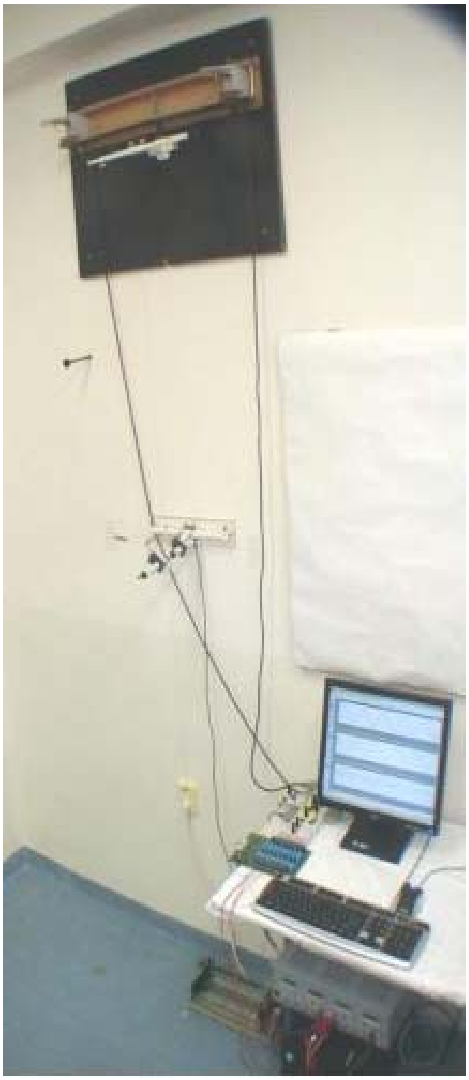

Fig. 27. Arrangement of the Penduum

For the university level physics course we shall demonstrate a popular experiment mathematical pendulum, an experiment which

is simple and easy to realize and straightforward for demonstration in a class. The problems in a deeper understanding start, when the educator tries to put forward the mathematical formulation of its movement, not speaking about the concepts of the pendulum dynamics or energy. Then the knowledge, the students may acquire, is limited in the best case, to its period of oscillations. Especially difficult is to explain by a chalk only the concept of small and large deflection cases. On the other hand, it is clear, the pendulum, even a mathematical one, may bring a vast information, covering the kinematics, dynamics of curved motion and its acceleration, energy - both kinetic and potential - and the role of dissipative forces that may be minimized wirtually to zero. The obvious obstacle for this fruitful approach, especially using the strategy of INTe-L, is the missing remote experiment on the pendulum with the data transfer. So we devised and produced hands on and later remote experiment of pendulum with adjustable initial deflection.

For the observation of curvilinear motion we devised the computer based experiment of pendulum with the instantaneous reading of its angle of deflection, so bringing on line information $\varphi = \varphi\ (t)$ [37]. For this purpose we used the couple of the ISES dynamometer modules, that give information of the forces applied to the platform, (see Fig. 26). Arrangement of the experiment is in Fig. 27**.** The parameters of the device can be seen from the Table 1.

PC based experiment with the system ISES, enabling both hw and sw solutions (signal recording and data smoothing, processing - recording of chosen typical data, fitting, etc). The forces and their time representation give information on the instantaneous deflection.

Table 1. Parameters of the devices Mathematical Pendulum.

The parameters of the device	Value
Maximal load	± 9.81 N (1 kg)
Differential load	± 0.98 N
Sensitivity	± 0.01 N (1 g)
Range	Two 1x and 5x

To plan and program the experiment the detailed time and logic scheme of experiment is needed, serving for the proper functioning of the experiment. For this purpose serves the standard flow chart, resulting in the corresponding program and the www page of the experiment, that will be uncover on http|://remotelab5.truni.sk in these days. To transform the hands-on experiment to the remote one, the most demanding task was to give the pendulum the initial preselected initial deflection. This was accomplished by the module with thestep motor controlled motion (1), position sensing resistor (2) and electromagnet fixed to the moving trolley (3) in Fig. 28.

Let us to consider again three aspects of the experiment: kinematics, dynamics and energy for individual component of a strategy INTe-L.

a) Kinematics aspects of remote experiment Mathematical pendulum. To study the kinematics of a mathematical pendulum as a part of two dimension circular motion, it is necessary to start with the observation and defining the terms angular displacement φ, angular velocity Ω and angular acceleration α. For the determination of these quantities it is necessary to know only the radius of the circle (the length of a pendulum) and its instantaneous angle of deflection,

$$\varphi(t) = \varphi_o \sin(\omega t), \qquad \Omega(t) = \mathrm{d}\varphi / \mathrm{d}t.$$

The representations of kinematics, dynamics quantities of pendulum is in Fig. 29. All these quantities are possible to express in terms of the instantaneous deflection e.g. tangential and normal acceleration.

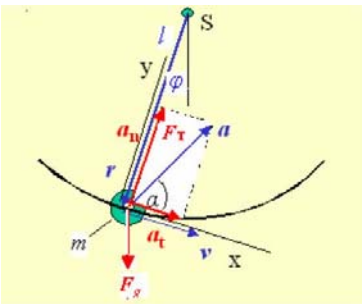

Fig. 29. A simple pendulum consist of a mass *m* suspended by a light string of length *l*.

The velocity v, tangential a_t and the normal a_n components of the acceleration then is

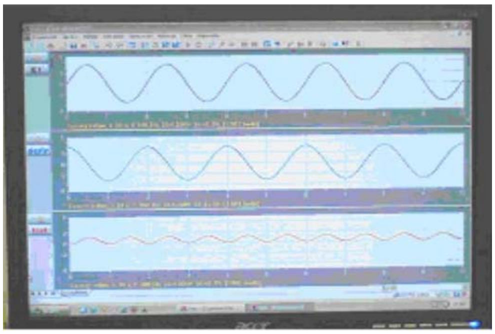

Fig. 30. The signals corresponding to the forces $\boldsymbol{F}_1$, $\boldsymbol{F}_2$ and deflection $\varphi(t)$.

$$v = l\left(\frac{\mathrm{d}\varphi}{\mathrm{d}t}\right) = l[\varphi_0 \omega \cos(\omega t)]$$

$$a_t = \frac{\mathrm{d}v}{\mathrm{d}t} = l\alpha = l\frac{\mathrm{d}^2\varphi}{\mathrm{d}t^2} = -l\varphi_0\omega^2 \sin\omega t$$

$$a_d = l\Omega^2 = l\left(\frac{\mathrm{d}\varphi}{\mathrm{d}t}\right)^2 = l(\varphi_0 \omega \cos\omega t)^2$$

After some geometry, the resultant deflection angle $\varphi(t)$ was calculated [37] and this operation is executed by ISES on line. The record of the typical forces F_1, F_2 and the resulting deflection φ is in Fig. 30.

b) Dynamics aspects of remote experiment Mathematical pendulum. In Fig. 26 (right) is the board with two dynamometer modules that give two time dependent pull forces F_1 and F_2 in the suspendsions as the pendulum oscillates. The forces and their time representation give information on the instantaneous deflection angle. The magnitude of the force of the pull F_T was calculated by Majerčík [37] and can be written a function of the measured forces F_1 and F_2

$$F = f(F_1, F_2).$$

c) Energy aspects of remote experiment Mathematical pendulum. Energy provides us with a simple method for deriving an expression that gives the velocity of a mass undergoing periodic motion as a function of position. The sum of the kinetic and the potential energy is constant in any position and equals the total mechanical energy.

$$E_k + E_p = \frac{1}{2} m v^2 + m g h$$

or

$$\frac{1}{2} m l^2 [\varphi_0 \omega \cos(\omega t)]^2 + m g [1 - \cos(\varphi_0 \sin \omega t)] = con.$$

The. increase in the potential energy ΔE_p equals the decrease of the kinetic energy $-\Delta E_k$. As no real or real remote experiment was not accessible, it was useful to work with simulations. In the strategy of Inte-L we recommend to work with both of thesedidactic means. On the Internet can be found a lot of interesting applets with the pendulum. Our students prefer those of Colorado university, shown in Fig. 31, but also Fendt´s pendulum simulations we use very often to observe the change in quantities and energy.

For a more detailed study the students are encouraged to utilize any physics text book covering basics physic courses in paper form or in e-form, as we have already mentioned

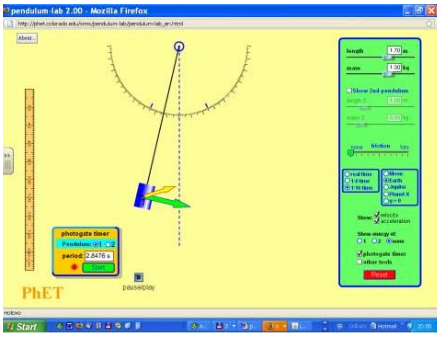

Fig. 31. Mathematical pendulum http://phet.colorado.edu/sims/pendulum-lab/pendulum-lab_en.html.

4. Summary

Among the teachers of physics exists the prevailing opinion for the necessity of the change of physics teaching strategy. By using the new teaching tools educators can move students from mindless memorization to understanding and appreciation.

Our teaching group devised and prefer a new strategy, called Integrated e-learning- including the new teaching tools with the combination of all three INTe-L components. We also adhere to the opinion that remote laboratories and virtual laboratories may deeply change the education in physics.

The course in the first term Physics course using LMS (Learning Management System) Moodle was introduced using the general scheme of INTe-L with full use of remote experiments and physlets. The survey regarding the comparison of the two types of education technologies (INTeL and the classical form) showed the advantages of the former type:

- Learning was easier,
- Learning with interactive simulation and real remote experiments was more interesting ;
- Teaching was more comprehensive;
- Students appreciated detailed task solving and their graphical design in multimedia textbook;
- The LMS system allowe better communication among the teacher and students and more time for individual work with students;
- With the same time allotted to both types of exercises, the students calculated more tasks in the computer-aided exercise;
- Students appreciated free access to study material on Internet; ….

On the other hand students complained about short time for elaborating home assignments and project work and the demanding less of the introductory course.

The main conclusions may be formulated as follows:

- The new strategy of an education basic Physics course has been prepared and the authors find presence and distance education via Inte-L strategy a highly progressive, effective, affordable and attractive way of education.
- 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 and their skills;
- INTe-L strategy support development of

the ability to solve real problems and creates attractive and more interesting form of method of delivery of acquire knowledge, which can be used in active manner in the students carriers.

- Students confirmed that this form of study is suitable for them and it is helpful for them. ICT supported education will increase the students interest in technical disciplines.
- The students get experience of the whole scientific process in a relevant and stimulating format.
- The remote real experiments are suitable for international exchange at the university level of education in all its forms (lecture, laboratory exercises, self study);
- Furthermore, students 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;
- Although the INTeL strategy is a valuable tool in an educational methodology based on constructivism and collaborative learning This methodology has been applied in a computer architecture course that uses the Moodle platform as a framework for collaboration between students and teachers.
- The technical and financial requirements to build such experiments call for the establishing of the global university network of remote experiments, covering the basic course of physics, based on nearly identical syllabi.
- 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.*!*

Acknowledgements

The author wish to thank Professor František Schauer for invaluable comments and suggestions. Financial support provided by the Ministry of Education of the Slovak Republic under KEGA project No. 3/72277/09 "Completion of the remote e-laboratory - as a tool for development of student's and teacher's key competencies for third millennium" and VEGA project No. 1/0332/08: "Globally available natural sciences experiments as a constituent part of Integrated e-Learning" is gratefully acknowledged.

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