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Chapter 11

Integrated e-Learning – New Strategy of Cognition of Real World in Teaching Physics

FRANTIŠEK SCHAUER[1,2], MIROSLAVA OŽVOLDOVÁ[2,1] and FRANTIŠEK LUSTIG[3]
[1]Tomas Bata University in Zlín, Faculty of Aplied Informatics, CZ-760 05 Zlín, Czech Republic. E-mail: fschauer@ft.utb.cz. *[2]University of Trnava, Faculty of Education, Department of Physics, SK-918 43 Trnava, Slovak Republic. [3]Charles University, Faculty of Mathematics and Physics, Department of Didactics of Physics, CZ-121 16 Prague, Czech Republic*

Information communication technologies development have made it possible to introduce Integrated e-Learning (INTe-L) as a new strategy of education of physics based on the method sciences used for the cognition of the Real world. Formally, 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 first experiments with INTe-L on teaching units Electromagnetic Induction, Oscillations, and Photovoltaics are presented and the experience gained discussed.

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, 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, 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.

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.

COMPONENTS AND FIRST EXPERIENCES WITH 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 and Photovoltaics. 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.

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://kdt20.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

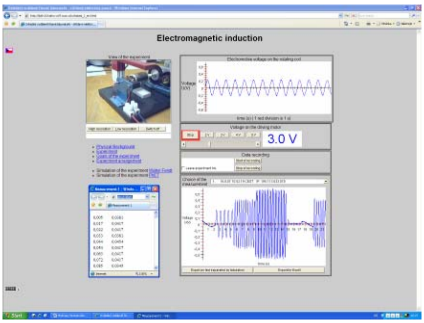

FIGURE 1
WEB PAGE OF THE REMOTE EXPERIMENT FARADAY'S LAW WITH CONTROLS, OUTPUT DATA AND THE GRAPH OF THE OUTPUT VOLTAGE AND VIEW OF THE EXPERIMENT BY LIVE WEB CAMERA

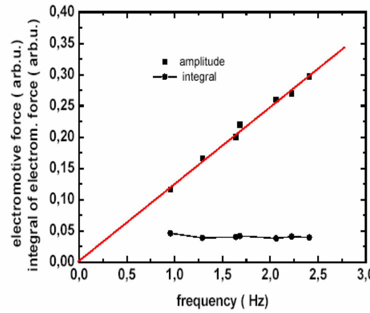

FIGURE 2
DEPENDENCE OF THE AMPLITUDE OF THE OUTPUT VOLTAGE ON THE FREQUENCY OF THE ROTATION (RED) AND THE INTEGRAL (BLACK)

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

[21] (Figure 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.

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

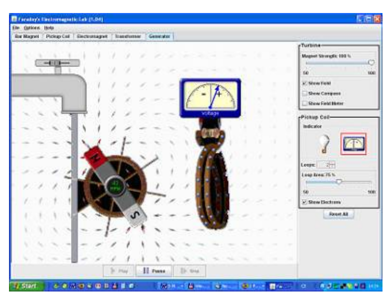

FIGURE 3
FARADAY'S LAW IN ACTION IN THE COLORADO APPLET SIMULATION [9]

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

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] (Figure 4 and Figure 5). These remote experiments can be studied both free damped and forced oscillations and such phenomena as the resonance or energy coupling of oscillator to the driving force.

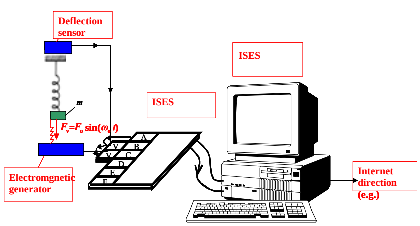

FIGURE 4
REPRESENTATION OF THE REMOTE EXPERIMENT OSCILLATIONS WITH ISES HARDWARE

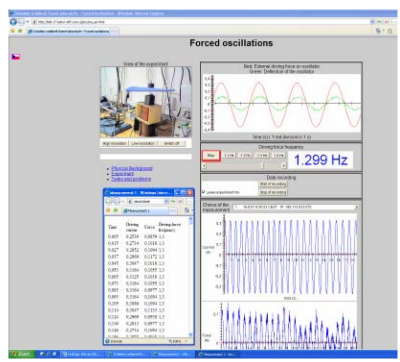

FIGURE 5
WEB PAGE OF THE REMOTE EXPERIMENT OSCILLATIONS WITH LIVE WEB CAMERA VIEW (TOP LEFT), GRAPH OF THE TIME REPRESENTATIONS AND CONTROLS

The transferred data give 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 acquired data, evaluate the requested quantities of the model oscillator, discuss the obtained results, and critically assess the errors of the measurements. Figure 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.

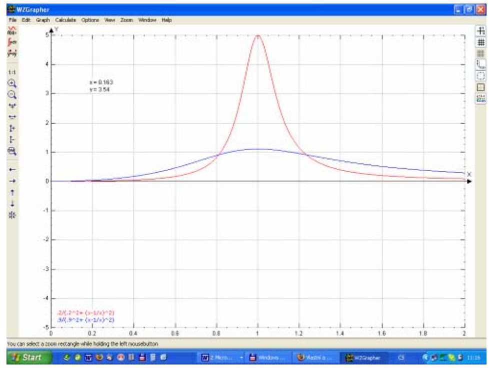

FIGURE 6
ENERGY TRANSFER FROM THE DRIVING FORCE GENERATOR TO THE OSCILLATOR VS. FREQUENCY OF THE DRIVING FORCE WITH DAMPING AS PARAMETER (BLUE-HIGHER, RED-LOWER)

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 Figure 7, provide the same sets of the data as depicted in Figure 4 or Figure 6, and were compiled by Walter Fendt [22] from the University of Magdeburg. The Java applet (Figure 5) provides the simple 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.

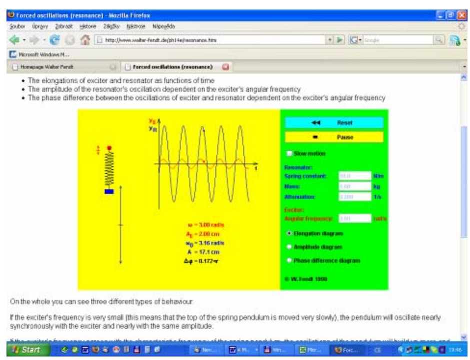

FIGURE 7
EXAMPLE OF THE SIMULATION - FORCED OSCILLATIONS; SEE [22]

Teaching Unit Photovoltaics

The third teaching unit we present here is the unit on Photovoltaics. Besides solid state physics, 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/fotodioda.html)
As the third example, we present the remote experiment Photovoltaic (PV) cell characterization in Figure 8 and Figure 9. This is a popular real-world experiment interesting both from the physical and environmental views. 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 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.

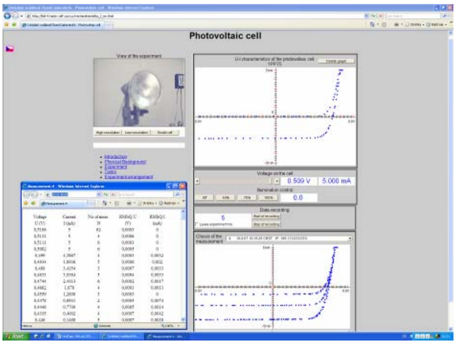

FIGURE 8
WEB PAGE OF THE REMOTE EXPERIMENT PHOTOVOLTAIC CELL CHARACTERIZATION WITH CONTROLS, LIVE WEB CAMERA PICTURE AND GRAPH OF THE *I-U* CHARACTERISTICS

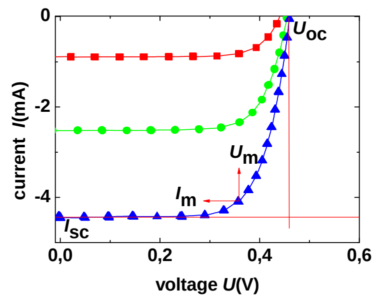

FIGURE 9
I-U CHARACTERISTICS OF THE CELL FOR ILLUMINATION WITH THREE RELATIVE LIGHT INTENSITIES: *L* (TRIANGLES), 0.7 *L* (CIRCLES) AND 0.4 *L* (SQUARES)

E-Simulation - Photovoltaic Cell

We use for this unit the excellent applet from the Australian National University in Canberra which provides support solar radiation data for the solar cell devise and its energy output [24].

All three 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 Figure 11. In Figure 12 and Figure 13 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.

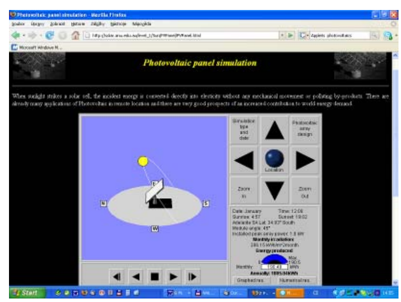

FIGURE 10
THE SIMULATION APPLET FOR THE DETERMINATION OF SUN RADIATION FLUX [24]

It is premature to try to summarize the impact and the effectiveness of the newly applied strategy of physics education. As we have 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). This is a set of 24 statements that asks students about the relevance of the course, provides opportunities for reflection and interactivity, provides peer and tutor support, and facilitates interpretation. These factors are based on social constructivist theory. The results of standard COLLES inquiry on MOODLE course based on INTe-L strategy for 110 respondents of Applied Informatics can be seen from the diagrams in Figure 14. Detailed results of the pedagogical research will be published.

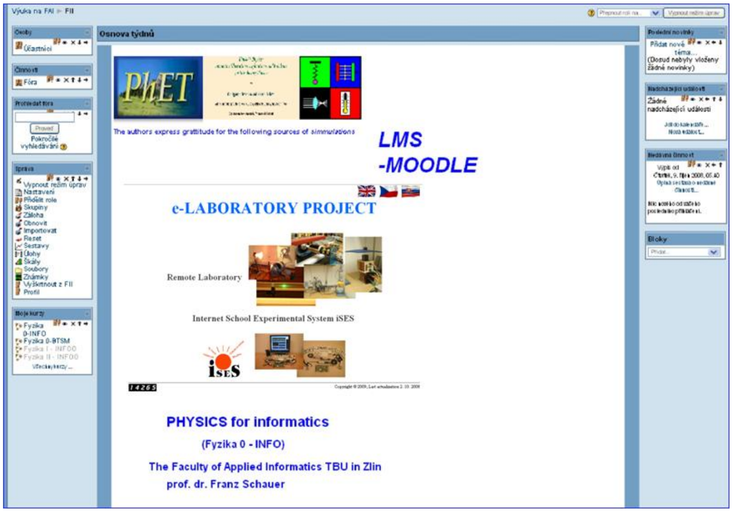

FIGURE 11
THE FRONTPAGE OF THE LMS MOODLE FOR THE COURSE DELIVERED IN INTEGRATED E-LEARNING

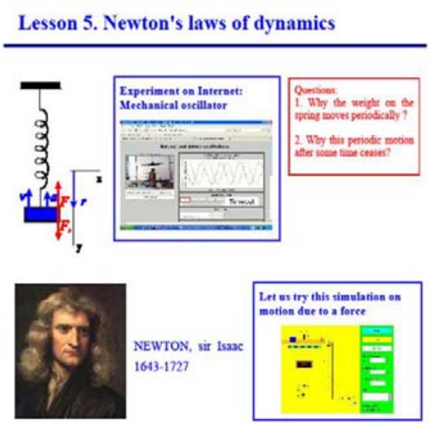

FIGURE 12
EXAMPLE OF INTE-L:
LECTURE ON NEWTON'S LAWS

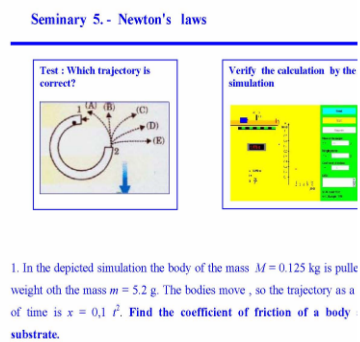

FIGURE 13
EXAMPLE OF INTE-L:
SEMINARY ON NEWTON'S LAWS

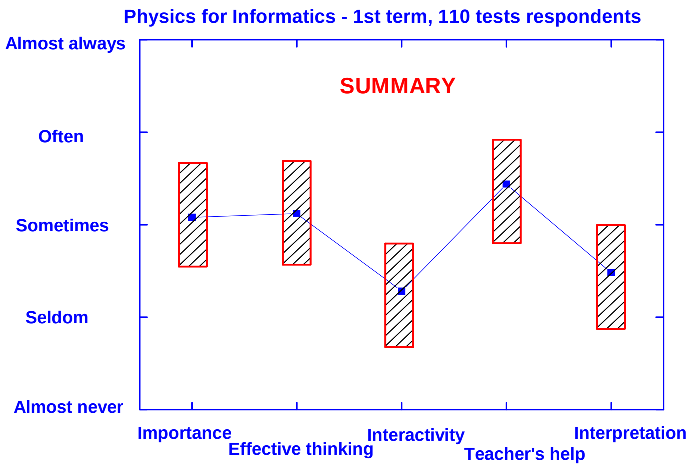

FIGURE 14
RESULTS OF STANDARD COLLES INQUIRY ON MOODLE COURSE
BASED ON INTE-L TEACHING STRATEGY

The e-modules were received and mastered by the students without any major problems. The students were positively surprised, active and involved. In every case all of them were given project topics either from remote e-experiments or e-simulations, which required written reports and in some cases delivering their results to the teaching group in form of oral presentations. The faculty competition of the best student work in physics was then organized with excellent presentations. During the examinations both remote experiments and simulations were used for the interactive communication on a practical problem with the teacher. It is fair to mention that the course on Mechanics and Heat comprised no labs, to lessen the students load in the first semester. We have now at present the second term of the basic course on Electricity, Magnetism and Oscillations and Waves, using identical INTe-L strategy, but with the practical PC based labs, where the main stress is laid on the physics, experimentation and corresponding skills, the e-modules are then used as supporting teaching tools.

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].

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 inspire 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. Technologies 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.

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.

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:

- suitable organizational structure, based on his/her prior thinking and experience;
- it reduces the cognitive load by supporting the individual comprehension processes offering manifold accesses to knowledge and being individually adaptive; and
- 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.

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František 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.

Miroslava Ožvoldová Received her M.S. degrees in Physics from Comenius University in Bratislava, Slovakia, in 1973, and 1981 a Ph.D. Physics-Mathematics Science. In 1992 she was appointed Associate Professor, and in 2002 Extraord. Professor at the Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava. Since 2003 she has been active at the University of Trnava, Faculty of Education. Since 2008 she is also with Faculty of Informatics, Tomas Bata University in Zlin. Her main activities are optical properties of chalcogenide and heavy metal optonic glasses and e-learning in Physics teaching.

František Lustig received his M.S. degree in Didactics of Physics from the Charles University in Prague in 1976. He received his Ph.D. degree in Plasma Physics from the Charles University in Prague in 1986. In 2005 he was appointed Associate Professor in Didactics of Physics. He is the author of ISES (Internet School Experimental System) and iSES (internet School Experimental Studio). His main activities are computer-aided experiments, remote laboratories and videoconferences from experimental laboratory.