

# **New teaching Approaches in Engineering**

**Prof. Ing. Tomáš Kozík, DrSc.**

**Mgr. Miroslav Ölvecký, PhD.**

**Ing. Marek Šimon, PhD.**

**Mgr. Peter Kuna, PhD.**

**Ing. Peter Arras, PhD.**

**Assoc.Prof. Ing. Yelizaveta Kolot, PhD.**

**Assoc.Prof. Ing. Galina Tabunshchyk, PhD.**



**Tempus**

Education

**DesIRE**

This publication is supported by the European Commission within the Tempus project DesIRE:

Development of Embedded System Courses with Implementation of Innovative Virtual Approaches for Integration of Research, Education and Production in UA, Ge, AM

## NEW TEACHING APPROACHES IN ENGINEERING

Tomáš Kozík -head of the author's team, authors: Peter Arras, Yelizaveta Kolot, Tomáš Kozík, Peter Kuna, Miroslav Ölvecký, Marek Šimon, Galina Tabunshchyk

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## **List of used abbreviations and symbols**





## Introduction

The textbook "New Teaching Approaches in Engineering" is an output from implementation of the Tempus DesIRE Project titled Development of Embedded System Courses with Implementation of Innovative Virtual Approaches for Integration of Research, Education and Production in UA, GE, AM. The texts consist of three main chapters: E-learning Methods in Education, Information Technologies in Remote Experiments and Technical Aspects of Construction Remote Experiments. Each chapter contains several subchapters that are thematically oriented on the issue of remote experiments in terms of their use in educational practice. They were made up of contributions already being published by the authors in professional journals and in scientific proceedings.

The texts follow the Proceedings of the Summer Course lectures conducted under the DesIRE Project in September 2014 at the Constantine the Philosopher University in Nitra. They broaden the information and knowledge contained in the Proceedings of the Summer Course - New Teaching Approaches in Engineering that has the same title.

The textbook due to its complexity approach to the studied issue will appeal not only to a narrow group of specialists, but will address wider public and will be challenging even for the researchers from the field of research of advanced training methods and their effective use in practice, as well as for the designers of remote experiments.

January 2015

Prof. Ing. Tomáš Kozík, DrSc.,  
on behalf of the team of authors

# 1 E-learning Methods in Education

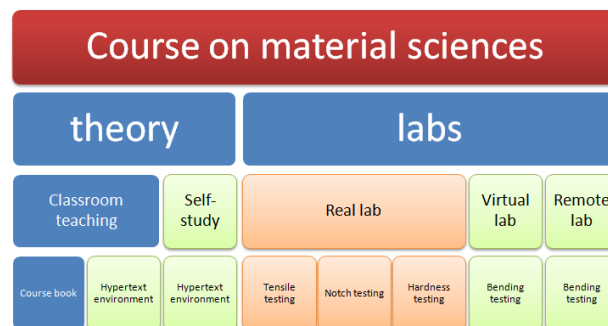
## 1.1 E-learning Environment for the Remote Study in Material Properties Courses

The field of material science is defined as a key knowledge area for engineers. Many – if not all – innovations in modern technologies are related to the use of new materials, or new technological methods of using existing materials. However, study time in existing curricula is limited and new findings in material sciences cannot be fitted in. E\_learning modules could help make up for this lack of time. This paper is devoted to the Computer Aided Learning Module (CALM) (Arras et al, 2013A), developed for the supporting e-learning courses in Material Science Properties.

### 1.1.1 Structure of the Computer Aided Learning Module

A complete driving learning module for material sciences is constructed. The structure of it can be found in fig. 1. It is the framework in which fits the theoretical courses, and the different laboratories described.

The present remote lab in the Computer Aided Learning Module (CALM) is intended to be used to study the phenomenon of material versus shape stiffness. The CALM contains all the learning contents students are supposed to study on the subject. The CALM will be used in classroom teaching and demonstrated to instruct students on how to use the remote lab.



**Figure 1 Structure of the course on material science, integrated in the CALM**

Students will study theory afterwards at their own pace, using the hypertext environment, and next simulate different combinations of materials and shapes in the virtual laboratory. Finally students can experiment on real material and shapes in the remote laboratory.

Different techniques are combined: hypertext linked contents, virtual lab (using Shockwave Flash) and a remote lab (controls for it using Javascript) (fig.2). Slideshows are provided for documentation purposes and to include the classroom presentations (fig.3)

The structure of the theory on the CALM reflects the materials in the students physical course books. As such the look and feel of the e\_learning

environment is similar to what students experience in the classroom sessions (Arras et al, 2013B).

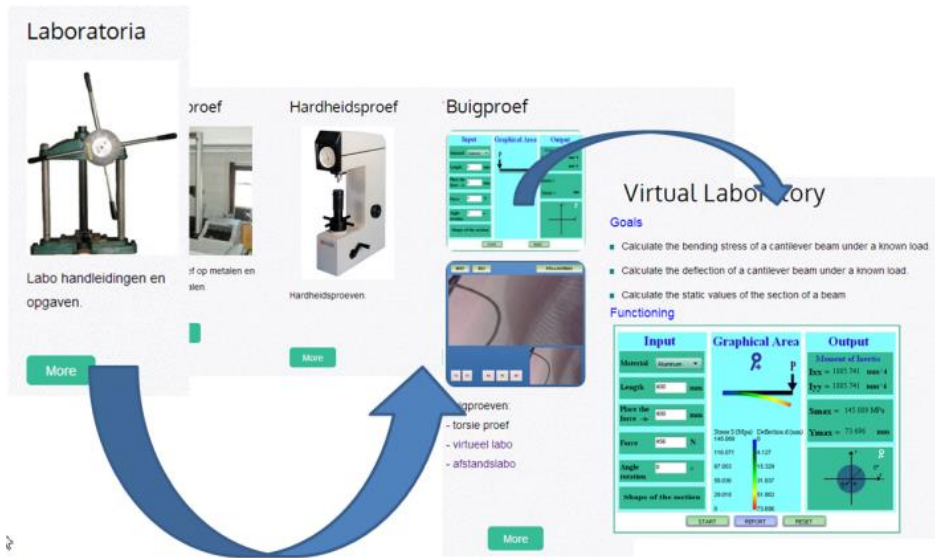


Figure 2 Navigation in the hypertext

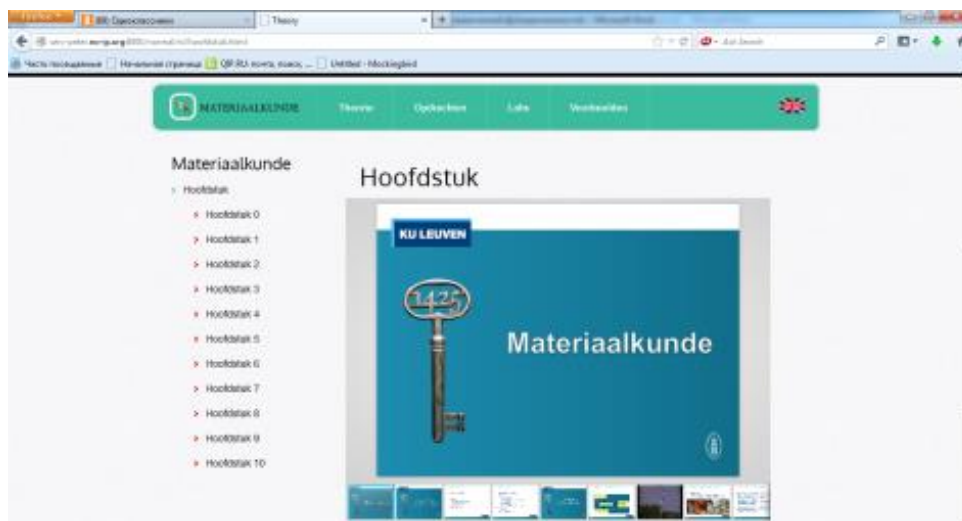
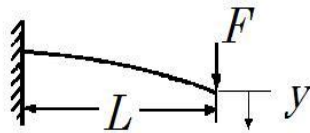


Figure 3 Lectures presentation

### 1.1.2 Virtual Laboratory

The virtual laboratory is a simulation of a test in the physical laboratory for material properties study (Arras et al, 2013B). It was constructed using the basic formulas for the bending of a cantilever beam. In the virtual lab a number of specimen with standard sections can be tested. Applied force, shape is changeable to offer a wide variety of possibilities. The only limitation with the basic formulas is that asymmetrical test specimens will yield erroneous values, because bending outside the plane of the specimen is not considered in the basic formulas (fig.4).



**Figure 4 Deflection of a cantilever beam.**

Used formulas for bending of a cantilever beam (Hibbeler, 2014):

Maximum deflection at the free end:

$$y = \frac{F \times L^3}{3 \times E \times I} \quad (1)$$

Maximum bending stress in the cantilever beam (at the supported end):

$$\sigma = \frac{F \times L}{I/v} \quad (2)$$

Moment of inertia (I): e.g. of a rectangle:

$$I = \frac{b \times h^3}{12 \times I} \quad (3)$$

TABLE I. USED SYMBOLS

Used symbols		
<i>Symbol</i>	<i>Name</i>	<i>Unit</i>
E	Young's modulus	MPa
I	Moment of inertia	mm <sup>4</sup>
F	Load	N
s	Maximum bending stress in the cross-section	MPa
y	Maximum deflection	mm
L	Length of beam	mm
v	Distance to neutral fiber	mm

A. Functional requirements for the virtual lab:

1. Calculation and visualization of the deflection of a cantilever beam, with measurement of deflection at the end and indication of maximum stress and force.
2. The values for different Young's modulus for a variety of materials should be chosen according to reported values (Hibbeler, 2014).
3. For a variety of shapes (rectangular section, H-beams, U-beam, hollow shapes...) the shape stiffness can be used.
4. For different orientations of the same shape (increment angles 1°) about the principal axes.
5. For a variety of dimensions in the same shape. (cross section dimensions and length). The different values should be entered by the student experimenter.

## B. Supplementary Requirements for the virtual lab.

Experimenting students should be able to select all different possibilities with the aid of pull down menus and selection panels, and dialogue boxes for dimensions.

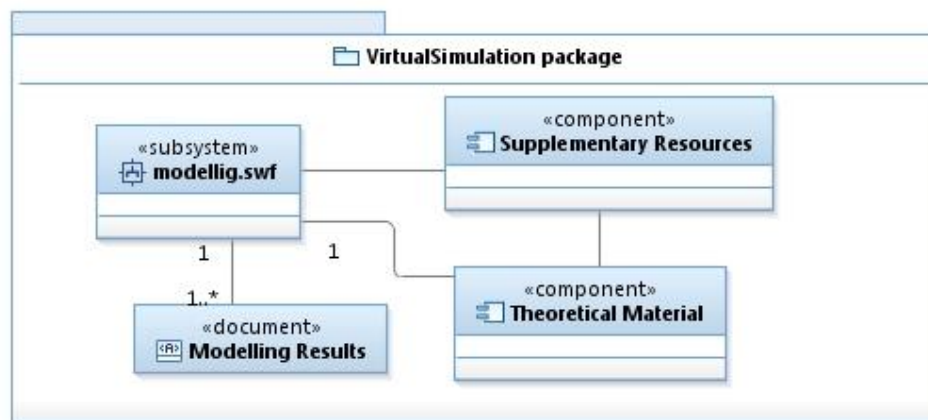
Readings of deflection, force and stresses with the aid of look alike analogue meters.

Force should be applicable with the aid of a slider bar, and real time adjustment of readings should be taken care of.

Readings should be exportable: available in a window from which to copy, together with material and cross section data. This feature is necessary for the students to make their reports. As such they can copy the data without retyping, but also without any special formatting in the virtual lab, so it can be fit in any report.

## C. Virtual Laboratory Realisation

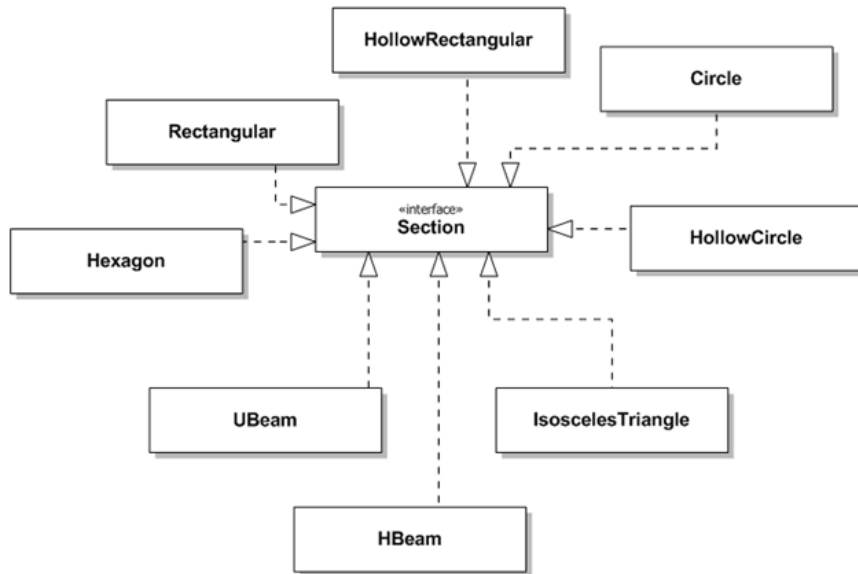
For the virtual lab realisation were used HTML5, ActionScript and JavaScript. The component diagram of developed application is presented on the fig 5.



**Figure 5 Component Diagram for Virtual Lab**

Subsystem "Modelling" is an interactive animation, based on Flash and ActionScript. It consists of 3 components: a visual component, a component for calculations and the component showing different shapes. Such realizations make it possible to easily add new shapes.

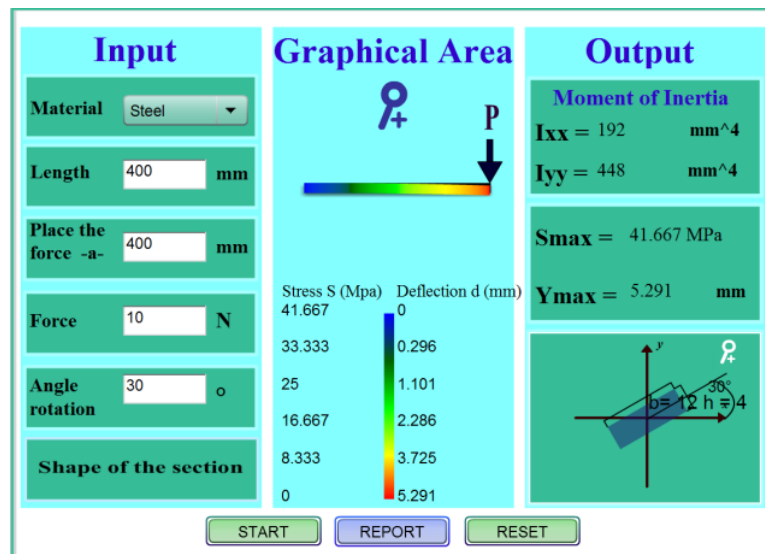
The realization of the calculation for different shapes is realized by classes put in package beam, which is part of subsystem "modelling" shown on the fig. 6.



**Figure 6 Class Diagram for the cantilever beam calculation depending from the shape**

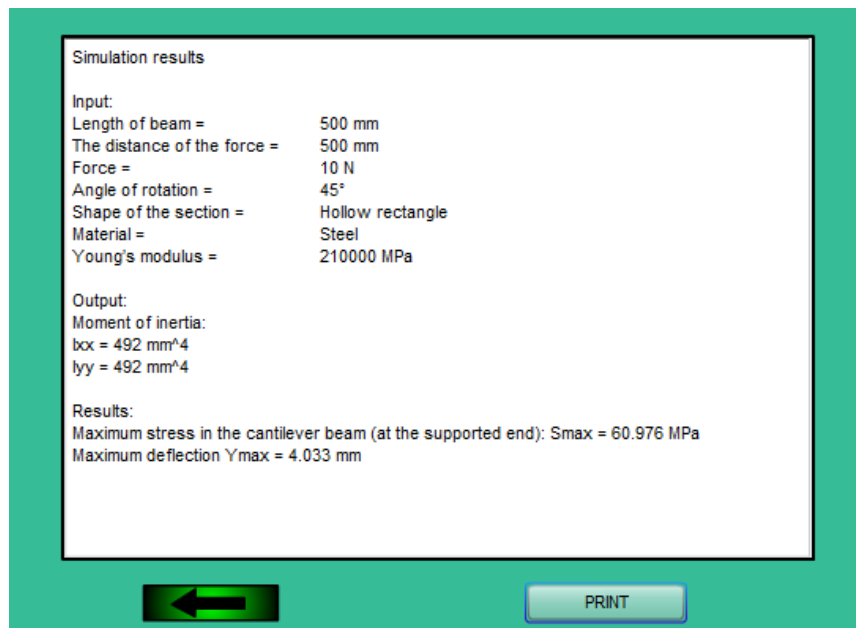
#### D. Virtual laboratory functionality

To run the experiment on the client side user should use any web-browser with an installed Flash Player. The main screen of the virtual lab is in figure 7.



**Figure 7 Screen shot of the actual virtual lab**

All results can be viewed in an additional window and printed (fig. 8). The report window is a simple text window which allows the student/experimenter to copy paste these results in his lab reports, without having to type all texts.



**Figure 8** Screen shot of the report screen

### 1.1.3 Remote Laboratory

The objective of the experiment in the remote lab is similar to the objectives of the real physical lab on bending. First objective is to see and to measure the deflection of the cantilever beams. These values can be compared to the theoretical results from the virtual laboratory. Second goal of the physical lab which is substituted by the remote lab is to let students understand the influence of errors in measuring values on the uncertainty of their results. Students need to calculate the (possible) error on their values by means of the theory of errors, considering all sources of errors in the experiment (accuracy of tools, uncertainty of loads, distances...)

#### A Hardware construction

The construction of the experiment consists of sets of beams. The beams can be any basic shape (round, square, rectangular, hollow). The beams as deformed by pulling them with pneumatic cylinders (fig.9). A reading scale is attached at the front end to measure the deflection by means of a camera. The reading scale resolution is 1 mm. To improve the read-out of the deflection, at the end of each beam, a blue marker was attached, to contrast as much as possible with the reading scale. Electronic control of the lab is with a simple relay board, on the USB-port of the computer.

In the lab uses an IP-cam for the measurement (reading the scale) and a web-cam for board control and monitoring the deflection.



**Figure 9 The hardware construction**

#### B Remote Laboratory realization

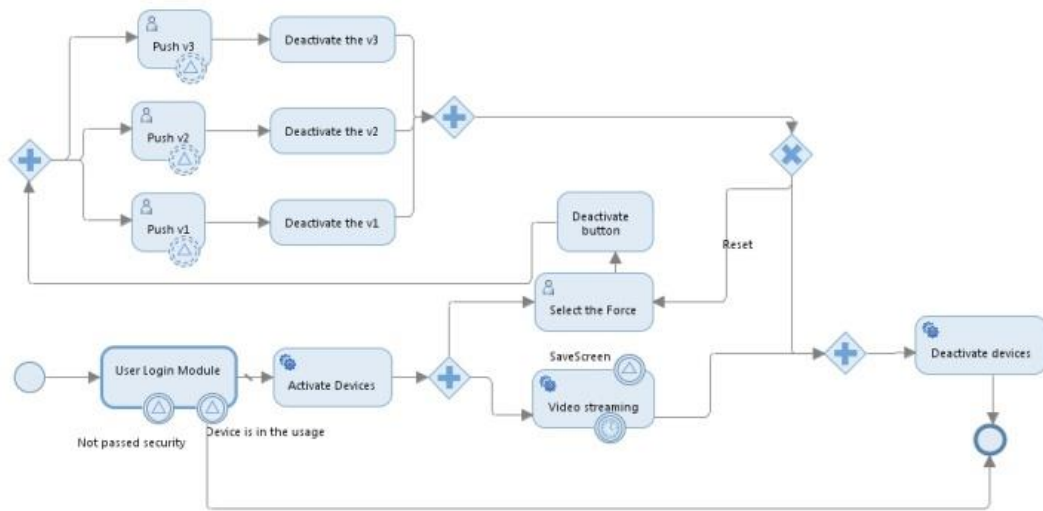
The control software driving the remote lab and integrating it in the CALM-website was developed with the collaboration with ZNTU, leading to a graphical user interface containing camera pictures and controls in one screen.

In general the software for the remote lab consists of three main subsystems:

- for control of the cameras,
- for board control,
- for lab control.

The subsystem for lab control is a controller which allows to control the process: initiate the session, safety control, process the logic of the experiment, close the session (fig.10).





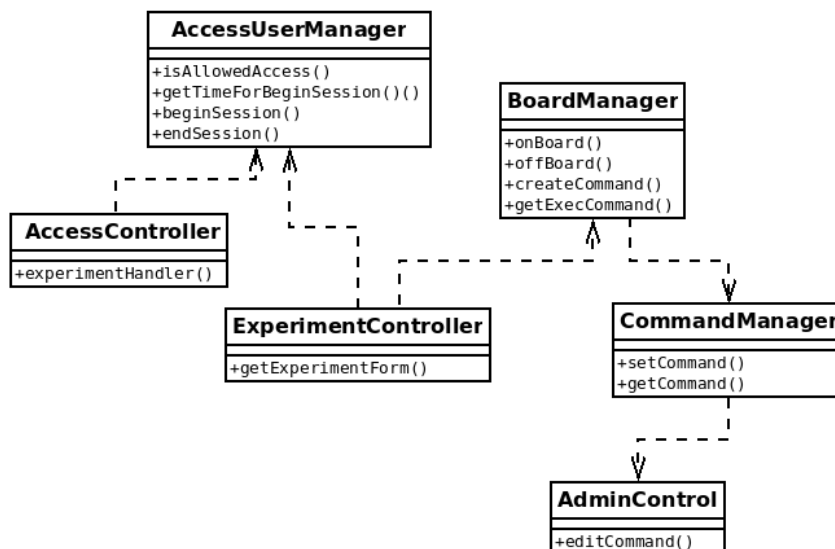
**Figure 10 Remote Laboratory functionality**

The subsystem for board control task is for switching the relays on the relay board.

In figure 11 is shown the class diagram for these two subsystems.

The subsystem for camera control is an independent system, which allows to output video-streams using the rtsp-protocol and to save screenshots of the device with high resolution for further measurements. Using the rtsp-protocol allows to display the video in browser after installing the vlc-plugin.

For the realization was chosen the Spring MVC Framework. The basic logic was realized with java, for visualization were used HTML, CSS, Javascript, JQuery, JSP.



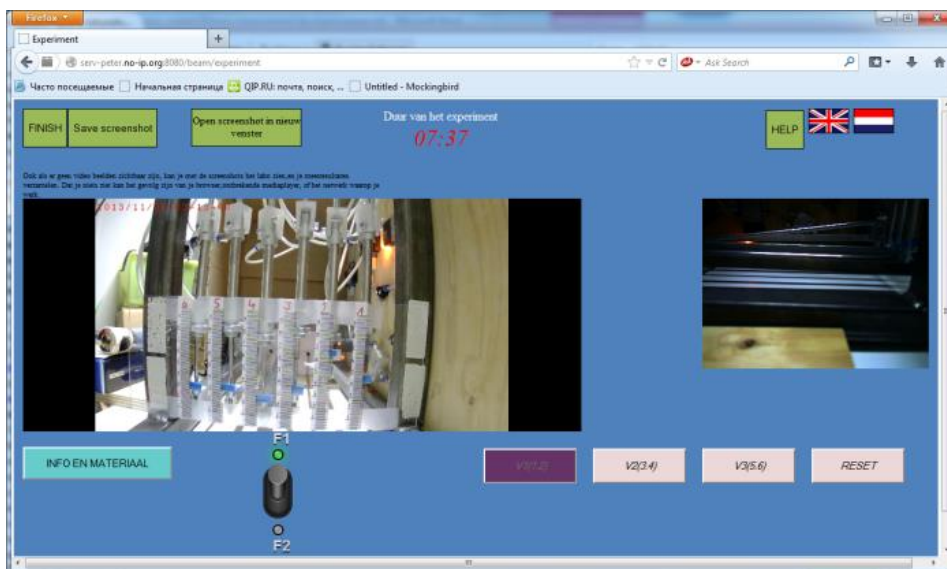
**Figure 11 Class diagram**

## Functionality of lab-control module

After getting access to the remote lab student can choose the force applied to the beams and activate the forces on the different test specimen (beams) by pressing the different valve buttons.

To cope with possible problems on images and video, a section for saving screenshots was integrated for offline working with the experimental results. The different screenshots can be reviewed to measure the deflection at the end of the beams. As such experimenting time could be reduced to 10 minutes per student. Security measures are installed to avoid automated/hacked control of the lab.

The view of remote laboratory control through web interface can be seen in figure 12.



**Figure 12 Remote Laboratory: left IP-cam for measuring, right webcam for viewing the deflection**

First evaluations of the lab show that overall functionality of the lab is appreciated by the students. Most of the problems arise with the video (speed of connection for live-streams) and the interference or no connection with plug-ins. Also the use of the lab in different browsers (Internet Explorer, Google Chrome, and Firefox) show causes of ineffectiveness as all 3 browsers treat videos differently. This makes it somewhat difficult for the students, as they (sometimes) need to tune their browser first.

### 1.1.4 Conclusion

The blended learning approach shows the most efficient results among different approaches with the usage of e-learning systems. The developed e-learning environment CALM is useful both for students needs (self-study needs) as for teachers (central source of all course related materials). It consists of different e-learning tools – html content of learning material as theoretical background and recommendations for practical tasks, tools for lecture presentation, elements of experiments with material properties simulation and remote laboratory, which give possibilities for a more practical approach to learning.

In future, new tasks on expanding the CALM are to modify the architecture to incorporate new infrastructure for other remote laboratories and to enhance the security model, as there are plans to increase number of students using the remote labs. Security is necessary to ensure the safety of the equipment and to avoid early wear or destruction by unwanted use of the remote labs.

## **1.2 Simulated and Real Remote Experiments in the Process of Education**

Under the influence of implementation of new information in technical applications as well as a consequence of the dynamically developing information and communication technologies (ICT), the social-economic environment of contemporary society have significantly changed in a worldwide dimension. It is understandable that the changing environment creates new requirements for content and forms of educational process. In the consequence of this progress, it is necessary to change the requirements and demands in the area of preparation and work for educators (teachers) at each level of educational system. Society immediately makes the pressure on pedagogical practice, to apply the newest information of pedagogical science in the shortest period applying in response to development in the area of ICT in education. It becomes obvious that besides the demand on the high level of professional knowledge of educators (teachers), the contemporary pedagogical practice expects and assumes as necessary, that educator (teacher) in practice would have in a defined range appropriate skills in using ICT in the pre-teaching and teaching process itself.

### **1.2.1 ICT in Education**

In the professional community, the opinion about the positive influence of using ICT in education on the quality and efficiency of school teaching is common and generally accepted. One of the progressive developing educational methods nowadays based on using the information technologies, is a method of real remote experiment and simulated experiments.

In recent years, the increased the interest of teachers in implementation of educational methods, where teaching is supported with ICT and especially with using of personal computers (PC) and Internet. Teaching natural science and technical subjects with this support is also popular among pupils and students. By the implementation of teaching based on the real remote experiments (experiments controlled via PC connected to the Internet), as well as by using simulated experiments, the educational process functionally combines clearness of understanding the physical principle of functioning of technical equipment with the possibilities provided by ICT.

In recent times published results of the research studies are focused primarily on analysis and evaluation of the success of the educational result, which was achieved by using ICT. Among the educators is widespread the opinion, according to which the use of ICT in education presuppose the achievement of higher level of education. Frequently, this opinion is accepted without a careful examination of the influence of ICT on the results of education in the relation to the organizational structure of the

school teaching unit, in which ICT are used. Particularly, it is true in the area of using the real remote experiments. Till nowadays, it has not been experimentally approved their efficient and optimal inclusion in the structure of the teaching unit.

Specific case from the perspective of the teaching management is simulated experiment. This type of experiments is particularly suitable for technical subjects, because their use in educational process allows achieving higher level of visualization of the technical principle or phenomenon. They do not need to create complicated controlled experimental set as the real remote experiments. This was one of the reasons that led us to think about the draft model of the structure of the teaching unit with the application of simulated experiments in the combination with real remote experiment and verify the educational successfulness in pedagogical practice.

The validity of research, which was orientated on the effectiveness of application of the real remote experiment and simulated experiments, is given:

- by the currently formed social environment, which is characterized by a high level of ICT use in practical life of individuals, as well as in the economical activities of the society itself,
- from the importance of implementation of innovative progress in education with regard on the current educational trends, which are based on the mediate of such knowledge and information to pupils and students, which will be able to immediately apply in their further professional education and in practical life and will be able on the basis of acquisition knowledge and skills create new original solutions of problem tasks,
- with the recommendations of the European Union about acquisition of necessary skills of the population in using ICT for lifelong learning.

Investigation of starting points and conditions for the optimal application of ICT in education, with the contemplation of using their strengths in education, seems to be objective reality and present social requirement.

In our research (which was made last year) we verified (using natural pedagogical experiment) the appropriateness of using the real remote experiment and simulated experiments in the university study programme of teaching vocational subjects and practical training. The benefits of this education for knowledge level of students were experimentally observed, and there were also analyzed the attitudes of teachers and students in relation to teaching, in which the real remote and simulated experiment was used.

### **1.2.2 Real Remote Experiment**

The term real remote experiment means the experiment, which we can actually observe and control via PC connected to the Internet. The basic principle is based on the real laboratory experiment with the difference, that physical or technical task is not made directly within the teaching process of natural science or technical subjects by students in the classroom, but here is only observed or in some cases controlled via PC

connected to the Internet. This way of making an experiment is one of the main advantages of real remote experiment. The user (experimenter) is able not only to observe a particular experiment, but can also control it from the PC. S/he follows the progress of experiment, sets various parameters, can easily download the measurement data to the PC and further process. (Schauer, 2008).

So far acquired experience from pedagogical practice and knowledge from application of real remote experiments show (Schauer, 2008), that real remote experiment as a means of education in natural science and in technical subjects via Internet has the following benefits in the educational process:

- increase the motivation level of students,
- involve more senses of students in the educational process,
- increase the level of logical thinking by students,
- support the development of activities and in self-reliance by students (transformation from passive to active approach),
- time efficiency – despite wasting time on learning definitions, the direct observation of the particular phenomenon,
- optional change of the parameter values in the modelling experiment,
- launching the experiment anytime and anywhere via PC connected to the Internet,
- development of digital competences.

Real remote experiment, which development is not completed yet, means for students one of the most interesting ways of education. (Schauer, 2009) In the school laboratories there is often used Intelligent School Experimental System (ISES). On the web page of ISES is at disposal not only the technical support (instructions for installing hardware and optimizing system), but also the software (here is free demo and upgrade of software at disposal to download) and teaching (free manuals, references to the other publications, description of individual modules and others) support. The user can measure, manage and process the measurement data with this system. ISES was developed in the Czech Republic (Lustig, 2000).

Nowadays, the following experiments can users observe or controls via PC connected to the Internet:

- Water level control,
- Meteorological station in Prague,
- Electromagnetic induction,
- Natural and driven oscillations,
- Diffraction on microobjects,
- Solar energy conversion,

- Heisenberg uncertainty principle.

The real remote experiment Electromagnetic induction was used in the draft lesson of electromagnetic induction. (Fig. 13)

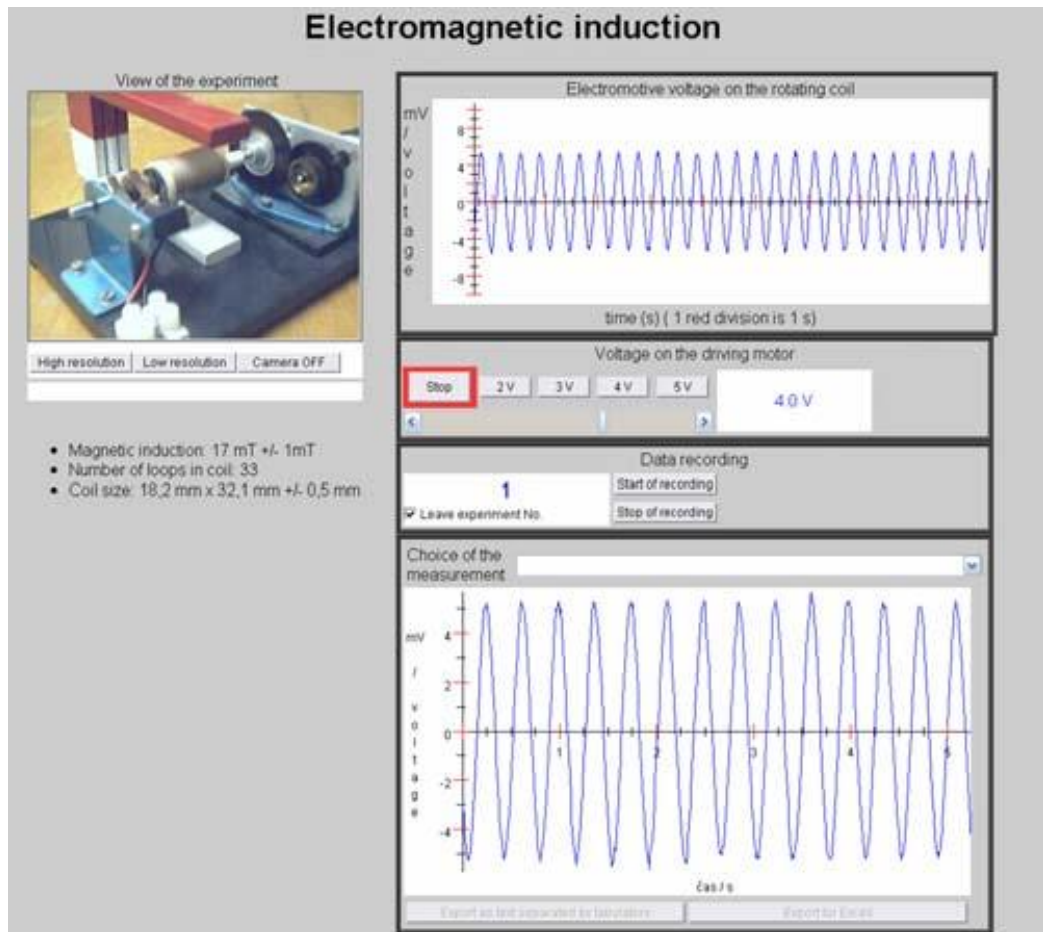


Figure 13 Remote experiment Electromagnetic induction

This experiment is freely available on the web page [www.ises.info](http://www.ises.info), currently in four language versions (English, Slovak, Czech and Spanish). As a part of this experiment are made: motivation page, physical basis of the phenomenon of electromagnetic induction, the experiment guide, short assignment, several pictures of experimental arrangement and finally real remote experiment. The user can via PC connected to the Internet control the amount of voltage on the engine, which determines the speed of the rotating coil in homogeneous magnetic field. Via the system ISES, the induced voltage is scanned and is online rendering the time-dependence of the amount of induced voltage on the coil. All the measurement data are recorded and the user can download the data (for example into a text document or into a spreadsheet) and further work with them. It is possible to choose the data measured by another user from drop-down option Choice of the measurement and compare them with data measured by user. On the left section of this web page (Fig. 13) is a view of actual experiment (the user can view the rotating coil of engine).

### 1.2.3 Simulated Experiment

Educators, who in the recent years implemented the computer simulations and animations in the process of education, noticed an increase in the level of clearness, motivation and activation of students, as well as increasing the level of achieved knowledge and skills. Applets help in the high rate to the development of analytical thinking (observation), implicational skills (formulation of assertions, reasoning), logical thinking and to have the ability of application the observation and learned phenomenon in the education. Using the simulated experiments contributes to the efficiency and attractiveness of the educational process, because students and teachers are working with ICT (mainly with PC, Internet and simulations) at the lessons and sometimes time-consuming and complicated construction of physical experiments is removed from the lessons.

Created simulations (applets), which are available on the Internet, or creation of the own simulation, which demonstrate the physical principle of the particular phenomenon, is possible to integrate to the teaching unit, mainly at the lessons of natural science and technical subjects. The web page of specific applet contains mostly the accompanying text, theoretical ground, formulas, derivations, manual tasks, questions, etc.

Nowadays, there are applets for various scientific field, most of all dealing with problems of natural or technical science – for example, the applets in teaching of physics are called physlets.

The outward appearance of applet mostly depends on the intuition of the software engineer, how the specific applet was prepared. Some applets are demonstrated from a graphical side relatively easily, because the author of the applet put more emphasis on professional side of actual problem. This applet contains more formulas, theoretical explanations, the simulation is not so much dynamic; but on the other side contains more particular figures; possibly monitor the interaction of several physical parameters (in the case of simulation of physics). Then here are conversely applets, which do not put the emphasis on theoretical explanation of specific problem, but their assignment is to take observation of common user, to which is adapted the graphical form of this simulation. Sometimes, these applets look like simple computer games.

Nowadays, the interesting interactive Java applets are created especially on the following web pages:

<http://physedu.science.upjs.sk/ejs/index.htm>,

<http://surendranath.tripod.com/AppletsJ2.html>,

<http://phet.colorado.edu/index.php>,

<http://webphysics.davidson.edu/Applets/Applets.html>,

<http://www.walter-fendt.de/ph11e/>,

<http://hockicko.utc.sk/>,

<http://kf.elf.stuba.sk/~cerven/SimulacieAdresar/simulacie.html>,



<http://fem.um.es/EjsWiki/index.php/Main/Examples>

In the individual stages of the lesson design, at the main topic of electromagnetic induction were used the simulated experiments (magnetic field simulation, magnetic field of a straight current-carrying wire, electromagnet, electric engine and generator), which are freely available on the web page of the University of Colorado, as well as on the web pages of Walter-Fendt. Before the first using of the applets on the lesson the individual experiments were set up so that they motivate students to deal with issues.

#### **1.2.4 Integrated E-learning**

Continual development and advancements in the area of ICT create for educators the modern environment, in which they can innovate and improve already created electronic teaching materials, real remote and simulated experiments. According to Ožvoldová (2006), the global e-learning educational resources are mostly demonstrated as a theoretical concept of comprehension at particular field of science through mathematical formulated laws, models, simulations and animations, applets, exercises, graphs and presentations. In almost any electronic text (e-text), which is focused on the understanding the principle of formation (function) the particular phenomenon, isn't included the real remote or simulated experiment, so there is created not very homogeneous files of information. (Ožvoldová, 2006) We can understand the integrated e-learning as a higher generation of e-learning, which is based on the use of three components, as follows:

- experiment – real laboratory and real remote experiment,
- simulations and interactive applets – one of the form of experiment,
- electronic educational texts and teaching materials – e-textbook, e-study material.

Jesche et al. (2005) began to use the term of the e-LTR (e-Learning, e-Teaching and e-Research) and Schauer (2006) called the system (of these three components) as a integrated e-learning, in which the student reproduces, compares, observes, sorts, connects, deduces, generalizes, analyses and so on.

In our research, the real remote and simulated experiment (two components of integrated e-learning) was used. We hope, that the combination of particular ways of the Internet support as the form of the integrated e-learning in the educational process, can contribute in significant way to the quality of learning, improvement and deepen already acquired knowledge. Also, the e-learning can contribute to form the general knowledge, as well as in the development of skills with the use of modern ICT. (Ožvoldová, 2006)

#### **1.2.5 The Project of Research and Results**

We based our methodology of lesson, with real remote experiment in combination with simulated experiments, on this statement: *Tell me and I Will Forget; Show Me and I May Remember; Involve Me and I Will Understand* (Confucius, 450BC). The main (primary) goal of our research



project was to gain the knowledge about the benefits of application the real remote a simulated experiment in the process of education by students in the university study programme and how the experiment can increase the level of knowledge by students and to find out the benefit of using this experiments in the teaching in the area of durability their knowledge. The secondary goal of the research was to find out the influence of the experiments on the level of motivation and activation the interest of students in the topic of particular school curriculum during the school teaching.

The research was made by the method of natural pedagogical experiment. The representative sample was created by 103 students of the university study programme of teaching vocational subjects and practical training. The students were divided into two groups (control and experimental) on the basis of the results of the preliminary test of cognitive knowledge, so that the groups were homogenous. The control group was created by 47 students and the experimental group was created by 46 students. We used the Fischer two-sample test for dispersal to statistically verify the homogeneity of these groups.

The school teaching in the experimental group was made by the draft model of methodology with the support of the ICT, especially with real remote a simulated experiment. In the control group the teaching was made in a traditional way – the lecture with a discussion. The main topic of curriculum was the electromagnetic induction for both groups. This topic was chosen with respect to:

- the type of completed secondary school,
- importance of the problem of electromagnetic induction in the technical applications, in the further study and the knowledge application in their professional practice,
- accessibility of the real remote experiment on the Internet,
- already created simulated experiments concerning the topic.

The level of students' knowledge was found out with the non-standardized didactic test of cognitive knowledge at the beginning and at the end of this natural pedagogical experiment. The durability of knowledge (which is acquired in the school teaching the electromagnetic induction) was found out with the same, but little editing tests (the order of questions was changed), after a lapse of time with the students both of groups.

Attitudes and views of students and the future teachers to the draft school teaching form were found out with the method of questionnaire.

The primary goal of school teaching in the experimental group was to design the methodology of school teaching so that in this teaching were strengthen the phase of deepening and consolidation of particular topic in curriculum. The teaching was focused on the repetition of theoretical and practical knowledge and their deepening and consolidation. From the perspective of individual phases of educational process the attention was centred on the fixation phase, which the main objective is to consolidate and practice the curriculum in the form of solving the theoretical and practical tasks. This condition of the designed model of teaching was carried

out by application of simulated experiments in combination with real remote experiment.

For this reason, the project of research was not focused on the observation of the influence of experiment in the individual phase of school teaching unit, although if the research would be focused on the individual teaching phase, from perspective of innovation the methodology would be very interesting. In our methodology, the process of education was made using the method of fixation (questions and answers) to support the interest of students to the particular topic, arouse curiosity and avoid passivity. This means that the goal of the research project was to create the methodology, with which the educator should achieve the efficiency of impact on deepen and consolidated curriculum, which the students acquired in previous study.

The significance of differences in the results of didactic tests of knowledge, which were gained from students in both groups, was evaluated by student's two sample test by equal variances. We compared and evaluated the differences in the middle of values of control and experimental group of students in the final didactic test with the next comparison of value the tested criteria  $t_{stat} = 8,66 > t_{krit} (1) = 1,66$  on the level of significance  $P(T \leq t) (1) = 0,00 < 0,05$ .

The evaluation of acquired results from the final didactic test showed, that results of students in the groups are statistically significantly different. The students in the experimental group achieved the higher performance in the area of cognitive knowledge in comparison with students in the control group. Similar results were found out in the area of durability of knowledge. Statistically was confirmed the higher level of cognitive knowledge by students in the experimental group in comparison with students in control group, which were educated in traditional way.

With the questionnaire, focused on attitudes and views of students, was found out that students consider our methodology (based on real remote experiment in combination with simulated experiments) as attractive and suitable in for technical subjects. The results of didactic tests and questionnaires were compared with the results of researches of other authors, carried out in the past or recently.

Fričová et al. (2008) found out, that the support of interactive applets using at the teaching contributes to better understanding and finding the connection between theory and practice. The courses of physic, with the interactive applets, are more interesting and attractive for students.

The results of the research team of S.B. McKagan et al. (2008) show that if there is applied the interactive lecture in combination with simulated experiment in the process of education; the result of teaching is higher than in traditional education.

Thornton (1999) considers the support of real remote experiment as efficient in the way, in which the students observe real phenomenon. Students do not waste a time of lesson to make routine calculations, but they can focus on learning, deepening and consolidation. The students learn to work together by solving the problems and to communicate with educators.

Halúsková (2008) considers (on the basis of students' statements) the use of the real remote experiment in school teaching more interesting than real laboratory experiment, which is created at the lessons.

Kocijancic (2009) came to the similar conclusion in his research as the other authors and he focused his research on analysis of the attitudes and views of students to the application of simulated experiments, which were integrated at the beginning of the lesson.

Rakovská (2004) focused her research on finding out the benefits of Java applets, which were integrated at the lesson. She found out that students did not focus on physical content of particular phenomenon, but they focused on graphical or technical aspect.

From these conclusions of researches it follows, that using of progressive methods of education supported by ICT to achieve the higher effect of education, requires making research projects focused on the problem area. Besides this, it is very important to pay attention to the specialized vocational preparation of teacher in the area of using ICT in the process of education.

We can certify (by analysing and comparing the results obtained from our research and from researches of the other authors) that the application of real remote and simulated experiments integrated in the school teaching of natural science and technical subjects:

- contributes to the achievement of higher level of cognitive knowledge of students,
- contributes to the deeper explanation of particular topics of the school teaching,
- allows better understanding the topic of school teaching,
- leads students to the better understanding of the relations between theory and practice,
- increases the durability of acquired knowledge,
- supports the increase of students' interests for deeper understanding of fundamentals of particular physical phenomenon,
- helps to increase the motivation level of students to study and has a positive influence on increase of the manual activity of the students at the lesson,
- increases the level of creativity by students at the lesson, in which they can create the own real laboratory experiments, when the students observe the real remote and simulated experiments,
- has a positive effect on active cooperation between students,
- supports intercurricular relations in the school teaching.

The results of the carried out research project, which was focused on consideration of suitability of the application of real remote and simulated experiments, in the university study programme of teaching

vocational subjects and practical training, have demonstrated the importance and relevance of the application the ICT in the subjects, which are not very attractive and favourite from the students point of view. The main topic of curriculum Electromagnetic induction, belongs to the topics, that students perceive as a theoretical one with a high proportion of the acquired definitions and formulas, that are necessary for various calculations, without deeper understanding of the basis of physical phenomenon and its use in practical applications. Therefore, the main goal of our research project was to pay attention to the ability of students – future teachers of vocational subjects to achieve in the natural pedagogical experiment the higher level of deepening and consolidation of the basis of particular curriculum with the natural science and technical specialization and with topics that are more theoretical than practical. Our created methodology is based on the use of real remote and simulated experiments in the educational process. With the method of natural pedagogical experiment was confirmed that the application of ICT, particularly the use of real remote and simulated experiments in the teaching, is suitable to achieve the increase of students' interests in the natural science and technical subjects, educational activities of students in the teaching and has the positive influence on increase the level of durability knowledge.

## 2 Information Technologies in Remote Experiments

### 2.1 School Experiment as a Part of Teaching Lesson

The role of the experiment in the educational process is to demonstrate the new knowledge to the students, help him understand relationships, verify hypotheses, calculations or deduct conclusions. Another benefit of the experiment is to develop skills in handling devices and measuring instruments. Laboratory experience is directly related to the student's previous knowledge. Clough (2002) states that "they produce active mental struggle between knowledge and new experiences and encourage metacognition"

For the implementation of educational experiments, it is necessary to possess technical equipment, whose price level corresponds to its parameters. For the active work of students, it is ideal to have the same equipment in several groups simultaneously. After discussions with teachers in schools, we have new information that most schools in our country as well as neighbouring countries only maintain their obsolete laboratory equipment with minimal upgrade. So it happens that a number of samples, measurements, observations and investigations remain only theoretical. Another problem for realisation of the experiments is the curriculum. As stated in Škoda and Doubík (2009) "greyhound race against ruthless curriculum attempts to shift the active use somewhere to the edge of the interest of teachers, because the time required implementing the experiment and drawing conclusions is necessary to overload students with other abstract concepts". Kozík (2011) calls attention to wards a shift from practical training in technical and scientific education. As the author states "not so long ago, there were demonstrative experiments used in teaching of technical and scientific subjects, whose task was to validate the theoretical conclusions".

With the arrival of information technology in education, e-labs were formed besides e-learning. E-laboratories are formed by computer-mediated remote real or simulated experiments. The distanced and simulated experiments accompanied by electronic study texts create an integrated e-learning, which Ožvoldová, Schauer and Lustig (2006) consider one of the most progressive and nowadays also the most quickly developing teaching methods.

Considering the above mentioned facts, it is possible to ask: Why develop training with support of real experiments?

#### 2.1.1 Characteristics of hands-on laboratories

Real laboratories include real research process. From other types of laboratories they are distinguished by two basic features:

- all necessary laboratory facilities are real and located in the laboratory
- students participating in laboratory experiments, are physically present.

Experiences gained in real laboratories are generally regarded as a solution which helps students to learn science. Intuitively, it seems that direct experience improves the understanding of students. Laboratory experiences are still not enough to understand the knowledge. Students must also share the idea of experiment. As stated in Cloug (2002), "laboratory "cookbooks" used in science teaching rarely catch the student and help them comprehend."

Bransford and Brown (2004) point out that "hands-on" experiments can be an effective way to create a basis for new knowledge of students, however, themselves do not reflect the fundamental conceptual understanding, so necessary for the generalization of observed features.

In carrying out experiments, a student confirms their acquired theoretical knowledge from which they create general conclusions. This meets the requirement of constructivism, active construction of knowledge to students. Experiments which the students should not carry out themselves, in terms of safety and legal standards, are done by the teacher demonstratively. Other experiments should be done by students depending on the possibilities and laboratory equipment individually or in small groups.

In carrying out the experiment, it is important for the teacher to make clear its evaluation of students and meaningful interpretation of the results. It is also important to help students during the experiment procedure with the acquisition and implementation of fundamental safety rules during physical observation, measurement and experiment. As stated in Blaško (2009), pupil attempt should be simple, convincing and safe. After completion of the experiment the learner should demonstrate and explain the phenomenon, describe and generalize. Alternatively, student can make a written document. By developing the ability to observe, describe and analyse the demonstrated phenomena, the student learn the basic elements of scientific work.

Social environment in the school laboratory is usually less formal than in the traditional classroom. Thanks to this, the laboratories provide opportunities for productive interactions between students and teachers that have the potential to improve the learning environment. Hofstein and Lune (2004) argue that the learning environment is strongly dependent on the nature of the activities carried out in the laboratory, the expectations of teachers and students, and the nature of the assessment. This environment is partly influenced by the materials, equipment, resources and physical environment, but mainly a function of climate and expectations for learning, collaboration and social interaction between students and teachers, and the nature of the examination in the laboratory.

### **2.1.2 Experiment in the education lesson**

Teacher's behaviour during the experimental lesson is focused, as defined by Blaško (2009) on learning activities which help the students to:

- create and test hypotheses from observations of various features, find explanations for it,
- compare different opinions and approaches to solve experimental tasks,

- determine what additional information is necessary to determine the performance of a task experiment,
- choose one of the alternative solutions,
- implement experiments and verify the results of solutions, consider its application in practice,
- self-observe, measure, experiment, using mathematical and graphical resources, discuss mutual communication and teamwork,
- compare, find links between causes and their effects,
- solve problems that require matching of knowledge and skills from several subjects, the use of practical skills in different areas of human activity, which allows to use many approaches to address them,
- practise model examples to solve problems using algorithms; determine their own workflow and choice of sequence drafting tasks, self-monitor results,
- correct and improve their own work.

As we mentioned, an additional benefit of the experiment is to develop skills in handling devices and measuring instruments. Blaško states the acquisition of following competences:

- communication,
- information,
- mathematical fields of science teaching,
- problem solving,
- personal and social,
- jobs and business.

From the perspective of experiments in physics, Pavlendová (2010) identifies the following core competencies:

- competence to lifelong learning,
- competence to apply mathematical thinking and knowledge in the field of science and technology,
- social and personal competencies,
- work competencies, competence to perceive and understand the culture and speak the instruments of culture.

Halušková (2009) point out good experiences with the inclusion of simple experiments in physics lectures for first level university study. Simple and inexpensive material experiments repeatable by students at home, brighten the lecture and help students understand lectured material.

Baník (2010) explains the possibility of physics experiments, easily made at home using everyday objects. It is encouraging the students to make experiments at home, which helps to improve the perception of physics.

The author recommends collecting topics for individual household experimentation at every level of education. These topics should then be provided to teachers to help them motivate the students to make such experiments at home. A physics publication for experimenting at home is welcome as well.

Kireš (2010) mentions the following key elements for problem solving:

- unconventional problem,
- availability of experimental equipment,
- the ability to use their own (not prescribed) original solutions,
- ambiguity of an answer to the problem,
- the need to seek answers on the basis of experimental results,
- the opportunity to formulate their own scientific conclusions.

Because of the time required for the experimental discovery of knowledge the author recommends their inclusion primarily in leisure activities in non-formal education.



## 2.2 Using Remote Experiments – Everyday Reality

Teaching with the support of information technology became a popular form for teachers in recent years. It is perceived positively by students as well (Schauer, F. - Ožvoldová M. - Lustig, F. 2008) (Domingues et al, 2010), (Clough, 2002). The use of computer-mediated educational experiments - remote real experiments, allows to carry out educational activities on the basis of individual needs of students (Grimaldi and Rapuano, 2009).

By a remote laboratory we understand the environment in which management and observation of real devices and objects is mediated by computer and needed remote access is carried out via a computer network. For the connection of computer networks, it is possible to visualize the Internet via remote laboratory from any computer on the Internet.

According to Nedič et al. (2003) the remote laboratory provides students the best alternative compensation for work in the real lab. If a remote laboratory is properly designed and built, it can provide the students with:

- feeling of real presence in the laboratory (telepresence),
- participation in conducting experiments on real devices,
- learning through trial and error,
- work with real data,
- the possibility to choose when and where the experiments will take place.

### 2.2.1 Remote Experiments at Universities

Despite the fact that the popularity of applying RRE in education increases, the efficiency of the education is questionable. By Nedič et al, by some students, RRE are not perceived as real. They see differences between the remote real and simulated experiments, despite the fact that RRE provides the experiment with real data. Abdulwahed and Nagy (2011) draw attention towards the absence of the teacher in consultation and communication with students, resulting in the isolation of the student from the real learning environment.

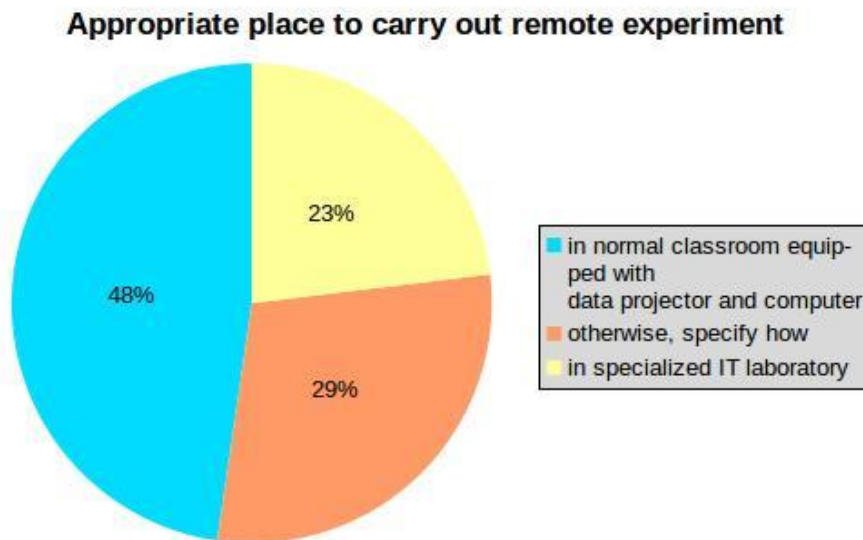
Lack of feedback is considered a major disadvantage of RRE by the authors. A particular problem is raising funds to build and operate RRE. Some experiments are able to be activated automatically, regardless of the time of connection of the user (such experiments are usually in the area of electrical engineering), others require continual human intervention in place (this is typical for chemical and technological experiments).

From the point of view of the user, the most restricting condition of RRE is the transmission speed. The high-speed Internet access is required. Another deficiency of remote real experiments is just One-sense involvement of the student when working with RRE.

There is a need for the RRE users to have an overview of current state of regular use of RRE at universities around the world. To obtain this information, we conducted a survey, in which representatives of university

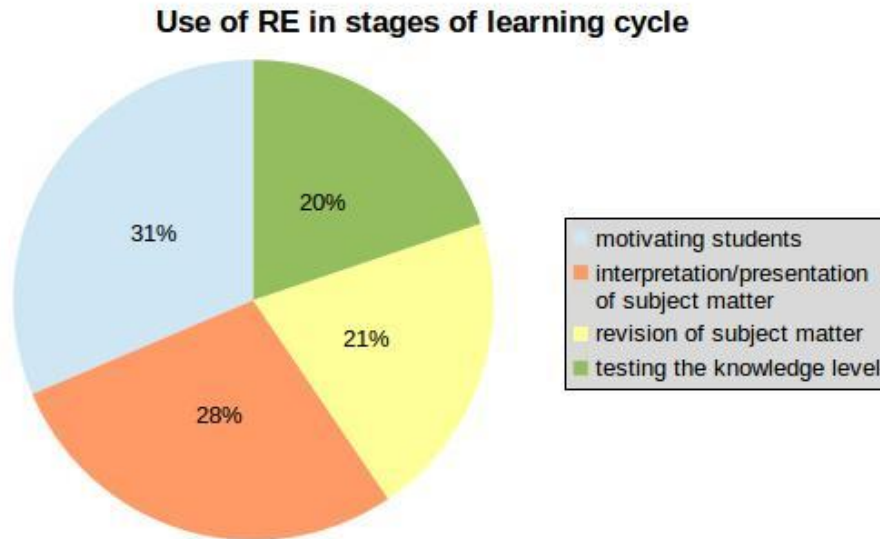
departments were contacted with a request to complete a non-standardized attitudinal questionnaire. List of workplaces was created based on an analysis of publications in scientific journals dealing with issues of RRE and data publicly available on the Internet laboratories RRE.

In the questionnaire, respondents were given the opportunity to name the place appropriate for the implementation of RRE. Responses confirmed the assumption that a computer with an Internet connection, data projector and possibly camcorder can create a laboratory from any classroom. One point of the questionnaire was aimed at identifying the most common place of the use of RRE. Respondents could select more options and furthermore there was the option "otherwise" where they could express their opinion. The most often reply from the respondents was anywhere on the internet network and mobile devices." This response highlighted the advantage of RRE using. Students can easily connect to the RRE at the time and place they consider the most appropriate for their learning (Figure 14).



**Figure 14 Named the place appropriate for the implementation of RRE**

From the perspective of achieving positive results from the application of RRE in teaching, it is important to know the attitudes of respondents towards the use of RRE on different stages of the learning cycle. The results of the respondents indicate that RRE are mainly used in the initial phase of teaching and to motivate the student/learner. This phase of the lesson is very important from the point of view of overall teaching success, as it is the phase in which the teacher tries to evoke the learner's interest in the subject (Figure 15). This conclusion corresponds to the knowledge of the use of RRE described in specialized publications, according to which the students examine the research by RRE first and then carry out the experiment in a laboratory.

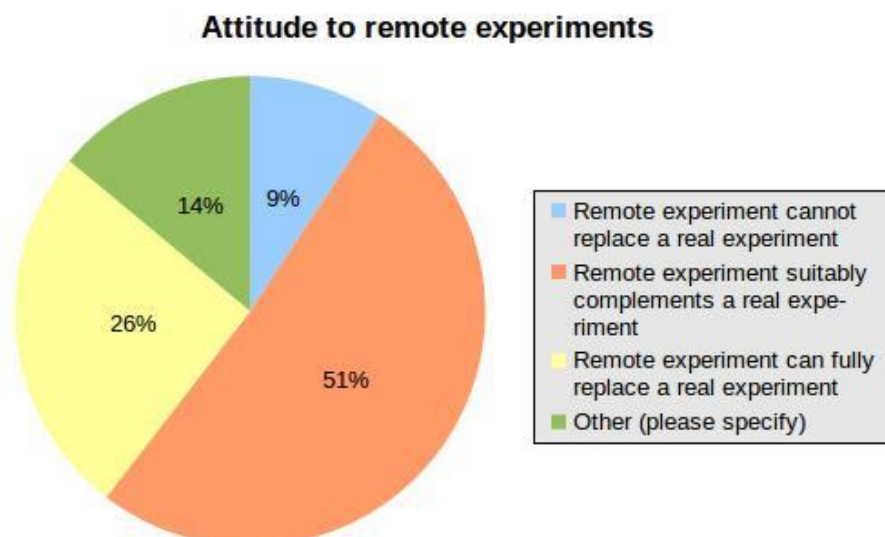


**Figure 15 Attitudes of respondents to the use of RE in different stages of the learning cycle**

Overall attitude of respondents towards remote real experiments in relation to the real experiment is represented in Figure 16.

An interesting opinion was expressed by one of the respondents: "Here I could mark all of 4 options". Other respondents answered in a similar sense:

*„Really depends. We consider them complementary in general, but some can not be remotified (where instructor wants to teach how to plug cables), and others are superior in their remote version (e.g. better management of resources, etc.)“ and „its depends on the particular phenomenon“.*



**Figure 16 Overall attitude of respondents to remote experiments**

Representatives of university departments using RRE from all continents engaged in the survey. There were 94 university departments addressed, of which 44 completed the questionnaire.

An analysis of the responses of each part of the questionnaire shows that remote experiment has its place in education. In specific cases, it is even more appropriate than a real experiment (for example, in distance education in various scientific fields). In general, it is not really possible to compare the real and remote experiment; however, it is necessary to take into account the training and educational goals of the institution, which carries out educational activities.

### **2.2.2 Summary**

The goal of the authors of the questionnaire survey was to gain insight into the actual regular use of RRE by university departments in the world. This was done by the analysis of the questionnaire, where there were several interesting findings about the use of RRE in the workplace of universities in the world.

The largest group of functional remote experiments are experiments in electrical engineering. This is understandable, because the electrical RRE are much easily realised and maintained than RRE in the fields of chemistry and technology.

For access to RRE just the Internet network is needed. As noted by the majority of respondents, data projector with a computer with high-speed Internet creates a laboratory from any classroom.

The attitude of respondents towards RRE applied in educational process raised some interesting findings:

- 51% of respondents consider RRE an appropriate complement of real experiments.
- 26% of the respondents consider RRE a suitable replacement for a real experiment.

In several cases, respondents supplemented their responses by verbal expressions. They agreed that it is not possible to assess and compare the RRE at all, because, as one respondent said "it depends on the particular phenomenon". This expression of the author pushes the question of the possible replacement of real experiments by remote experiments in another position. This must be considered when comparing the effectiveness of training conducted with the support of real or remote experiments.

## **2.3 Will the Real Experiments be replaced by the Simulated Ones ?**

School experiment in natural sciences and technical subjects has a special status. Enables teachers to non-violently and for pupils / students in an acceptable way to encourage and develop in them creativity and creative thinking. It teaches them to work systematically and purposefully. In case of organizing a group work, students will learn and acquire the necessary experience with work in a team and be responsible for work performed in front of collective.

The experiment is the primary method of scientific research. Methodically properly designed educational experiment is identical in content and methodology to the scientific experiments. The aim of scientific experiment is gain new knowledge about natural sciences phenomena or changes of variables that characterize them at a given internal and external conditions affecting the studied system.

The pupil / student by carrying out school experiment also gaining experience and manual skills to work with the technique in preparing the experiment. Acquires the ability to analytically correct approach to the evaluation of experimental results. Gained skills and experience of working with experiment is significant in terms of their future career prospects or application in real life.

The role of the experiment in the educational process is illustrate to the pupil / student procedures of observing a phenomena in nature as well as the investigation and management of technical and technological production processes. Laboratory experiences which the pupil / student obtains by work in the laboratory are very interactive with his/her previous knowledge. Evoke in him/her an internal conflict between him/her already previously known knowledge and experience and new knowledge and experience, which positively affects the cognition (meta-cognition) (Clough, 2002).

The positive effect of educational experiments in natural sciences and technical subjects is unquestionable. Nevertheless, in recent years we observe a decline of interest in the use of school experiments in teaching at all levels of education among teachers. This trend also appears in universities with technical and natural focus.

What is the cause or which is a consequence of this situation? In the last decade of the 20th century and early 21st century, all countries in the EU preparing new educational strategies. Strategies that reflect the existing level of socio-economic relations, and which would allow individuals to gain education to lifelong application. The complexity of decision-making on strategy of education is given by contradictions between the currently applicable form and content of education, and the current requirements of social practice in relation to the projected development needs of the society in the near and distant future.

In the historically short period of time was created the society with dominant position of information technologies in economic and social terms, and in manufacturing. Due to changes in interpersonal communication as well as the management and control of production processes and systems, it changes the philosophy and goals of education. In education started to promote the philosophy of lifelong employment. According to this philosophy, the individual / citizen to get in lifelong learning knowledge and skills necessary for flexible application of the labor market.

In this context, not only in academics, but also at school and and in public practice are discussed questions: what to teach, how to teach and when to teach? Answer that, at first glance a simple question, as it turns out, is not so simple, obvious and unambiguous (Kozík, 2011).

At the beginning of the 21st century has without reservations use the term information society to refer to contemporary society. The main feature of the information society is rapidly expanding and dynamic innovative use of information technology not only by experts in specialized industrial

applications, but also the general public, including children in different areas of everyday life.

In addition, development continues in the scientific study of natural phenomena, in discovering new yet unknown technical solutions and the development of advanced materials and technologies. Increase in numbers of new knowledge are reflected in an effort of educators and teachers in schools to include these new knowledge into teaching (curricula) in the widest possible range. From the pedagogical and organizational reasons it is not possible to increase the number of teaching hours in individual subjects. It turns out that one of the possibilities which can educators and teachers use in enhancing the educational content, without administrative problems, while preserving the original time devoted to the subject, is application of appropriate motivational and innovative methods in teaching. These methods, which are currently actively used in educational practice and have a strong incentive effect on pupil / student are the methods supported by information technology (Kozík, Handlovská, 2011).

Students already in the youngest age have a strong source of information, in which can very well versed. This source is the Internet. Teachers like to use Internet in teaching. And pupils / students show great interest on learning supported by information technology, which is attractive for them. The digital technology is close to them and easily therein oriented.

Information and communication technologies (ICT) in education can be successfully used in each educational stage of teaching hours:

- At the beginning of the lesson to motivate pupils / students to concentrating and to interesting in the subject of the course.
- In the exposure phase.
- At the stage of fixation of acquired knowledge.
- In the diagnosis and knowledge level of pupils / students.

Mázorová et al. (2004) sets out the following benefits of ICT in teaching:

- a high level of motivation of pupils / students (dynamics, liveliness, animation, sounds), making inaccessible (eg. Movie electron microscope),
- elimination of hazardous situations (dissection, blood grouping and the like. ),
- simulation of time-consuming phenomena in a relatively short time (eg. cross *Drosophila* ordinary),
- interactivity - the pupil may intervene directly into the action, changing conditions (eg. Grades),
- constructivist approach - the student does not receive a finished knowledge, but obtains him alone,
- develop creativity,
- individual pace,

- click Help,
- fast feedback,
- generating random combinations of tasks.

By Grimaldi and Rapuana, (2009), multimedia technology based on new hardware and software technology plays an important role in the management and organization of the lesson. This technique brings new opportunities how to learn interestingly what is taught hardly. From the perspective of the teacher this allows to bring a dynamic relationship into the learning, accelerate learning, go into greater depth of knowledge and thoroughly explain learning material. Even from the perspective of a student brings ICT changed conditions. Student learning process in an environment with ICT is different from learning in a traditional classroom or lab environment.

ICT in education, however, are also negatives. Labašová and Kozík (2011) in the use of electronic presentations on lesson sets out the following drawbacks:

- perception presentation by pupils is sometimes more superficially than making notes with pen in hand,
- creating a slide show cost teacher takes much more time than writing his training in points,
- create a slide show to a single topic (lesson) is uneconomical,
- failure of used technique (projector, computer, ...) and so on.

The use of digital technology in teaching has resulted in crowding out practical activities and exercises from the course, even in such a subjects which until recently had a dominant position. In this context, it is important that teachers of natural science on the one hand, led her pupils / students to understanding of digital technologies in education and on the other hand, their use in experimental measurements and exercises taught and led to the acquisition of practical skills in the design and implementation of these technologies in engineering applications and manufacturing technologies.

The use of computer-mediated school experiments, from simple simulations through real remote experiments to virtual reality allows to carry out educational activities based on individual requirements (Grimaldi and Rapuano, 2009).

Teachers perceive simulated laboratories as an appropriate solution to the increasing financial demands for the creation of real laboratories (Ma and Nickerson, 2006). It is expected that the application of simulation methods in teaching will shorten the length of time that a student needs to learn or understand the nature and the principle of clarifying the phenomenon. Nedic et al. (2003) considered simulation as appropriate to explain the theoretical principles and practices.

Virtual laboratories are perceived as support and supplement the real laboratories (Domingues et al., 2010). Tsuda et al (2008) describe a Japanese research virtual laboratory, which was built to create a comfortable environment for fusion research.

### 2.3.1 From Simulation to the Virtual Laboratory

Simulated laboratories (often referred as a virtual laboratories) are created as imitations of real experiments. The entire laboratory infrastructure is simulated on computers. Virtual Laboratory allows use in the educational process various prepared simulation, virtual models and simulate these experiments. Typical tools for creating simulated experiments are Java, Adobe Flash or Microsoft Silverlight. In terms of performance, the most preferred tool is a Java (Spring et al., 2008).

Applets and animations are designed to clarify and clearly show the phenomenon in an attractive graphical way. It should be noted that the simulated remote experiments are not directly designed to provide data for further processing, although some makers applets incorporated in their products even this option. That is why most of the publicly available remote experiments does not provide input or output data, which are necessary for the scientific examination of phenomena to compare real experiments with models (Lustigová, Lustig, 2009).

Virtual laboratories with elements of virtual reality are based on the use of virtual instrument (Virtual Instrument). In general, there are two methods of using virtual instruments (Grimaldi and Rapuano, 2009):

- The first way is to use virtual instrument as sophisticated graphical user interface (GUI) to manage real instrument (step motor, the temperature sensor and the like).
- The second possibility is the use of computer simulation of behavior of the real instrument (device).

Both options can be combined. The result is a more sophisticated and flexible system that allows not only to simulate the experiment, as well as to manage the tools of the real remote experiment.

By Grimaldi and Rapuana (2009) virtual laboratories with elements of virtual reality brings the following benefits:

- exercise can be optimized for each student,
- phase of testing knowledge can be automated,
- laboratory resources can be better utilized because, students have access to a laboratory anywhere, anytime,
- feasibility level is higher than the simulation,
- time-consuming and ease of use is optimized and the difficulty of acquiring the curriculum is minimized,
- is possible to perform dangerous experiments without risk to the student,
- intensity of experiments is graded according to progress of the student.



Choi et al (2009) argue that virtual laboratories can significantly contribute to a better understanding of the principles and theories of each experiment. The use of Flash animations and Java applets in virtual laboratories leads to a better understanding of the theory and experimental procedures. Provides to the students the opportunity to realize experiment without the cost, risk and time limitations.

The basic advantages of virtual laboratories by Tsuda et al, (2008) to be considered by the user:

- high user safety,
- easy to work with providers,
- undemanding management.

Users conditions is high-speed access to the Internet.

Domingues et al (2010) after the first year use of the virtual laboratory referred improve the performance of students at three levels:

- in the preparation for laboratory work,
- in the improving laboratory skills and in the organizing laboratory exercises,
- quality evaluation of experiment results and discussion.

By analysing of scientific publications came Abdulwahed and Nagy (2011) concluded that, despite the many advantages of computer simulations and virtual laboratories, is between teachers and students generally agreed that simulation cannot and should not replace every experiments and by pupils / students gathered experience in the real laboratories.

Grimaldi and Rapuano (2009) also mentioned disadvantages of virtual laboratories. Among others also mentioned the following:

- even a high level of realism of virtual laboratories not solve the fundamental problem, which is that the student is not in direct contact with real experimental facilities,
- the student does not have direct communication, support and assistance of the teacher.

### **2.3.2 Virtual Laboratory in Education**

Combining simulations with real data gathering and management of remote processes enables pupils / students to observe various specific and rare phenomena (e.g. earthquake), securely remotely manipulate with objects and dangerous chemicals, realize more complex measurements and record them in the measured values (data) without that the having technical issues and parameter settings. Thanks to this, experimenting pupils / students can focus and concentrate their attention on conceptual understanding of the experiment (Lustigová, Lustig, 2009).

Dalgarno et al (2009) have created a complete virtual 3D model of the chemical laboratory (Charles Sturt University), Fig.17. This model was created using the Virtual Reality Modeling Language (VRML) and applications Blaxxun Contact VRML Browser1. Model with the necessary applications received students on the installation CD. This allows the students to become familiar with the laboratory structure and equipment at home. Until then came to the real laboratory they has necessary knowledge of laboratory equipment.



**Figure 17 Environment of virtual chemical laboratory from the perspective of pupil / student (Dalgarno et al., 2009)**

Masar et al (2004) created a virtual laboratory for controlling an inverted pendulum and gantry crane in real time. In the laboratory was used a system with combination of real and virtual machines. In their experience, the system is very attractive to students. For a realistic presentation of the experiment through Internet were used several visualization methods. Students by the speed of their Internet connection, choose either the receive audio-video in the real-time, 3D animation, rendering simple graph or all three options, as shown in the illustration, Figure 18.

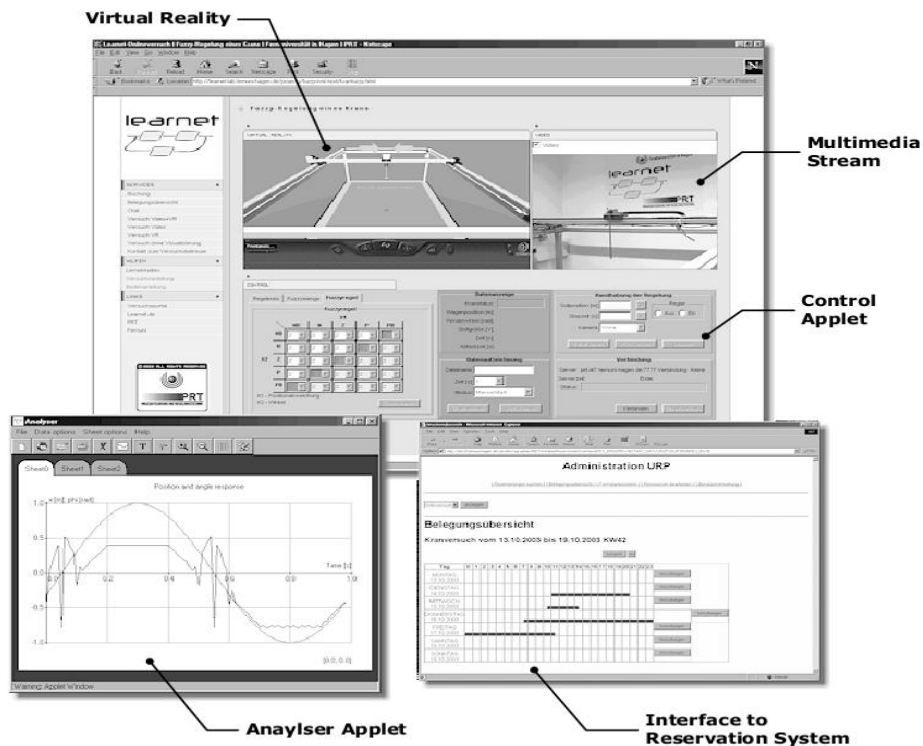


Figure 18 Web interface of the student who access the virtual laboratory (Masar et al., 2004)

Jara et al (2011) reported good experiences with two conducted consecutively teaching modules of the course "Automatics and Robotics". The first - a virtual, students programmed simulated robot in a virtual environment. In the second - real remote, sent students to the real remote laboratory program that was previously created and debugged in a virtual environment, Fig. 19

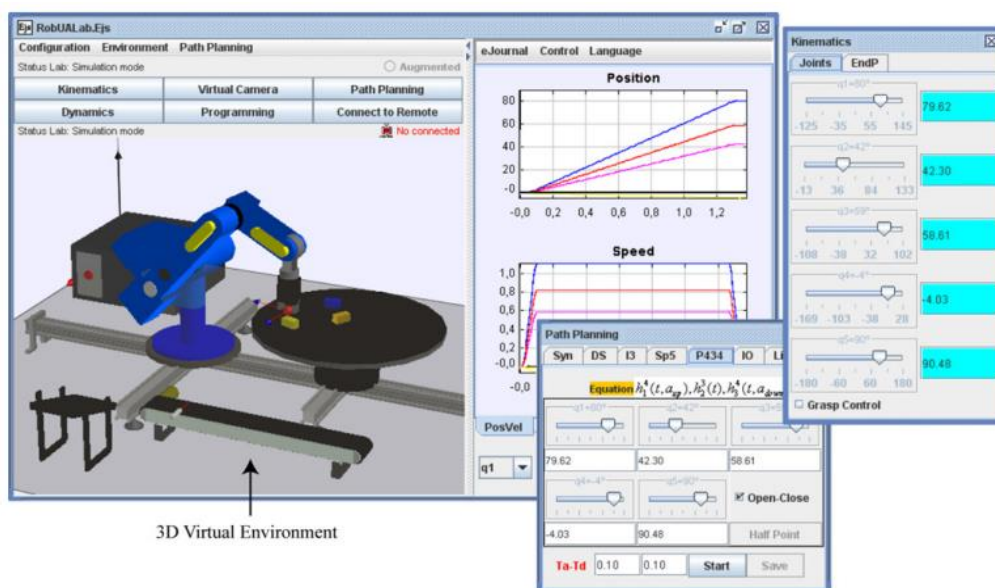


Figure 19 Controlling virtualized robotic arm by student (Jara et al., 2011)

This teaching method helps students obtain a realistic picture and visualization to understand the interdependence between the virtual model and the real system. Educational virtual methods are based on two methods of access of students into the remote laboratories:

1. When participating in lectures and practical exercises at the university. The system is used in the computer room with computers connected through local area network. The teacher explains the issue in a virtual lab and student watching progress of the experiment on its screen. Where it is somewhat unclear, so called "chalk" mode is activated. This allows him to manipulate with shared objects in the virtual laboratory. This enables possibility to show exactly what he does not understand to the teacher.
2. Participation in practical exercises over the Internet. The teacher uses this system in collaboration with the on-line discussion application (chat) when discussing with students during consultation hours. Students entering into the virtual laboratory, either from school computers or even from home through Internet.

### 2.3.3 Reality and substantiality of Virtual Laboratory

The benefits of lesson with a real experiment, in addition to other benefits also develop skills in the handling with devices and measuring instruments. Blasko (2009) provides the following key competencies that students acquire by carrying out school experiments in real labs. These are following:

- communication,
- information,
- Math-science,
- learning,
- competence to solve problems,
- personal and social,
- jobs and business.

In virtual experiments is obtaining above mentioned competencies significantly affected by the principle of computer simulation. For example, the development of communication competence is limited by isolation of pupil / student and his dependence on electronic communication. This is related to personal and social competence.

Conversely, the development of competencies for informatics and mathematics is for obvious reasons more intensive.

Ma and Nickerson (2006) in their publication noted an interesting idea: "Belief May Be More Important than Technology". They do not consider a technology (remote or virtual-simulated experiments) as crucial for gaining skills or acquisition of educational knowledge. Important is the credibility of the experiment environment in which the learner is working. Regardless of whether it is remote or simulated experiment.

Reliability of the environment can be supported by sound. Computers (but also laptops, netbooks, tablet and smartphone) from which pupils / students visit the virtual / remote laboratories are equipped with sound cards. It is thus sufficient change on side of the lab to alter the quality of the environment and the environment for the learner acted more credible.

A mere sight of the authors on the importance of physical presence in experiments is not uniform. Sheridan (1992) indicated three types of presence: physical presence, telepresence and virtual presence. Physical presence is linked to the real laboratories and understood as "physically be there". Telepresence is defined as "feeling like you're actually at the remote site of operations". A virtual presence is defined as "feeling like you were present in the environment generated by computer".

According to Loomis (1992) the presence is a mental projection of a physical object. This is not a physical condition, but the phenomenal attribute, which can only be identified by the conclusion. Another go even further into the philosophy and psychology of perception of the environment and the objects in it. Lombard and Ditton (1997) described the presence of six dimensions:

- presence as a social richness is related to two important notions originally applied to the impossibility of mediation of interpersonal communication: intimacy and immediacy,
- presence as a realism to what extent can the media create ostensibly accurate representation of objects, events and people - representations that look, sounds and / or to feel like the real thing,
- presence as transfer, three different transmission types can be identified: "You are there," in which the user is transferred to another place, "It is here," in which are the other places and objects transmitted to the user, and "We Are Together" in which two (or more) communicators are transferred together to the place which they share,
- presence as immersion, sensory and psychological immersion, which can be measured by the number of connected / disconnected user's senses,
- presence as a social actor, various fictional characters from movies or computer games, users illogical perceive as a real and try to communicate with them,
- presence as media as a social actor, include social responses of media users not to the entities in the media, but to the stimulus of the medium itself.

By Witmer and Singer (1998) the presence is sensory flow that requires direct attention. It is based on the interaction of sensory stimulation, environmental factors and internal trends.

### **2.3.4 Virtual Laboratories on the Internet**

Virtual laboratories available on the Internet are with its content aimed at different educational areas, including technical and natural sciences. They

appear also virtual laboratories, which are mainly focused on research and simulation of complex processes. A typical example is a simulation of nuclear fusion (Tsuda et al., 2008).

Main information about some of these are highlighted below.

#### **Virtual laboratory Walera Fendta, Germany;**

Website: <http://www.walter-fendt.de/html5/mde/> and [www.walter-fendt.de/html5/phde](http://www.walter-fendt.de/html5/phde)

Virtual laboratory containing simulations (Java applets) for mathematics, physics and astronomy. Applets are accompanied by explanatory text and links to other web sites. Language is German.

#### **The website of the University of Colorado, USA**

Website: <http://phet.colorado.edu/en/simulations>

The website contains dozens of simulations from different areas. Applets are clearly arranged. It can be run directly from the website, but also download and use the computer without connecting to the Internet.

#### **Commercial portal Virtlab**

Website: <http://www.virtlab.com/>

The portal provides as a paid service access to a series of experiments and simulations in a virtual chemical laboratory.

#### **Virtual laboratory for Minh University, Portugal**

Website: <http://vlabs.uminho.pt/laboratorios.html>

This project is an attempt to introduce "weblabs" in the curriculum. The portal provides access to a virtual laboratory, which contains animations, videos and experiments. Content and teaching materials are created specifically for virtual laboratories and allow students to discover and explore the laboratory objects such as microscopes, reactors and the like.

### **2.3.5 Summary**

It is clear that students do not learn only from working with the equipments, but also communication with colleagues and teachers. The development of new learning technologies aimed at enhancing the quality of coordination communication forms, to achieve compensate mutual isolation in distance education, may significantly shift the opinions on the successful use of virtual experiments in education in a positive direction.

Virtual laboratories provide pupils / students the opportunity to understand the theoretical nature of the phenomenon, or process or variables. They allow their visualization. Incorporation of simulated and real remote experiments in the organizational structure of the object acts as an incentive to pupil / student. It also increases its interest in the topic of the course. It creates the presumption of increase the interest of pupils /

students on their knowledge level. It supports its autonomy in working with the experiment and its ability to analyse and document the results of the experiment (Domingues et al., 2010).

In the teaching practice is commonly known Comenius principle according to which the success of education depends on how can teacher in rendering knowledge actively involve the senses of their students in the learning process (J. A. Komenský, 1646). The merits of Comenius principle has been verified in the 400 year history of education. In contrast to this pedagogical principle is full replacement of real experiments with simulated experiments. Total replacement of real experiments (practical exercises) in education, whether remote experiments or simulations does not have for a number of pedagogical and educational reasons rationale especially in the case of teaching natural science and technical subjects. The unsuitability of full replacement of real experiment is also confirmed by some recent studies. It is very likely that developments in this area will lead to the efficient use of pedagogically sophisticated system of teaching. System that will efficiently combine the benefits and advantages of hand's on experiments with remote and simulated experiment. Ma and Nickerson (2006) argues that with application of a suitable connection or a combination of hand's on, remote and simulated experiments will be possible to reach a solution which is acceptable on the part of price, as well as in relation to the educational outcome. This presumption of is confirmed by the research of AbdulWahed and Nagy (2011), which propose to integrate hand's on, remote and simulated experiments into a single unit called TriLab.

## **3 Technical Aspects of Construction Remote Experiments**

### **3.1 Remote Experiment Using Elements of Industrial Automation**

By the progressive expansion of internet services and by the progress made in the field of automation and control technology the remote control/real experiments (RCE/RRE) have been gaining in popularity not only in university education but in the other types of schools – as elementary and grammar schools. The extension of the RRE applications is caused by looking for the teacher's answers: *WHAT, WHEN and HOW* to teach?

Advances in science and technology and the resulting new unconventional technical solutions together with development of informational technologies create an environment in education which necessarily requires a change in the educational contents and in the forms of education. It is expected that the newest knowledge of science and technology and also more information will be smoothly available for a human during his whole active life due to the development of information technology and other scientific and technical progress. In the educational system there is allowance for an exchange of requested knowledge and abilities for everyone in lifelong learning.

There has been occurred a task for teaching science and professionals working in education how to solve education at this level of development of scientific and technical knowledge and at the requirements of the society. Furthermore, a very important requirement is to propose a solution with signs of economic approach.

Situation in technical and natural sciences is even more complicated due to formation of practical skills and experience during preparation for the profession which is essential part of the preparation and of the education of future specialists. It is very costly to build laboratories and technically complicated workplaces as well as their run and innovation.

One of the possible solutions how to reach the requested quality in education of technical and natural branches (subjects) in connection with the gaining of practical skills when working with measurement equipment and systems is an application of RRE in education.

Thanks to the internet there is a network of the remote real laboratories where the experiments are installed with the possibility of remote control by computing. An ambition of the Department of Technology and Information Technology at Faculty of Education, Constantine the Philosopher University in Nitra is an active entrance into the global network of existing remote laboratories by creating own remote laboratory complying with exacting technical and educational parameters.

#### **3.1.1 Remote Control Experiments (RCE)**

The experiment is defined as the basic method of scientific knowledge. It serves to obtaining or testing of new theoretical results. However, the



experiment is not a domain for scientists and specialized scientific institutions only. The experiment is applied as one of the teaching methods in teaching practice. This type of experiment differs from the original scientific experiment in its requirements and objectives. Pupil or student will understand an experiment only if he makes it by himself. Therefore it is important that every pupil/student participates actively in control and evaluation of an experiment. The ideal solution would be to make several identical experiments in parallel in groups. Pupils/students would have more space for personal practice in the implementation and control of the experiment. At the same time pupils/students could compare the achieved results to each other and analyse them. It is well known that the school instrumentation for realization of experiments is often insufficient. Studies in the field of educational research show (e.g. results of educational research by Thorton (1999)) a didactic suitability of demonstration of the natural science and technical effects and principles in teaching. At such a teaching the pupils/students better understand the link between theory and practice. Science achievements are directly related to observing and studying of events in nature. From this point of view the experiment becomes an important teaching and learning tool. Currently pupils/students of many schools do not have any possibility to confront their theoretical knowledge with practice. A large range of science lesson's theory leads students to memorize the learning knowledge. (The authors reached this conclusion on the basis of discussions with teachers of primary schools at workshops). This approach does not allow pupils / students adequately understand the discussed topic. The result is an inability of pupils / students to apply the acquired theoretical knowledge in practice. Under the influence of this approach, pupils / students take a negative attitude to the subject which results in a reduced interest of pupils/students in the study of natural science and technical subjects. Currently it is showed a significant reduction in a number of students of natural science and technical subjects what is perceived as a result of the longtime school practice. (Thorton, 1999),(Aburdene et al., 1991),(Corter et al., 2007),Kozik et al., 2005),(Kozik, Depesova, 2007).

One of the possibilities how to solve the current situation in the teaching of science and technology in relation to the use of experiments is the use of remote control experiments. Remote control experiment (RCE) is a real physical, chemical and technical experiment which is realized in a real laboratory. The difference from „classical“ real experiment is that an observer and an executor of the experiment is out of the laboratory and whole running of the experiment is controlled and monitored through the commands and image transmission via a computer network Internet. The design of this type of experiment requires much more time, personnel and financial costs in comparison with the classical real experiments. It is necessary to realize that such an experiment, which is installed in one of the educational workplaces (laboratories) via the Internet, can be used by Slovak, whether European or global electronic network. Accessing of the RCE in a global scale can help to sort out a problem of financial unavailability of experiments in schools of all types. (Clough, 2002)

The results of research of the examination of the application of the executed RCE in teaching and their influence on education level show that the use of the remote control experiments clearly improves quality and efficiency in teaching of science and technology. Thorton (1999) research, which aimed to compare the success of teaching with the support of the RCE to the classical teaching without experiment showed much better

results of the teaching with the support of the RCE. According to research results:

30% of the respondents were successful at the use of the classical teaching method, it means teaching method without experiment and

even 90% of the respondents were successful at the use of the teaching method with the support of the RCE bolo.

Score in favour of the teaching with the RCE use was even more significant in understanding of physical effects and principles. The subject of the study with the use of demonstration of the RCE was understood by up to 90% of pupils/students (respondents) in comparison to 15% of the respondents educated by traditional way without experiment. According to Thorton and others (Ali and Elfesi 2004, Haluskova 2009) the high efficiency of the RCE is achieved thanks to the following factors:

- the RCE has a positive influence on an activity of the students,
- independent work of pupils/students on the research technique,
- immediate feedback,
- reduction of the time need for theoretical calculations in relation to deepening the knowledge of students

### 3.1.2 Structure of the RCE

The idea of remote control and monitoring of remote experiment brings special technical requirements for the methods and technical means. In terms of technical requirements of the implementation the technical means of the RCE can be divided into the following groups:

#### **1. Technical means carrying out the very natural principle of the experiment**

Technical means carrying out the natural or technical principle of the experiment are all the components of the content essence of the experiment itself. These components are often completely identical, whether it is a real implemented experiment or remote control experiment. In this category in case of the RCE (experiment of measuring of fluid flow) there are following components represented: three-phase motor, fan, flow tube, Venturi or Pittot (Prandtl) tube and plastic tubes.

#### **2. Measuring device of physical quantities**

This group of components is created by all the measuring device of physical quantities which are involved in the measurement. In case of the remote control experiment there is necessary a measuring device which is equipped with communication ports for sending out the value of measured physical quantity into the control system of the remote experiment.

#### **3. Technical means providing remote control of the experiment**

Technical means are a specific group providing remote control of the experiment. Here we include all the hardware and software systems which

provide for control of the RCE, communication with user, sensing and processing of measured values and also for software control algorithm throughout experiment.

#### 4. Devices for scanning and transmission of a video stream

Success of the RCE in teaching practice depends on the quality and speed of transmission of the video stream which provides a general view of experiment course for the user. Transmission of poor and low quality of the video stream can be a key reason for their absence in teaching process. Also in case of excellent technical structure or didactic support the use of the RCE by teacher or by users (pupils/students) can be refused because of the poor video stream. From this reason it is necessary to pay a close attention for this group of devices at the preparation of the RCE.

#### 3.1.3 Block Diagram of the RCE

The RCE shown in the block diagram (Fig. 20) is divided into two basic parts. The first part is the experiment itself which is controlled by the user, client over the Internet by the client application. To explain the function of each part of the block diagram we are presenting an illustrative example of the start of measuring evoked by the user. The user presses the START button in his graphical user interface /2.2/. Client application /2/ evaluates the request and through the communication block /2.3/ sends data via computer network of a server application. The server application /1.5/ receives data about client's requirement using the communication block. /1.5.4/

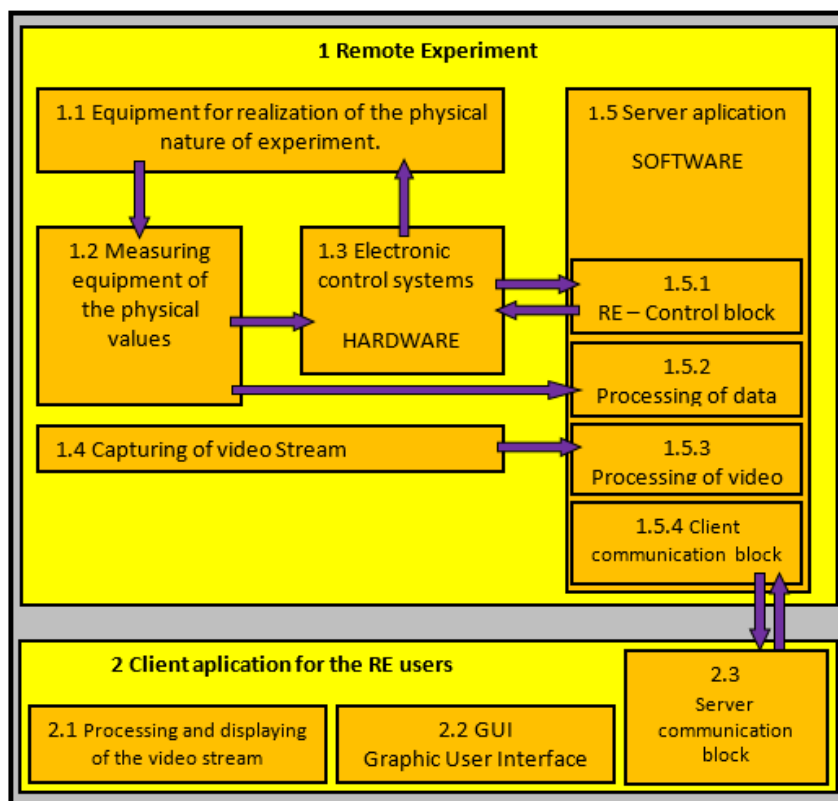


Figure 20 Block diagram of the RCE

The entered information is evaluated (e.g. if the requirement is valid or if its realization is not implemented under the previous command, etc.), after that it is prepared and it is sending a command in the form of electrical signals via software control block of the RCE /1.5.1/ to the appropriate electronic device /1.3/. Components of the electrical control system /1.3/ are implementing the appropriate clients request in the space of the experiment itself /1.1/. Feedback of the control is realized by sensing probes and measuring instruments /1.2/, which are sending the obtained data to the control electronics/1.3/, or via server application /1.5/ using the relevant blocks /1.5.2/ and /1.5.4/ directly to the clients application /2/. Received data are processed by client's application /2.3/ and they are displayed on the computer screen/2.2/. Feedback function is also realized by scan and video stream transmission system. The picture is scanned by using the camera /1.4/ and it is processed by server application /1.5/ in the block /1.5.3/. The processed video stream is transmitted over a computer network to a client application /2/, which is processing and displaying the received video data in the module /2.1/.

The set of all software and hardware components providing the remote experiment control by users is called structural framework or constructive system. During the development there were more constructive systems designed and successfully implemented. One of the most well-known systems is LABView constructive system.(Alves et al., 2007)

### **3.1.4 Purpose-designed Control Constructive Systems of the RCE**

Based on economic and technical problems related to the RCE design several designers came to draft of their own control electronics and their own software control through the serial structural systems. Such a design framework is usually very closely and purposefully designed for specific task what causes an inefficient handling with time and effort of the designer. The designed closely specialized system which is used for one specific purpose only is waste of the time, knowledge and technical abilities of the designer in comparison with incurred effort. Low economic attractiveness of design of constructive systems for the RCE is logically reflected in the low number of such experiments. (Pastor et al., 2003),(Choi et al., 2009).

Construction and operation of the RCE is difficult to funding, the organization and the technical knowledge of designers. From our experience we know that the operation of the RCE in the market system is not sufficient to cover even the overhead costs associated with their operation. To keep the operational capability they need to be subsidized. Discontinuance of the operation of several RCE is a result of ran out of the financial resources necessary for their operation and maintenance. (Kozik et al., 2011),(IEC online)

### **3.1.5 Industrial Automation Systems**

Word „automation“ is becoming one of the most frequent words of the present. It is obvious because along with the development of information technology enters into all areas of human activity. Automation has become one of the important criteria in assessing the capabilities and the overall level of the individual, society and humanity as a whole.

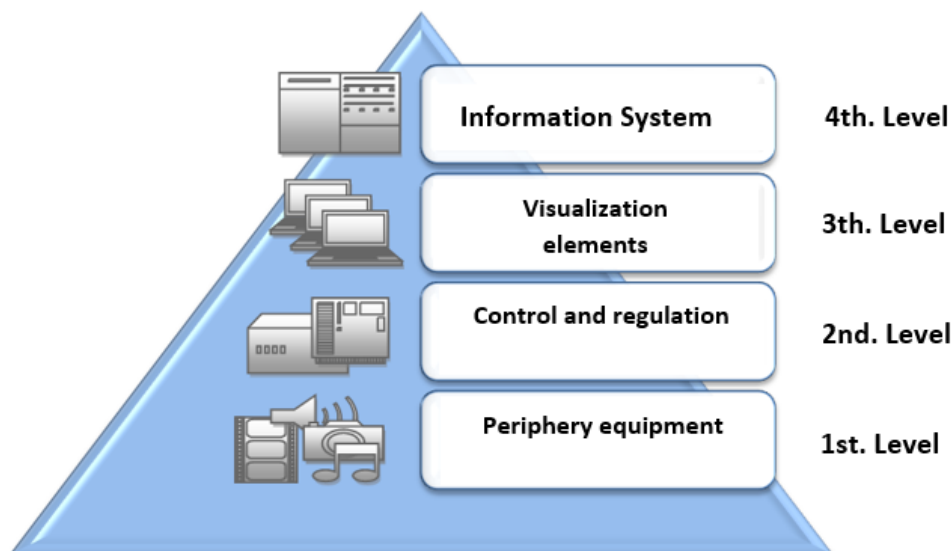
The term automation means the use of control systems (e.g. regulators, sensors, computers ...) for control of the industrial devices and processes.

In terms of industrialization it is a step following the mechanization. While mechanization provides people with mechanical means and tools to facilitate their work, the automation means reduction of human need in the performance of certain activity. Under certain conditions (complex automation – beginning of artificial intelligence) there could theoretically come up to the total disappearance of man from the production process. However, in practice this possibility seems to be impossible yet. (Smejkal and Martinaskova, 2007)

From the point of view of the designers it is possible to understand the remote control experiment as a remote control automation system. New possibilities for solutions have been opened for the implementers by changing the view of the RCE construction. The existing broad range of elements of industrial automation and their mutual smooth compatibility have created an unbounded space of technical combinations and possibilities of the problems. The structural design of remote control automation system with the use of industrial automation has become a challenge and motivation for verification of the technical skills of the executive team of the RCE of the Department of Technology and Information Technology at Faculty of Education, Constantine the Philosopher University in Nitra. To handle this challenge it required at first an extensive study of the problems of design and creation of the remote control automation systems. (Jara et al., 2008)

### 3.1.6 Integrated System of Industrial Autmation

Hierarchical arrangement of the elements of industrial automation in an integrated control system is shown in the form of a pyramid with more levels (Fig. 21). (PLC user guide)



**Figure 21 Levels of automation system**

From a functional principle, all automation systems show the presence of devices on the 1st and 2nd level (pic.21). Using sensors and measuring

devices, the system detects the state of the controlled process. Through activators it interferes with running of the process what means its affection and control.

A crucial element in the regulation system is a regulating or control system (member). On the basis of the inputs it evaluates the current state of the system and decides on the activity of activators.

Levels 3 and 4 in the pyramid model present optional features of the regulatory system. These are mostly occurred in more complicated control systems. In accordance with the model scheme (pic. 2), below we will pay attention to technical and application analysis of elements which are going to be used in a technical design solution of the control of a model remote control experiment. (Smejkal and Martinaskova, 2005)

### 3.1.7 PLC – Programmable Logic Controller

The very process control, in the scheme (pic. 2) it is marked as a regulatory or control system, is mostly provided by PLC automats. Even from the shortcut PLC - Programmable logic controller it is obvious that the PLC automat is a control computer in its principle. Hardware and software means of the PLC automats are created at the same principle as the classic PC-type computers are. However, due to the special requirements of industrial automation they differ significantly from conventional computers in many structural modifications. The demanding requirements for parameters of working environment such as dustiness or moisture are an example of it. Another important requirement is for compatibility which requires to be able to communicate with various group of peripheral sensors, measurement system or activators. These, as well as the other special requirements for PLCs affect their technical solutions so they are completely different form classic computers at first sight (pic. 3). (Smejkal and Martinaskova, 2014)



**Figure 22 Sample of the PLC system (PLC user guide)**

PLCs are used for solution of automation tasks with different technical difficulty. The impact of this fact together with a strong commercialization of their production is a development of a wide range of the PLC ´s types and formation of a big group of the producers.

Programming of the PLCs is realized in a development environment which is specific for every type of the PLC. The development environment is a software executable on most classic computers of PC series. The finished

control code is at first tested on simulated PLC system which is normally part of the development environment. The finished program is transformed from a PC to the PLC memory system using standard communication lines such as RS232, RS485, TCP / IP, WIFI, USB, or is transmitted through normal memory cards. Control program can be run in the PLC in different ways depending on the setting of the PLC system parameters:

- automatically when you turn on the PLC,
- by setting the appropriate digital input (RUN) to the logical drive,
- by switching the manual switch to position (RUN).

The PLC has got different internal system architecture in comparison with a classical computer. Its programming is therefore different from program creation for classical computers. At the programming of the PLC there are five programming languages preferred (IEC online):

1. Assembler – machine code of the system processor in the PLC system,
2. Programming language C and its variations – extension to the machine code,
3. STL (Statement List) – list of orders, very similar to the Assembler,
4. LAD (Ladder Diagram) – contact scheme, very similar to electrical schemes,
5. FBD (Function Block Diagram) – scheme of function blocks.

It depends on the specific manufacturer of the PLC system what language will be supported by its development environment. The languages STL/LAD/FBD are considered to be an industry standard which is currently supported by almost all the PLC systems. The Assembler and programming language C are understood as expanding opportunities for the programmers. (PLC programming)

### 3.1.8 Remote Control of the PLC Systems

Systems of remote control of the PLC control systems had been developed much earlier than we started to use the computer network Internet massively. It is understandable because also in the past the PLC system mounted in the electrical distributor of the automation system had to communicate with computers in the „control centre “which were often apart for several hundred meters. It was directed at the development of industrial communication systems whose role did not lie in the ensuring of communication of the PLC system with computers of the control centre only but also with other elements of industrial automation. Sensors, measuring devices, probes, frequency converters, pneumatic valve matrixes, switches, valves, stepping motors are nowadays equipped with industrial communication systems. The best known systems are ProfiBUS, ProfiNET, CanOpen a FieldBus. All these systems have been designed for their use in severe operating environment of industrial automation. Massive arrival of the Internet meant also new challenges and opportunities in application of remote control of the PLC systems. The distance between computers of the workers and the PLC systems themselves are nowadays measured in

thousands of kilometers. There are several elegant ways how to implement remote control of the PLC systems via the Internet.

### **3.1.9 Communication Module Supporting TCP/IP Protocols**

TCP/IP protocol family is communication standard in the Internet. The PLC system with such a communication module has got a physical IP address which is able to identify the system on the Internet and the related client applications can establish direct communication with it. It is necessary to say that the communication module for easier PLC systems is often more expensive component than the PLC system itself. At the same time the programmer has to bear a lot of problems in his client application which are related to communication between the PLC and the client PC. (Network programming)

### **3.1.10 Communication Module TCP/IP with Integrated Web Server**

The PLC system with integrated web server is an elegant solution for remote control systems in real time. Such a PLC system has a control web page saved directly to its internal web server. Response speed of the control applets running on the internal web server of the PLC system itself is not limited anymore. The use of this type of the PLC system in this case would be an ideal technical solution. Unfortunately, these systems are designed for commercial applications and they are equipped with other technical elements which would not be used in our solution (extended number of inputs, outputs, modules of industrial communication, DNS server, SMTP server, WIFI router, ADSL modem, network switch, backup power system,...) The price of such a PLC system is thousands of euros what is an impossible barrier at designing of the RCE. (Network programming)

### **3.1.11 Communication via a Computer Connected to the Internet**

Paradoxically, the cheapest and most appropriate solution is to bring a classic computer which will be acting as a communication port between the Internet and the PLC system itself. Such computer is becoming a server and is acting as a communication interface between a remote client application and the control algorithm in the PLC system. Software ensuring these tasks is running on the mentioned computer and it is called OPC server (OLE for Process Control). „Classic“ technology OLE (Object Linking and Embedding – object connection and insertion) is a server service (Server OLE), which enables the applications to use the services of another applications. For example you will insert a drawing created by AutoCAD in text editor Word. Despite the absence of any possibility to edit the drawing in Word, it is possible to use AutoCAD functions and to create directly in Word (by double-clicking on the drawing) a workspace for editing drawings, along with all the functionality of AutoCAD. For software developers such a system means that they do not need to have any knowledge of processing of the video stream when they want to play video in their application. The application using the OLE server can manage to share functions of any video players. But let's get back to our OPC server. The short cut OPC in the figurative sense means OLE for process control. When programming the client application the programmer does not have to even assume what way the communication with the PLC system or server application established is.



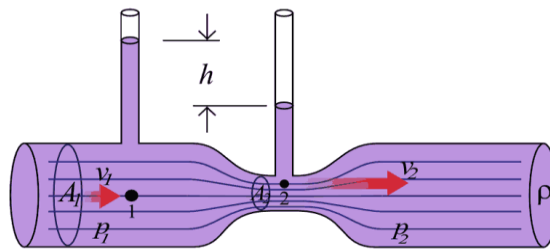
In this way the programmer does not have to think about any complications during solving many difficult problems. Communication between client applications and PLC systems via OPC servers is currently the most widespread and financially affordable solution in application practice. The producers of the PLC systems offer the designers also their own OPC servers designed for communication with their type of PLC automat. Price of the OPC server depends on the model of PLC system for which it is designed or on its technical parameters (response speed, number of simultaneously communicating clients, range of processed data, etc.). Strong competition among manufacturers of components for industrial automation has resulted in the release of licenses for OPC servers with lower technical parameters and for simpler and cheaper versions of PLC systems in recent years. (Building COM Objects)(Code project)

#### RCE – Measurement of the Speed of Gaseous Environment

Remote control experiment for measure of the speed of gaseous environment was model experiment, which is applied and verified of the PLC control system. Theoretic basis of this experiment is Bernoulli formula for fluid:

$$\frac{1}{2} \rho v_1^2 + \rho g h_1 + p_1 = \frac{1}{2} \rho v_2^2 + \rho g h_2 + p_2 \quad (1)$$

$\rho$  is density of flowing environment,  $h_1$  a  $h_2$  are surfaces levels of fluid in U – tube,  $g$  – gravity acceleration,  $h$  – is difference of surfaces levels ( $h_1 - h_2$ ),  $v_1$  a  $v_2$  are velocities of fluid in points 1 a 2.

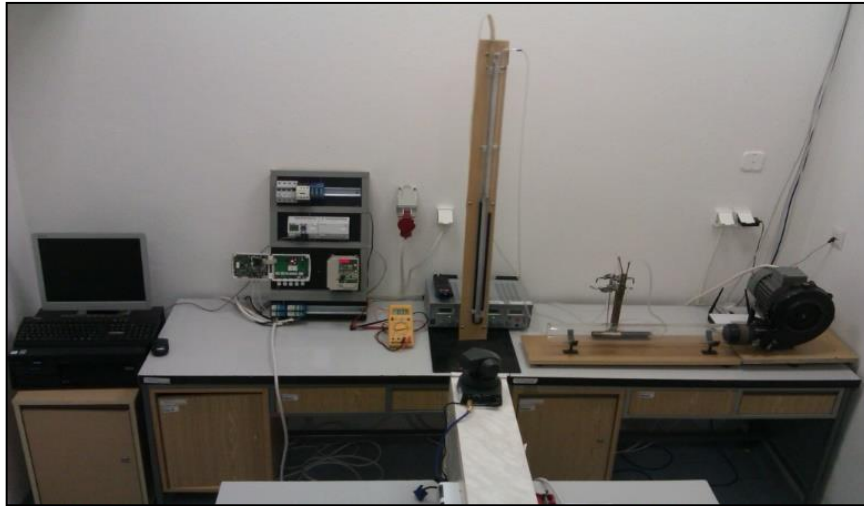


**Figure 23 Venturi tube (prutoky.cz)**

According to this formula the assuming of kinetic and potential energy of volume element and pressure is the same in flow environment everywhere.

#### **3.1.12 Measurement of Air Flowing Velocity in Tube**

Measurement of air flowing velocity is realized in plexi tube with internal diameter  $D$  in this experiment. Van is connected to one of the ends of the tube. Measurement elements are installed inside of the tube. View at this remote control experiment is on Figure 24.



**Figure 24 View of realized RCE**

Velocity of air flowing in the tube is defined by difference of surface levels in U manometer, which is connected to Venturi (Prandtle or Pitot) probe. According to

$$v_1 = d_2^2 \cdot \sqrt{\frac{2 \cdot (p_1 - p_2)}{\rho \cdot (d_1^4 - d_2^4)}} \quad (2)$$

Pressures  $p_1, p_2$  are measured by air gauge in practice. Thiers values are inserted in to formula (2). If air gauge is not available then pressure value will be calculated as difference of height level  $h_1, h_2$ , which is shown in figure (pic. 4). To calculate pressures  $p_1, p_2$  we can use:

$$p_1 = \rho_{tek} \cdot g \cdot h_1 \quad (3)$$

$$p_2 = \rho_{tek} \cdot g \cdot h_2 \quad (4)$$

$\rho_{tek}$  is density of liquid in tube,  $g$  – gravity acceleration and  $h_1, h_2$  height levels in tubes.

Industrial measurement instrument KIMO CP 300 was used for validation of measurement in the tube and calculated result in this experiment. Principe of this industrial measurement is same as measurement in the tube.

Didactic and educational aims are very important for designers of remote experiments. The aims for this remote experiment were as follows:

- to deepen the knowledge of students on relations between the basic physical parameters,
- to understand the essence of experimental measurements in solution of the physical and technical applications,
- to understand procedures of physical variables measured in the experiment and to use correctly in calculations,
- to understand procedure of validation and interpretation of measured functionalities,

- to deepen an interest of students in creative access to solution of physical and technical tasks,
- to motivate students to positive relationship to physical and technical subjects.

Design and construction of this remote experiment have defined more technical problems:

- to control and to change of the rpm of the van,
  - to scan difference of level height in U manometer and at the same time to watch another parts of the remote experiment
- block scheme of the realized experiment is in Figure 25

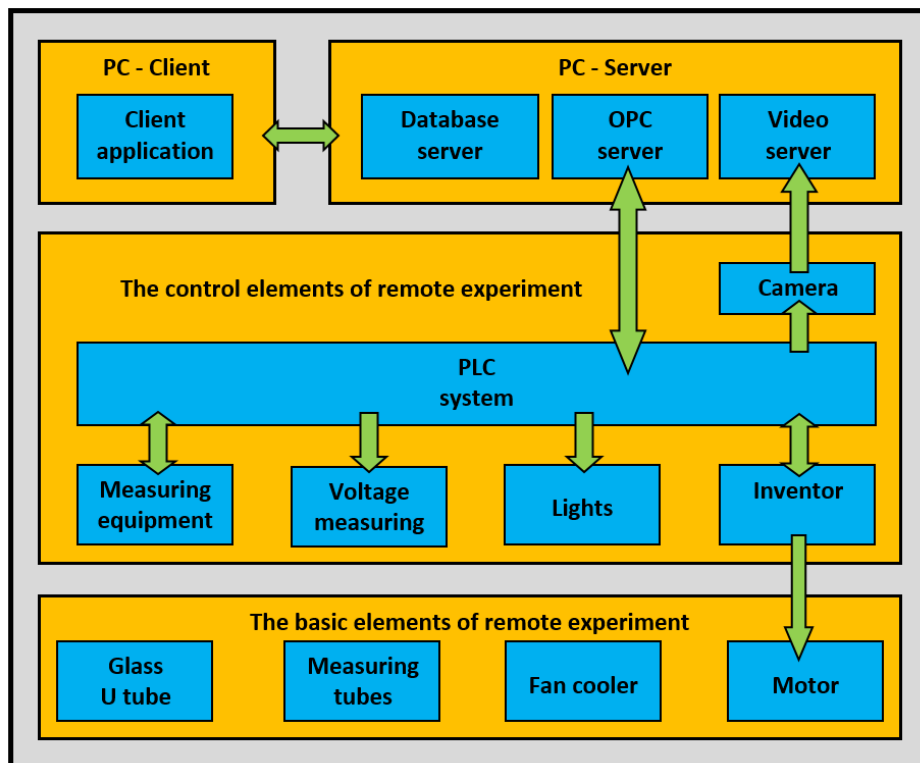


Figure 25 Blocks scheme of RCE

### 3.1.13 Selection of Control PLC System

After considering more possibilities we chose PLC EATON EASY 512 DC RC for control of remote experiment. Regulation of the rpm of van was realized by 3 phase inverter OMRON SYSDRIVE 3G3MV. For communication between client PC and PLC system there was used our own OPC server, which was programmed for this solution. Connection between OPC server and PLC system was realized by serial port RS 232.

Second key aim was to find a solution for video transmits. The first trial video stream was realized by VLC video server. Delay time of this solution was not acceptable, because value of this was 12 seconds. Such delay time was not useable for remote experiments. This problem was solved by our own video server, which was designed and programmed for this solution too. Delay time of our own video server was 0.5 - 0.8 sec. which was

acceptable. Such a good result was achieved by our video server, which saved captured picture directly in data block of RAM memory without saving in hard disc. Data block from RAM memory was sent to users by the Internet. This system of capturing, saving and sending pictures is faster than usually used by common video-servers.

Client application was created in programming development environment MS Visual C#2008 Express Edition.

### **3.1.14 Summary**

These initial results have been achieved by solving the RCE design – measuring of air flow speed and by the implementation of the design:

- There has been designed a new software system for rpm control of three phase asynchronous motor by frequency converter, also useable for easy PLC systems which did not have such possibilities initially.
- There have been achieved better technical communication parameters by programming our own OPC server for implementation of the RCE in comparison with original communication OPC server from producer.
- Creation of video server based on its own software algorithm, without lengthy compression methods, allowed to speed up the transfer of the video stream to match the needs of the RCE.
- The new design concept of the RCE using the elements of industrial automation has been designed and tested in practice.
- By preparing a specific RCE for measuring of fluid speed another RCE has been added to portfolio of didactic tools for teaching purposes which is useful in teaching of science and technology.

## 3.2 Preparing and managing the remote experiment in education

Advantages and disadvantages as well as the benefits of remote experiments for teaching practice are well known from the literature (Abdulwahed and Nagy 2011, Aburdene et al. 1991, Alves 2007 ...). What has been overlooked and out of the focus among the developers and users of remote experiments was the question how to manage the long-term operation, reliability and innovation of the remote real experiments installed at remote (virtual) laboratories. In extending and improving the experimental base in remote laboratories, besides highly trained educators with the necessary didactic competences and ability to work with information technologies, collaboration of the IT technician of real experiments responsible for the maintenance, management, operation and innovation of the installed experiments is needed. If there is no opening of such a position in the organizational structure of educational organizations operating a remote laboratory, then it can easily happen that the efforts of the developers of experiments, as well as the funds used for the development and research involving the preparation of experiments will fail to produce expected educational and research benefits and the remote laboratory will gradually stop working.

### 3.2.1 Characteristics of the Remote Laboratory

The idea of implementing controlled lab through the Internet for educational purposes can be traced back to the nineties, when Aburdene et al. (1991) suggested a futuristic solution for sharing laboratory equipments through the Internet.

According to Ma and Nickerson (2006), remote laboratories are characterized by mediated reality. Similarly to real laboratories, they also need space and laboratory equipment. They differ, however, in the distance between the experiment and experimenter.

Also other authors (Alves 2007, Lustigova and Lustig 2009, Schauer et al. 2006) describe remote laboratories as a situation where management and observation of real devices and objects are mediated by computers, and the needed remote access is provided via a computer network. Thanks to the computer networks, it is possible to access the remote lab from any computer on the Internet.

According to the used technology, remote laboratories can be divided into two groups. The first group is based on specialized client-server applications. This is the way the industrial applications, where it is needed identification of the remote user and recording of his activities, are used, too. A major disadvantage of this solution is the need to install specialized applications for the client - student. This can be very tedious especially on slower networks and it discourages many users from the very beginning.

For the fear virus transmission, users often struggle to download and install the application into their computers. And some institutions even do not allow it (Lustig, 2009).

This group can include unique hardware and software solutions. They are operated their mostly by university departments that have decided to go

their own way. The quality can vary and, unfortunately, they are accessible on the Internet for relatively short time.

The second group of laboratories is based on the standard Internet technologies. The advantage is that on the client - student side a standard browser with Java technology is sufficient. On the server side there is a web server which by the support of software provides communication with the hardware of the experiment.

### **3.2.2 Preparation of Remote Experiment**

In preparation of remote real experiments we feel two different groups of requirements.

The first group of requirements is formulated by a teacher and his intention to use the remote experiment in education.

The second group of requirements is formulated by the technical solution of remote experiment. Fulfilment of requirements of both groups is a prerequisite for a successful school experiment.

At the beginning of each experiment is the idea of the teacher. The teacher will decide to innovate teaching using own remote experiments.

Creating a real remote experiment, which will meet the requirements for the safe and reliable operation, as well as requirements arising from the didactics of education, is a challenging task. Complexity and specificity of this task requires participation and close cooperation of a team of experts - specialists. Therefore, we consider establishment of such a professional team to be the primary and essential role of the teacher - the holder of the idea of applying the remote real experiment in teaching. The mission and objective of the expert team will be to design and carry out the remote real experiment. The condition is that the design and the implemented form would meet the technical and educational criteria.

We assume that the established team engaged in the development and operating the remote real experiment will consist of at least four specialists.

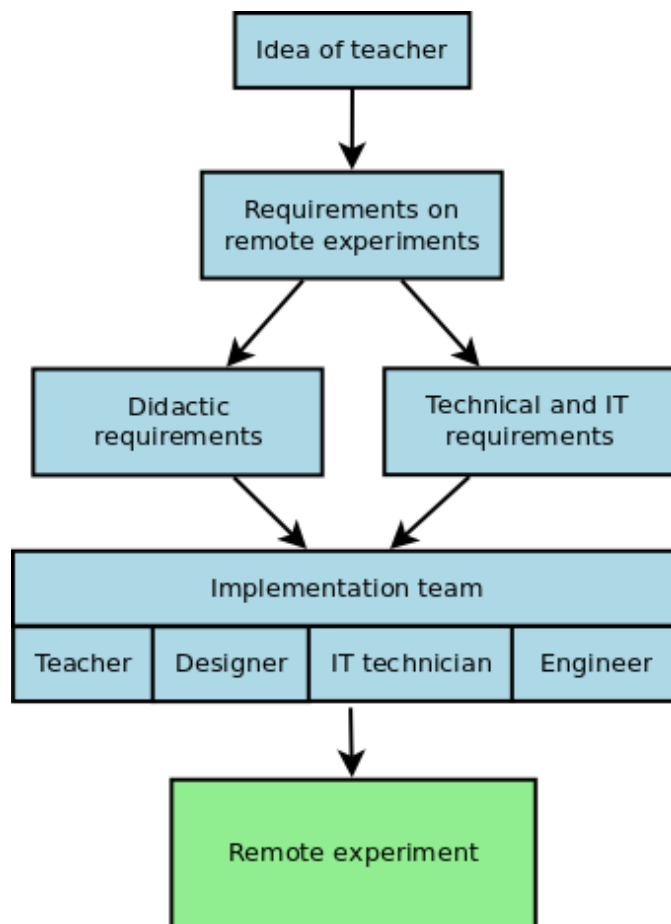
The leading and advisory personality in the creative team is the teacher who designs an experimental, topically oriented and the subject related task for the remote experiment. The teacher's role is:

- to define training and educational objectives to be achieved by applying the remote real experiment in teaching,
- to design assignments,
- to propose a content of theoretical information for the user,
- to propose procedures of practical activities in carrying out measurements,
- to propose the methods for evaluation of results and the didactical application of experiment in the various stages of the lesson.

Along with designers they define and solve requirements for the environment, in which the remote experiment will be located. They develop a list of all the information that will be provided to the user after logging into the Website of the remote experiment.

The role of IT technician in the team is to carry out technological aspects of the teacher's requirements. S/he solves also the designer's requirements concerning the structure and visual design of the website.

The design engineer is expected to design a technical solution to the arrangement of the measuring apparatus in the remote experiment, together with the design of supporting structures. In cooperation with the IT technician they will design the control and operational components of the experiment in its entire cycle: from launching the experiment to its closing by the user.



**Figure 26 From idea to remote experiment**

So, teacher must discuss with designer about design of user environment, with engineer about proposal of construction and with IT technician about remote controlling and monitoring through computer network, Internet.

### 3.2.3 Didactic User Requirements

The developer of remote real experiment must solve and pay attention to visualisation and the information contents of remote experiment. This must be consistent with the theme of the experiment and with the set educational goals.

The educational impact and its popularity will largely depend on the content and the level of its didactic and technical processing. The user environment of remote experiment must be designed and treated:

- user friendly,
- simple and clear navigation for user,
- clearly defined assignment and tasks of experiment with established educational objectives,
- theoretical background of the experiment,
- motivation for students to be creative.

At its opening, the users environment should attract the user's attention by its graphical design and gave him an interest in learning about the topic. Important is the way of visualisation of measurement or phenomenon and quality of image transmission of the set of experiment and monitoring its progress. Similarly, it should include theoretical background of the experiment, that the student understands the starting points of experiment and know what its purpose is and why. Whole course of the experiment should be simple and direct. Students should not lose in numbers of non-essential settings.

### 3.2.4 Technical Requirements on Remote Laboratories

Technical resources, by which the experiment is carried out in remote laboratories of experiments consists of an experimental apparatus with sensors endpoints, whose signals are processed electronically in modules connected with the control and check panel. This panel provides communication between modules, sensors and computer through input-output card of the computer.

In the development and technical solution of the set of the measuring apparatus in the remote real experiment, the designer (investigator) gradually comes to:

- an appropriate selection of sensors for measurement of physical parameters, properties or characterization of the phenomena observed in the processes of the remote experiment,
- the processing of modules with the transmission to the web server where the website of the remotely controlled experiment is located.

In practice, the user proceeds so that on the browser selects the website of the remote experiment from the corresponding web server to download all the graphics to the PC to be displayed along with all the texts. The user



through the website sends the commands that after evaluation of the web server launch the required operation.

This principle of operation has in some systems of remote experiments incorrect solution and imposes constraints in terms of having to allocate to each remote experiment the own web server with its own IP address and control panel. In case of the decision to place into remote laboratory further experiments, there is a need to install additional web servers with own IP addresses and control panels. Such a solution is demanding not only for technical equipment of the laboratory by further computers, but is associated with the availability of the allocation of public IP addresses.

When designing a laboratory of remote experiments it is important to realize the continuous development of hardware and software. Backwards compatibility is not always obvious. The laboratory should be built on open and widely used standards. It is thus a greater chance that the laboratory will use a platform that will be here in 3-4 years.

Another problem that can occur when operating the remote experiments is linked to an Internet connection. Low bandwidth and transfer rates of "live video stream" will be reflected in reducing the quality of transmitted video. If the arrangement of the remote laboratory experiment is considering the current way of taking images from two video-cameras, then the use two cameras in the design of remote real experiment requires a separate (specific) software solution.

In designing of the experimental base in remote laboratories, besides highly trained educators with the necessary didactic competences and ability to work with information technologies, a collaboration of the IT technician of real experiments is needed. If there is no opening of such a position in the organizational structure of educational organizations operating a remote laboratory, then it can easily happen that the efforts of the developers of experiments, as well as the funds used for the development and research involving the preparation of experiments will fail to produce expected educational and research benefits and the remote laboratory will be gradually abolished.

### **3.2.5 Administration of Remote Experiments**

In remote experiments, students, consciously or unconsciously, are trying the limit parameters of the experiment. Although such behaviour is important in terms of education, safety of the facilities must be taken into account.

In (Salzmann and Gillet, 2007) the three levels of protection of remote experiment are reported on the example of the assembled remote experiment of "inverted pendulum". The first level consists of software that sets the controller output to zero when the pendulum reaches a predefined limit. The second level consists of mechanical switches to turn off the power when the set limits are exceeded. The last level is made up of rubber backstops located at both ends of the pendulum.

The actual experimental facilities should be fully controllable at a distance by an administrator of the remote laboratory. Application controlling the remote experiment has to be robust to avoid the damage of experimental

equipment by the potential defective experiment parameters. The input data coming from user must be controlled.

When designing a laboratory of remote experiments it is important to realize continuous development of hardware and software. Backwards compatibility is not always obvious. The laboratory should be built on open and widely exploited standards. It is thus a greater chance that the laboratory will also be applicable on the platform that will be here in 3-4 years.

Ferrero et al. (2003) besides the others introduces the following requirements for remote laboratories:

- Realism. Students must use the real equipment involved in a real environment, to perceive all aspects of the real experiment. They should have available all the possible settings of the experiment. Possible errors must not be automatically filtered, but the students themselves must detect and correct them. The output measuring should students receive in a similar way and form as in the direct work with real equipment.
- Availability. Access to a remote laboratory should not be limited in time. Students can therefore carry out an experiment in time and from place that suits them best. The need of reserved software for access to the laboratory and processing of outputs must be strictly limited so that students would not be forced to download and install other applications. Under the availability can be considered costs for students and portability. The student must not be required for any other costs than those for the Internet connection. The system of the remote laboratory has not to be language and platform dependent.
- Safety and security. There is need of the remote laboratory equipment safety and security of the information system and its protection against malicious attacks.
- Implementation and maintenance costs. The process of school financing is working in such a way that finding the budget to create a new didactic laboratory is less difficult than budgeting for maintenance.
- Portability. The development of computers, operating systems and software applications are so fast that each application should be both portable and platform independent as possible. This can reduce the cost for future development and possible migration to another system. In this regard, the use of programming languages should be limited to the platform-independent languages such as Java and the like.

Salzmann and Gillet (2007) highlight the issue of sustainability of remote laboratories. The main challenge lies in the transition from remote experiments developed in the framework of the research projects to the professionally administrated and managed remote laboratories. Such laboratories would be available worldwide with guaranteed availability for 24 hours a day, seven days a week. Eikaas et al. (2003) came up with the idea of the business model (ESP Experiment Service Provider). ESP would offer a set of laboratory experiments to the customers from universities, secondary schools, but also the individuals or companies. The basis would

be global access portal and high quality remote experiments. As if it was a paid service, 100% performance and availability would be a necessity.

The issues of sustainability, extensibility and management are discussed in (Kara et al, 2011). The team of authors distinguishes technical and pedagogical perspectives. The software development and its management make the framework for technical issues. They draw attention to obsolescence of hardware. If we later need to replace some components, they may already not be available on the market. Equally important is the regular recalibration of laboratory equipment. What concerning the pedagogical perspective, it is important that teachers accept the remote experiment in order to understand its contribution to educational practice. Otherwise, they refuse to use it or the experiment can be used inappropriately.

The correct functionality of remote laboratory requires good management, proper and effective use of technologies. For the whole process it is important to have well-defined plans of management, accountability, monitoring and evaluation. Managing the remote laboratory is a continuous process that does not end by implementing all the necessary hardware and software components. Elements of the laboratory must be constantly monitored and controlled. Their hardware and software components have to be regularly updated by security patches. This process of permanent administration is referred to as configuration management.

Remote laboratories may become the target of computer attacks. Like any network service, also they may become victims of DoS (Denial of Service) attack. To strengthen the overall protection of remote laboratories it is important to improve their safety properties at all levels.

The first task is to prevent an unauthorized entry into the laboratory. Suitable authentication mechanism is the first step to achieve the access control. Authentication is usually enforced by creating user accounts for those users who authenticated by user name and password may access the experiment. This method is most widely used means of authentication. Since the remote laboratory is connected to the Internet, it is necessary to protect it by firewall. Firewall is a tool that separates protected network from unprotected one and, in many cases, one protected part from another unprotected part of the same network. Therefore, it is a certain throttle point, through which all the communication is passed to and from the protected network. With today's sophisticated computer attacks it is necessary to protect the remote laboratory also by another element - an Intrusion Detection System (IDS). The role of the system of intrusion detection is to identify, preferably in real time, an abuse, unauthorized or improper use of a computer system. The issue of intrusion detection has become very important in relation to the increase in the number of systems connected to the Internet. More systems mean more potential attackers and their identification becomes more difficult. An Intrusion Detection System, like other computer security tools should be included in the security policy.

### **3.2.6 Summary**

Technological development in information technologies provides many new possibilities for their exploitation in education. Remote and virtual laboratories are now a real fact, not only at technical universities, but also at lower educational levels. Teaching with the support of information

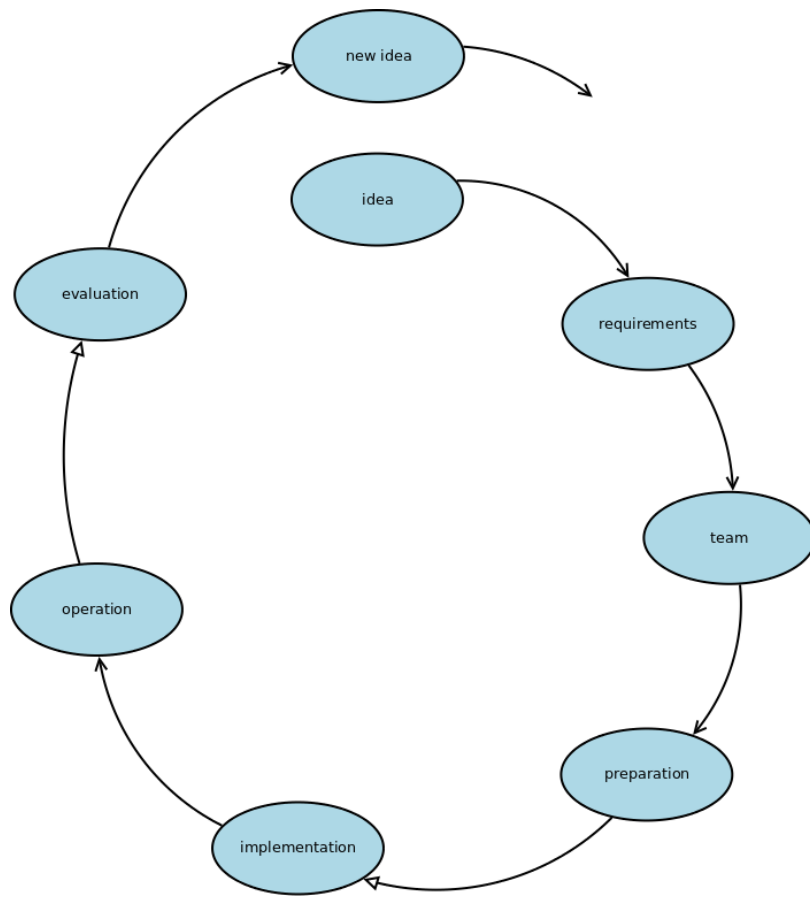
technology is popular not only for pupils/students, but also for educators themselves. The use of such technology in education is not associated only with the advantages, but it also brings emerging problems, pitfalls and risks, on the solution of which it is necessary to focus the attention of pedagogical research. The development and operation of remote laboratories requires some resources. Some experiments are able to run fully automatically (usually those from the Electrical Engineering), others require constant human intervention on the spot (this is typical in the chemical experiments). Correct functionality of remote experiments is critically important for its exploitation. As stated in (Kara et al, 2011), it includes not only technical problems and challenges, but also educational problems. Maintaining remote laboratory experiments can be surprisingly difficult in area of human resources and facilities. This should be considered during the developmental phase of the laboratory. Another hitherto little-examined issue is the integration of remote experiments into the structure of lessons to achieve the desired training and educational impact. Despite these reservations, not only locally but also worldwide, there are currently being discussed issues and paid attention to the preparation and evaluation of remote and simulated experiments and there continues interest in their integration into teaching.

If we want the real remote experiments to become innovative means of educations in schools and a popular teaching aid, it is important and necessary that the preparation and operation of remote experiment should have a spiral nature.

In its basic cycle, the implementation of the ideas of the teacher designer is carried out. The teacher designs an experimental task based on the curricular content, s/he defines the basic requirements for the development and operation of the experiment from technical and didactic perspective. S/he initiates establishment of a work team for preparation and implementation of the experiment. The outcome of the team collaboration is the developed experiment, the application of which in the teaching process is verified by the team and consequently provided to users over the Internet. An important stage in the further development of the experiment is evaluation of the operation associated with the design of innovative ideas and their implementation in the next development cycle.

In order for the remote experiment not to become a short-term concern, it is necessary so that the operator would solve and ensure the continued development and innovation based on evaluation of their own experience and users feedback. Therefore, we consider it important, so that the operator would ensure continuous care in the remote experiment and its innovation.

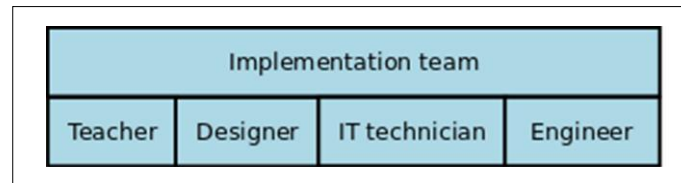
This requirement is well reflected and expressed by the spiral scheme of development, operation and innovation of remote real experiment. Operation and innovation of remote real experiments following the mentioned scheme makes provision for the long-term care and innovation of such experiments in remote laboratories.



**Figure 27 Live cycle of remote experiment**

### 3.3 Remote Experiments in Terms of View of Didactics of Education

Creation of a real remote experiment that fulfils demands for its reliable and safe running hand in hand with meeting methodical objectives is not a simple task. Challenge and specification of this task requires a close cooperation of real experts – specialists. (fig.28)



**Figure 28 Implementation team of experts**

So that real remote experiments can become an effective teaching aid it is important and needed to keep the valid principles regarding preparation and running of the remote experiment as may be seen in the developmental spiral (Kozik et al., 2011).

The basic idea comes from a designer – a pedagogue, who specifies a task for the experiment from the particular topic of a curriculum, defines fundamental demands for creation and running of the experiment from both technological and didactical points of view. The last but not the least there is a task regarding creation of an appropriate work team. Outcome of the cooperation of such team is the created experiment ready to be verified and consequently offered to users on the Internet. Other important phase in the process of further development of the experiment is the evaluation of its functioning that is closely connected to the design of innovative ideas and their implementation in the next developmental cycle.

To provide sustainable remote experiment we need to guarantee both its sufficient maintenance and continual innovations where demands from the side of users who in practice are teachers and pupils/students must be taken into consideration.

The crucial demand of teachers regarding remote experiments (RE) is to provide higher level of fulfilment of educational and edifying aims in teaching process. (Ali and Elfessia, 2004)

Design and application of remote experiment represent two separate troublesome areas. The first one deals with technical solution and running of remote experiment on the side of a provider who is responsible for:

- design and construction of a remote experiment on specific theme,
- system of management and control of functionality of particular experiments,
- philosophy of collecting and processing of the observed data,

- hardware and software support of the remote experiment via the Internet.

On the side of a user of remote experiment the situation is completely different. The most likely, user of the RE is a pedagogue – teacher, who decided to use the RE as an innovative tool in the lessons. Such user is primarily interested in the didactic side of the experimental topic and how the experiment can help him/her improve the level of education. Technical and programming issues of the RE usually are just secondary from the point of view of users – teachers.

When working with RE we deal with real laboratory equipment that is perceived indirectly on the side of a user. According to (Haluskova, 2009) one part of students does not perceive remote laboratories as the real ones and that is why we should try to reach the state where the display and controlling of the experiments are as authentic as possible. It must enable accessibility to all the possible settings of the experiment. Possible faults in the setting of incoming parameters of the experiment cannot be filtered out automatically, but the users must detect them and consequently try to correct them. Outcomes of the measurements should be obtained in the same way as if students take them in direct work with real equipment. (Kozik, 2005)

### **3.3.1 Social Conditions of Application of Innovative Teaching Supported by Remote Experiment**

In the last 20 years there is an obvious decrement in the interest in study of natural scientific and technical disciplines among students of elementary and secondary schools in the SR. Experience of the authors from numerous study stays abroad shows that there is similar development visible also in other European countries. It is generally known that subjects like mathematics, physics or chemistry are not very much preferred and favourite among pupils/students at elementary/secondary schools. A really sad fact is that similar opinions are heard also from the graduates and postgraduates of technical universities.

Successful study of these subjects is generally contingent on the adequate level of abstract thinking, good spatial visualization connected with logical and analytical thinking. These attributes are not automatically given to all people and even among those who have such skills it is needed to intentionally develop and improve them through the educational process.

Thanks to the information technologies much scientific knowledge is accessible to wide layers of inhabitants in the early decades of the 21. Century. E-technologies and their continual applications seriously influence traditional educational systems. It is a contemporary issue for the pedagogical staff to answer the questions what to teach, how to teach it and when. The philosophy of education itself changes constantly. There is a tendency to divert from the philosophy of education orientated on the lifelong occupation and consequently the philosophy of education for constantly changing conditions on the Labour Market comes forward.

What we know as the lifelong education is more and more being emphasized nowadays. Our society starts to realize meaning and importance of real fulfilment of a term knowledge society or so called

learning society in relation to its permanently sustainable development (Clough, 2002).

In the abovementioned social-economic environment there are also educational systems of particular countries whose fundamental aim should be provision of such educational level of inhabitants that has a potential to create preconditions of its future development.

Specification of teaching technical branches is in the necessity of applying whole range of creative methods for every particular technical or technological problem. This approach in education represents the very substance of innovative educational forms in which a teacher is in the position of a partner for pupils/students and at the same time he represents a role of authority and personage. Basic role of a teacher in this model of educational process lies in the activation of learners towards the subject of education thanks to which a needed place for individual activities of learners will be created orientated on the already mentioned attributes (abstract thinking, spatial imagination, logical thinking etc.).

In the history of development of human societies there had never been recorded such a huge acceleration of updating knowledge as it was in the 20. and at the beginning of 21. Century. As a consequence of quick mass widening of the ICT applications, new information regarding advance in science, research and social development have become easily accessible for people practically of all social groups. E-technologies are more and more frequently used in the area of education. Step by step the whole society gets to know the meaning and content of the term knowledge society in connection to the perspective of sustainable industrial growth (Clough, 2002).

In the abovementioned social environment there are acting and developing various educational systems. Specification of teaching technical specializations lies in preferential implementation of creative methods in the process of solving various tasks or problems. Getting familiar with this approach from the very beginning (ideally already at the level of pre-school education) creates positive predispositions for further successful understanding of more complicated technical principles in the course of further study and elegant mastering various technically orientated activities in everyday life.

### **3.3.2 Remote Experiments and the Didactic Cycle**

Creative approach is the substance of innovative form of education where a teacher stands in the position of a partner while keeping his authority. So that a pedagogue/teacher can reach required educational aim, he must be able to attract attention of learners to the particular topic. And the implementation of experiments (hands-on, remote, simulated) in education is the mean that enables it (Choi et al., 2009).

In both vocational and pedagogical literature there is no straightforward answer to the question regarding minimal ICT competencies of a pedagogue for creative application of remote experiments in the teaching process that would enable to design and create one's own educational experiments supported by e-technologies. There is also one reasoned definition of didactic demands for this type of experiments missing, which should be taken into consideration in the process of their design, construction and



running. The teaching process has got its specific attested sequence of activities on the side of a teacher as well as on the side of a learner that have been proven in the course of time. This didactic cycle consists of (Kozik et al., 2011):

- formulation of the aims of teaching process and consequently their acquisition by learners,
- reiteration of previously obtained knowledge that is closely connected to the new study content,
- exposition and acquisition of a new study content,
- consolidation of newly received information,
- check of the attained outcomes in the educational process,
- setting tasks for a home preparation.

In every of these phases a teacher can use different methods (Pastor et al., 2003):

- motivational (supporting interest in learning),
- expositional (getting acquainted with the new study content),
- fixative (reiteration and consolidation of information),
- diagnostic and classificatory (examination and evaluation).

Teaching supported by information technologies has recently become a favourite way of teaching among pedagogues galore and it is positively accepted by students themselves (Choi et al. 2009, Corter et al. 2007, Aburdene et al. 1991). This fact itself supports expectation for reaching better educational effect when compared to the traditional forms of education.

If we take into consideration all the mentioned didactic demands in the process of designing and running RE, then such system should fulfil following:

- easy accessibility on the Internet,
- simple orientation on the web site of the experiment,
- easily understandable guide regarding handling the experiment,
- assignment with clear definition of educational aims,
- corresponding theory to the theme of an experiment at the appropriate educational level of a user,
- definition of a way of communication between users and provider of the experiment,
- recommendations for pedagogues regarding deployment of the experiment in particular stages of a teaching unit (in didactic cycle).

From technical point of view the experiments should be constructed in such way so that:

- created experiment is in accordance with theoretical knowledge which it is based upon,
- it is technically resistant against user's failure in the process of control of the experiment.

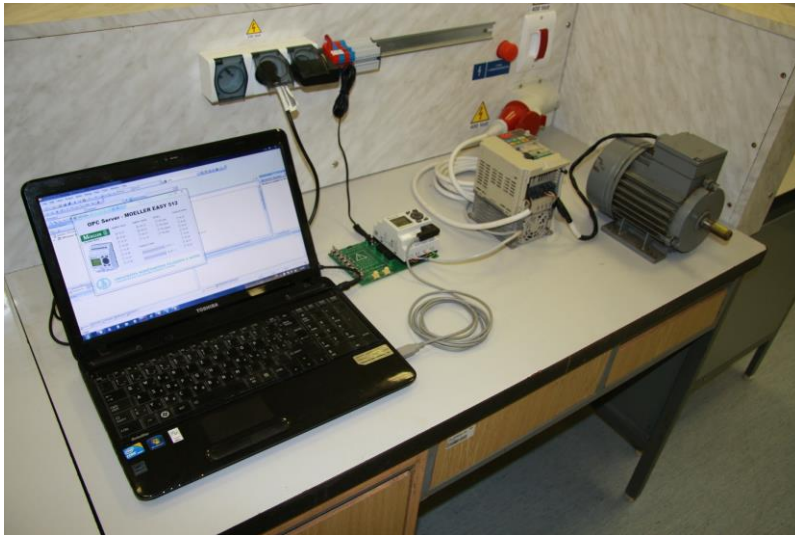
It is obvious that deployment of gradually widening net of e-laboratories that are used in pedagogical practice is going to be the subject of serious pedagogical research in the nearest future. The issue of development of new universal systems in management and control of remote laboratories that would provide safety and needed economy in the process of their running shall also be one of the topics of the research.

### **3.3.3 Technical Solutions of the Remote Experiments with Deployment of PLC**

Authors in the process of designing remote experiments and constructing remote laboratories have decided for the philosophy of applying the elements of industrial automation. In the process of searching for suitable technical solution of managing and handling the experiments in remote laboratories they decided to try to use technical parameters and attributes of PLC. PLC (Programmable Logic Controllers) are used in solutions of automatized tasks at different levels of technical difficulty. When deciding about deployment of PLC, the fundamental and original idea was creation of a universal system of handling and managing. System constructed in such way will be exploitable also in teaching the subjects orientated on automation.

The system of remote administration of PLC on the Internet is provided via web server which represents graphical interface (GUI) between PLC and users. Communication between the web application and PLC itself is provided via OPC server (OLE for Process Control).

In technical experimental tasks from the area of electro engineering we frequently may see a task regarding regulation of revolutions of an electric engine. The authors have decided to use the frequency transducer in their remote experiment. In fig.29 is displayed overall configuration of the remote experiment for the regulation of revolutions of the 3-phase electric engine by the 3-phase frequency changer.



**Figure 29 Configuration of the experiment regarding regulation of the engine revolutions by a frequency changer**

Parameters of the frequency changer are set in a way so that revolutions of the engine can be regulated by a time width of the input impulse. It means that if there is a logical 1 at the A master input of the frequency changer, then speed of the engine will continuously rise all the time while the logical 1 remains active at this input. B input will react similarly in relation to the decrement of revolutions. In case that at both inputs (A, B) is logical 0 or 1, revolutions of the engine will not change. In this configuration the PLC made by EATON EASY 512 was used. It is the bitwise combinative automaton managed through OPC server.

In the process of constructing remote experiments in remote laboratories the question of their economic efficiency becomes more and more important. Running the experiments in the remote laboratories is a difficult task from the point of view of illumination of the workplace. It is required to provide permanent source of illumination of particular experimental configurations even in such cases when there is nobody logged in on the server.

Interesting decrement in operating expenses can be obtained by installation of a system that after user's entry turns the light in the laboratory on and consequently activates particular experimental components. This function can be added into the remote experiment that is operated by programmable logical automaton (IEC programming language).

Model of a remote experiment simulating the abovementioned processes may be seen in the fig30.



**Figure 30 Model of regulation of illumination of the remote experiment**

Nowadays, it is not a problem to create practically any experimental configuration and consequently to make it accessible for users via the Internet. Still one open problem remains - how the experiment from the point of view of a user can be deployed in education, or in other words, how it will be implemented into the teaching unit so that a teacher can reach demanded educational goals.

### **3.3.4 Summary**

Already nowadays there are obviously visible changes in the educational environment at practically all types and levels of schools as a consequence of implementation of up-to-date applications of the information technologies in education. RE make a good example of their penetration into the teaching process especially in natural scientific and technical areas where there is an emphasis put on the deployment of methods regarding the work with experiments. In parallel, they are a challenge for pedagogical research in the area of searching for the answers to the questions regarding their implementation into the teaching process and the impact on knowledge level and specific skills of postgraduates from natural scientific and technical fields. Already published outcomes regarding deployment of the RE in educational sphere point at their benefit especially in the area of shortening the time needed for practical vocational training of pupils/students. We want to state that deployment of RE in education does not automatically mean total exclusion of real experiments from the teaching practice. Ideally, the RE should be combined with the real experiments (Choi et al. 209). Potential of deployment of remote experiments lies in the individual approach of every teacher, their ability to prepare a good experiment and the overall pedagogical mastership considering innovative principles of teaching and the effective exploitation of educational time.

### 3.4 Operational Sustainability of Remote Laboratories

Remote laboratories appeared on the market as the third choice between real laboratories and simulations. Critics of real experiments say that physical laboratories are expensive and require adequate place and time. Those who criticize virtualization in experiments oppose that students of technical orientation should work in the conditions of real environment. Remote laboratories are similar to simulations, as they are controlled through the computer interface. The difference is that compared to the simulations, in case of remote experiment the experimenter works with real equipment and obtains real data.

J. Ma, J. V. Nickerson (2006) analysed number of publications and information sources dealing with various types of laboratories. They claimed that it was no surprise there was no agreement in case of assessment of the laboratories themselves and the efficiency of laboratory work. Principal source of confusion lies in the inconsistency in definition of real, simulated and remote laboratories. In various studies, there are different labels used for remote laboratories like – web laboratories, e-laboratories or laboratories of distributed education. Another problem is the absence of agreement on the assessment of students' learning progress and also the lack of examples suitable for quantitative studies. Among other secondary sources belong unclear goals for evaluation of laboratory outcomes and a real mess in defining the laboratory purposes.

Remote laboratories according to the used technology can be divided into two groups. The first one is based on specialized client-server applications and this is a way that also industrial applications go ahead. In this case an identification of remote users and recording of their activity are required. Crucial disadvantage is the necessity of installing specialized program on the side of a client – student. This may take too much time (especially in case of slower net connection) and thus many students can be discouraged before they start to deal with the experiment itself. Users are generally afraid of downloading and installing applications to their computers and some institution just do not allow it (Lustig, 2009).

One of the most frequently used systems in the Czech and Slovak Republic from this group is the LabVIEW. LabVIEW requires a special software LV RunTime Engine to be installed on the client's computer which unfortunately is only compatible with MS Windows platform. There are also many unique software and hardware solutions provided by academic workplaces that have decided to go ahead on their own. Quality of their products is different and they have become available and accessible on the Internet just a short time ago.

The second group of laboratories deals with the common Internet technologies. The advantage is that there are no specific needs on the side of a client, just a standard browser supported by Java. On the side of a server, there is a web-server that provides communication with the experiment. This type of laboratories is considered a prevalent one nowadays.

### 3.4.1 Remotely Controlled Real Experiment

Remote real experiment is a real physical, chemical or technical experiment being executed in real laboratory. The difference between real and remote real experiment is that observer and executor of the experiment is outside the remote real laboratory what means that the observation or execution of experiments is realized via set of commands and visual transfer on the Internet.

When creating remote real experiments in remote laboratories it is needed to solve two different types of technical tasks:

1. Technical solution for the observation of particular physical or chemical process, or understanding the very substance of the technical principle.
2. Starting of remote experiment and its control.

Technical solution of arrangement of an experiment consists of three proposals:

1. Arrangement of an observation or measurement of the phenomenon, the way of measurement of characteristic quantities and collection and assessment of obtained data and information.
2. Control of the remote experiment from the user's (observer's) place.
3. Displaying and transfer of the video (feedback from the control management of an experiment).

Besides these technical tasks, designer of remote real experiment must pay attention to visualization and content of the web page that is used by a user in the process of communication. Its content must be in accordance with the topic and educational goal of the experiment. Web page design of remote real experiment represents a unique didactic issue whose solution is as important as the design of a technical solution and execution of the experiment itself. These factors will influence both educational efficiency and popularity of the web site. It must be designed with respect to the following aspects:

- Easy orientation,
- definition of needed theoretical information and conclusions that may be verified in the experiment,
- possibility of the application of creative approach.

The web site should attract attention of a user with its graphic friendly environment. This plus the video quality of transmission should help to increase interest in particular experiments among students.

Technical means that support the execution of experiment consists of experimental apparatuses with sensors of observed attributes whose signals are electrically processed in modules that are connected to the control board to provide mutual communication via input-output card of the

computer. When such computer is connected to the Internet, remote real experiment becomes available to all Internet users.

In the process of technical development of measuring apparatuses in real remote experiment designer makes these choices:

- Choice of suitable sensors for measuring physical quantities, attributes and characteristics of particular phenomena taking part in the experiment.
- How to process obtained data in modules and provide their transfer to web server, where the web site of a real remote experiment lies.

In practice, when a user decides to observe remote experiment, he must choose a website of the real remote experiment and in the next step whole graphics and texts from the website shall be downloaded from the web server. User sends commands through the webpage that after being evaluated by the web server activates required operation.

Such principle of work is solved incorrectly in some systems of remote real experiments and brings restrictions in form of necessity to earmark a web server with its own IP address and control board for every single remote experiment. In case of decision to add more experiments into the remote laboratory we are forced to install other web servers with their own IP addresses and control boards. Such solution is extremely impractical not only from the point of view of technical provision of laboratories, other possible problems lie also in the assignment of public IP addresses and; nonetheless, in low transfer speed that may affect the video quality of broadcasting.

If the experiment in remote laboratory requires 2 cameras, then the design of such experiment must take it into consideration (Modern software means enable faster transmission of high quality picture; for example, programmable library DirectShow).

Team of authors of the concept of administration of real remote experiments offer one possible solution in a form of implementation of PLC elements of industrial automation. (Kozik a kol., 2011)

These systems are commercially accessible and also fulfil specific demands that are put on the administration of remote experiments. From the point of view of future applications their advantage is that they are commonly used in appliances of industrial automation and are accessible on the market.

Author of the abovementioned publication come with the idea to apply controlling industrial PLC automatons in a remote laboratory in non-traditional and interesting way. They suggest that PLC automatons turn the lights in the laboratory on just after user's login and consequently all other needed equipment.

The mentioned concept of running fully functional remote laboratory leads us to the opinion supporting creation of a new profession in institutions that decided to offer services of remote laboratories within their educational curricula. In the process of improvement of experimental platform in remote laboratories besides highly vocationally prepared pedagogues with didactic competencies and ICT skills it is needed to cooperate with a



technological informatician who has knowledge and experience in remote real experiments whose job should lie in guidance, maintenance and innovation of the installed experiments. If we fail in our effort to create such specialization, if we do not find sufficient financial sources to educate specialists in this area, then we shall witness the obliteration of remote laboratory.

### **3.4.2 Remote Laboratories Accessible on the Internet**

Remote laboratories focus on various areas, including technology, natural sciences and education. In the frame of technology we distinguish further specific subdivision into branches like electrical technology, mechanics and aero engineering and so on. In the area of natural sciences there are laboratories orientating on physics, chemistry and biology; nevertheless, prevalent type of laboratories is orientated on the area of electrical engineering.

#### **Blekinge Institute of Technology/Signal Processing, Ronneby, Sweden**

Website: <http://openlabs.bth.se/>

Project of the remote laboratory at Blekinge Institute of Technology (BTH) uses original interface that includes displaying of laboratory board and also some other well-known apparatuses like oscilloscopes, multi-metres and signal generators. In the process of measuring the relay switch matrix is controlled from a long distance. Components installed into the matrix by teacher are displayed on the screen of the client's computer where students can assemble particular type of linkage. Thus, thanks to the relays connected to the matrix it is possible to assemble a circuit consisting of maximally 16 knots.

#### **AIM-Lab (Norway)**

Automated Internet Measurement Laboratory, Measuring of semiconducting components on the Internet

Website: <http://nina.ecse.rpi.edu>

This laboratory is used in connection with courses of power semiconducting components and circuits. Here students obtain practical skills and knowledge in the area of semiconductors. Distant semiconducting laboratory executes 2 series of experiments regarding the remote measurement of diode characteristics. Due to restrictions of power sources it is possible to perform only one measurement at once.

#### **LESIM (Italy); Faculty of Technology, University of Sannio, Italy**

Website: <http://lesim1.ing.unisannio.it/>

LESIM (Laboratory of Signal and Measurement Information Processing) is based on the software whose modular attributes enable insertion of new applications or modifications of those used ones. Thanks to the implementation via Java and C++ with CORBA communication level, the final solution is extremely flexible.



### **Remote Laboratory NetLab; University of South Australia**

Website: <http://netlab.unisa.edu.au/faces/frameset.jsp>

Remote laboratory NetLab has been developed at University of South Australia (UniSA) in the frame of School of Electrical and Information Engineering (EIE). Fully functional system has been used since 2003 by approximately 200 students per year. It is possible to execute various experiments through the NetLab system; for example, junction analysis of an RC circuit, alternating analysis of a phaser or analysis of a serial resonance circuit and an RC filter.

### **Remote Laboratory at university in Hagen, Department of ElectroTechnology, University of Hagen, Germany**

Website: <http://prt.fernuni-hagen.de/virtlab/>

This laboratory is deployed to teach the theory of regulation, where simple regulators with solid structure are being used. Students choose an algorithm for the regulator and then remotely define its parameters. Web browser displays a set of information. Web server serves as the interface between student and experiment. User must book the time for experimentation in laboratory in advance.

### **Distantly Controlled Laboratory Technische Universität Kaiserslautern, Germany**

Website: <http://http://rcl.physik.uni-kl.de/>

In the frame of a project called Remote Controlled Laboratories (RCLs), a team under the leadership of prof. Jodl has created 17 remote experiments orientated on both technical and natural science directions. Aim of the project is to create the RLC network at schools and universities all over the world.

### **Project e-laboratory, ISES e-laboratory, Czech Republic**

Website <http://www.ises.info>

Associate professor Lustig with his team has created 7 remote experiments in the area of technical and natural science fields. The experiments are based on a compound called ISES (Internet School Experimental System).

### **Real Remote Laboratory in Trnava, PdF, TU**

Website: <http://kf.truni.sk/remotelab>

Prof. Schauer and Assoc. Prof. Ožvoldova are the leading personalities who created this laboratory and with their academic and scientific titles they guarantee validity of obtained data.

The laboratory performs 6 freely accessible experiments from the area of physics and chemistry. The experiments are based on a compound called ISES (Internet School Experimental System).

### 3.4.3 Administration of Remote Laboratories

Students in remote experiments whether consciously or unconsciously try the outer limits of an experiment. Though, such behaviour has meaning from the educational point of view we have to take into consideration the question of safety. Salzmann with his team (2007) state 3 levels of safety of their remote experiment called Inverse Pendulum. The first level is represented by software that sets the outcome of the regulator to zero, if the pendulum reaches pre-defined borders. At the second level there are mechanical switches that turn the drive off, if the pre-defined border is crossed. The third and final one is created by rubber backstops placed on both ends of the pendulum.

All experimental equipment should be fully remote-controllable by the administrator of remote laboratory. Application that controls remote experiment must be sturdy enough, so that incidental defective parameters would not damage experimental equipment. Entry data coming from the side of a user must be under control all the time.

In the process of designing laboratories for remote experiments it is important to realize that development in the areas of software and hardware is constant and the backward compatibility is not always guaranteed. Remote laboratory should be created on open and widely used standards what increases the chance that it will be serviceable even in years to come.

Ferrero with his team (2003) states besides others these demands on remote laboratories:

- **Realness.** Student must use real equipment in real environment, so that they can perceive all aspects of real experiments. All possible settings of an experiment should be available. Incidental errors cannot be automatically filtrated, student himself must find and correct them. Output data should be obtained in the same way and form as in real experiment.
- **Accessibility.** Remote laboratory should be open non-stop, thus students are allowed to experiment at any time and from any place. Students should not be forced to download other additional applications and files. No other fees but for the Internet connection must not be enforced. System of remote laboratory cannot be dependent on language and platform.
- **Safety.** It is recommended to provide security of remote laboratories and protection of information systems against malicious attacks.
- **Implementation and maintenance costs.** The system of financing the school causes that building of a new didactic laboratory is less complicated and cheaper than the maintenance budget.
- **Compatibility.** Development of computers, operating systems and software applications is so fast that every application must be compatible and independent of the platform as much as possible. That is the way how to decrease expenditures on future development. From this point of view deployment of programming languages should be orientated on independent languages like Java and similar ones.

Salzmann with his team (2007) focus their attention on the long-term sustainability of remote laboratories. The main challenge is the cross from remote experiments created in the frame of particular research projects towards professionally administrated remote laboratories. Such laboratories would be accessible from the entire world with guaranteed 24/7 availability. Eikass and team (2003) have come with the commercial model ESP (Experiment Service Provider) that offers various sets of laboratory experiments to customers from universities, secondary schools and even to individuals or commercial companies. The platform would be represented by a global access portal and remote experiments of high quality. Since this is going to be a paid service, 100 % functionality and accessibility are a must.

Issue of sustainability, administration and extensibility is being discussed by Kara and team of authors (2011). They distinguish between technical and pedagogical issues. In the frame of technical sphere it is the software development and its administration. In case of hardware they warn of its extremely rapid dating what means that if it is needed to change some hardware components, there is no guarantee that such component is still being made. Regular recalibration is also one of the crucial factors regarding maintenance of laboratories. From the pedagogical aspect it is important so that teachers accept remote experiment as such and consequently understand its benefits for pedagogical practice. In opposite case there is a serious threat that they would refuse it or use it in unsuitable way.

Correct functioning of remote laboratories requires dynamic management and effective deployment of used technologies. It is good to have well defined plans for administration, responsibility, control and evaluation of experiments. Management of remote laboratories is continual process that does not finish in the point of implementation of all needed software and hardware components. It is constantly needed to monitor and control all laboratory elements and to update their software by safety patches. This type of permanent administration in the IT area is called configuration management.

It does not surprise that also remote laboratories can become the target of unexpected attacks. Like all network services, also remote laboratories become victims of DoS (Denial of Service) attacks from time to time. To increase the total protection of remote laboratories, it is advised to improve their safety attributes at all levels.

First task is how to prevent from non-authorized access to the laboratory. Suitable authentication mechanism is the first step to reach control over the access. The authentication is usually forced by the creation of accounts for users who only after inserting their names and passwords are allowed to access particular experiments. This method represents the most widespread mean of authentication. On one side, using of password is quite simple and comfortable still there are some disadvantages and risks connected with passwords. Truly, for more reasons the system of passwords is considered as definitely not a sufficient mean of protection against illegal access nowadays. Users usually choose various forms of their names, initials, or names from their neighbourhood, dates of birth and the like. Independent studies have proved that as much as one third of passwords are guessable up to the 10<sup>th</sup> attempt, not mentioning that sometimes password can be espied during its insertion into the system. In case of forgetful user it is not difficult to imagine the situation that password shall remain lost forever. Dilemma is to find a password long and complicated enough not to be easily

guessed, on the other hand quite easily memorable for a user. Unfortunately, people often let themselves be cheated and reveal their passwords.

Inasmuch as remote laboratories are connected to the Internet, it is inevitable to protect them through the firewall. It is a tool that divides protected net from the unprotected one and in many cases one protected part of the net from the other unprotected part of the same network. It represents something like a throttle through which all communication from and to the protected network. Firewall helps to increase the level of safe connection under two conditions:

1. Sources of protected network that shall be accessible from the outer network must be defined.
2. Definition of those users and computers of the protected network that are allowed to access the source from the outer network.

Since the sophistication of net attacks always rises, remote laboratories should be protected also with an effective system for intrusion detection. Its role is to identify, ideally in real time, misuses and non-authorized or incorrect use of computer system. The issue of intrusion detection becomes more and more important hand in hand with the rising number of connected systems to the Internet. More systems represent more potential attackers and their more difficult identification. Intrusion Detection Systems (IDS), just like other tools dealing with computer safety should be included in the safety policy that defines what IDS type is needed in particular cases, where they will be placed, what type of attacks it should detect and how it should react on a concrete type of attack.

### **3.4.4 Summary**

It takes time, energy and sources to create and run a remote laboratory. Some experiments are capable of fully automated running (usually in case of experiments from the area of electrical engineering), others need to be controlled directly in the laboratory (it is typical for chemical experiments). From a point of view of a principle of running remote laboratory, crucial parameter seems to be the speed of the Internet connection. Correct functioning of remote experiments is extremely important from the point of view of their exploitability. According to Kara et al. (2011), it includes not only technical issues and challenges, but also pedagogical issues.

Maintenance of a remote experimental laboratory may involve unexpectedly high consumption of human sources and technical equipment. This must be taken into consideration at the very beginning of the process of creation.

Despite all abovementioned reservations, not only in Slovakia, but also in the world, there are discussions on preparation and evaluation of remote and simulated experiments and it is obvious interest in their implementation into the educational process.

## Conclusion



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## Attachments

### **Actually working laboratories of remote experiments freely accessible through Internet**

1. E-laboratory of Trnava University

[http://kf.truni.sk/?page\\_id=356&lang=en](http://kf.truni.sk/?page_id=356&lang=en)

2. E-laboratory project ISES

<http://www.ises.info/index.php/en/laboratory>

3. Remotely Controlled Laboratories Universität der Bundeswehr München

[http://rcl-munich.informatik.unibw-muenchen.de/eng/lab\\_index.htm](http://rcl-munich.informatik.unibw-muenchen.de/eng/lab_index.htm)

4. Remote-LAB at Grammar-schools of Jaroslav Vrchlický Klatovy

<http://remote-lab.fyzika.net/vzdalene-experimenty.php?lng=en>

5. Openlabs at Belkinge Institute of Technology

<https://openlabs.bth.se/index.php?action=chlang&lang=1>

6. WebLab-Deusto, University of Deusto

<https://www.weblab.deusto.es/web/>

7. Remote connected laboratories at Buskerud University College, Kongsberg (Labview plugin required)

<http://rlab.hibu.no/>

8. Internet Shared Instrumentation Laboratory at University of Genoa

<http://isilab.dibe.unige.it/>

9. Remote farm at Berlin Institute of Technology (Free registration required)

<http://remote.physik.tu-berlin.de/index.php?id=1&L=1>