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FACULTY OF EDUCATION

Remotely controlled experiments

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This monograph is thanking all graduates, which I led and with whom I have worked for many years carrying out my professional and educational experience. Is thanking them continuously usually demonstrated interest in the results of my work performed, opinions and ideas. The result is the successful co-authorship of my PhD. graduates in the study program Didactics of professional technical subjects – technical education in the preparation of this monograph.

Prof. Ing. Tomáš Kozík, DrSc.

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INTRODUCTION

General increase of new knowledge in all fields of human cognition has become the subject of teachers' discussions with attempt to answer the questions what, when and how to teach. To set as much as possible of the latest findings of modern science and technology into the curricula is laudable and justified initiative in relation to the preparation of graduates for success in the labour market. Without the application of other organizational and innovative approaches in the curricula content and teaching methods is unrealistic.

In the school education systems we have noticed the search, investigation and application of new teaching methods or effort for innovation of well-established, proven teaching methods. In this way the important role is played by continual progress in the development of information technology and readiness for teachers and learners to apply latest outcomes from development in information technology.

It is known opinion that reasonable application of information technology in education can help to achieve the desired and necessary changes in education and to create the conditions for effective learning of the population in line with current social priorities and requirements.

Experiments and measurements are an important and significant part of natural and technical subject. Considering the given technical and time-consuming preparation, teachers replace them by another theoretical interpretation. The role and possibilities how to apply information technology with an emphasis on innovative approaches in organizing of practical exercises with experiments are the subject of this monograph.

In the introductory chapter the authors are focused on the application of simulated and remote experiments and laboratories. In addition to the description of the basic characteristics of school, simulated and remote experiments with indication of didactic requirements, the authors also define the necessary conditions for the planning, construction and exploitation of remote experiments in applications with a view to achieving their long-term operation

capability, anticipated innovation in line with achieved progress in science and technology. Part of the chapter is the analysis of the results of the survey of attitudes among university teachers to apply remote experiments in university education.

The second chapter is focused on the management and control of remote experiments using PLC (Programmable Logic Controller) systems from the view of their design and technical solution to ensure the security in operation of remote experiments. The technical conditions and requirements for PLC systems with use in technical solutions for remote experiments are listed. As an example, the remote experiment for measuring the speed of flow in gaseous atmosphere is given.

In chapter three, the authors are looked at a case study of the use of a real remote laboratory (RE) in engineering studies. As engineering students need experimenting to get scientific insight and professional skills combined with a decrease in resources (personnel and equipment), an e-learning environment (CALM) with real remote and virtual labs was created.

The CALM was tested in a pedagogical experiment to proof that RE can be used to successfully transfer knowledge to engineering students. The CALM was built to facilitate teaching and learning in the field of material sciences. As material knowledge worldwide drives innovation and the course of material sciences for bachelor contains both, theory and labs, it was an obvious choice for the experiment.

The RE was constructed to get the same learning outcomes as the physical material sciences labs with the aim to have a good basis for comparison. Also with the further aim in case of success to be able to (partly) substitute the physical lab and as such save on resources.

The construction of the CALM, remote and virtual lab is described in the chapter and the conclusions of the pedagogical experiment are also mentioned. The advantages, problems, methods are described to give an insight on the process of constructing the RE, virtual lab and relevant e-learning framework.

Authors, July 2016

1 EXPERIMENTS

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

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 meta-cognition".

1.1 ICT in experiments

For the implementation of educational experiments, it is necessary to possess technical equipment, adapted to the wanted learning outcomes. For the active work of students, it is ideal to have the same equipment in several groups simultaneously. This can have an huge economic impact on the budget. 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 due to the lack of resources. The consequence is that a number of measurements, observations and investigations remain only theoretical.

Another problem for realization 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 towards 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 and communication technologies (ICT) in education, e-labs were constructed besides e-learning. E-laboratories are made up of computer-mediated remote real or simulated experiments. The distanced and simulated experiments accompanied by electronic study texts create an integrated e-learning, which Schauer, Ožvoldová and Lustig (2006) consider one of the most progressive and nowadays also one of the most quickly developing teaching methods.

These e-labs can give more possibilities to teachers and students to implement and use experiments in teaching and learning.

1.2 School experiments

Educational experiments in natural sciences and technical subjects have a special status. They enable teachers to encourage and develop in students' creativity and creative thinking. Experimenting teaches students to work systematically and purposefully. In case of organizing a group work in the lab, students will learn and acquire the necessary experience with team work and to be responsible for work done as a collective.

By carrying out school experiments students also gain experience and manual skills in working with different techniques while preparing the experiments. They also acquire the ability to an analytically correct approach for the evaluation of experimental results. Gained skills and experience of working with experiments is significant in terms of their future career prospects and the application in real life.

Real (physical) laboratories include real research processes. From other types of laboratories they are different in 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 alone are still not enough to understand the knowledge. Students must also share the idea of experimenting. As stated in Clough (2002), "laboratory "cookbooks" used in science teaching rarely catch the student and help them comprehend." This means that students not only need a protocol for an experiment, but should actively think about how they experiment and what they are investigating.

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

In carrying out experiments, students confirm 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 (2011), students' attempt should be simple, convincing and safe. After completion of the experiment the learner should demonstrate and explain the phenomenon, describe and generalize. Alternatively, students can make a written report describing what they did, and explain about the phenomena. By developing the

ability to observe, describe and analyze the demonstrated phenomena, the student learns the basic elements of scientific work.

The social interaction between teacher and students in the laboratory is usually less formal than in the traditional classroom. Thanks to this, the laboratories provide opportunities for productive interactions and discussions between students and teachers that have the potential to improve the learning process. 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.

Teachers' behaviour during the experimental lesson is focused, as defined by Blaško (2011) 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,

- ❖ practice 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 (2009) 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.

Halusková (2009) points 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, Kireš (2010) recommends their inclusion primarily in leisure activities in non-formal education.

In our opinion, there should be time in education practice for students to experiment and with the possibility to discuss results with “experts” (teachers).

1.2.1 Computer aided experiments

Students already in the youngest age have a strong source of information in which they get very interested and experienced: this source is the Internet. Teachers like to use Internet in teaching. And students show great interest on learning supported by information technology, which is attractive for them. Digital technology is close to them and their interest towards it is easily therein oriented.

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

- ❖ Motivation: At the beginning of the lesson to motivate students to concentrate and to become interested in the subject of the course.

- ❖ Exposure: In the exposure phase where students are taught about the topic.
- ❖ Fixation: At the stage of fixation of acquired knowledge during round-up or conclusion.
- ❖ Evaluation: In the diagnosis and knowledge level of students.

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

- ❖ a high level of motivation of students due to the dynamic features of ICT (e.g. liveliness, animation, sounds)
- ❖ making inaccessible items accessible (e.g. movie on electron microscope),
- ❖ elimination of hazardous situations (e.g. dissection of animals, working in poisonous environment),
- ❖ simulation of time-consuming phenomena in a relatively short time (e.g. time lapse of crossbreeding of the *Drosophila Ordinaria* which in real time takes 11 days),
- ❖ interactivity - the student may intervene directly into the action, changing conditions,
- ❖ constructivist approach - the student does not receive a finished knowledge, but obtains knowledge by learning in the lab and by reflecting on the results,
- ❖ develop creativity (e.g. in setting up new experiments, in finding technical solutions for lab manipulations),
- ❖ individual pace: the student works at his own pace, not at the speed of the teacher
- ❖ click Help: help and scaffolding in learning can be (easily) implemented,
- ❖ fast feedback: automated feedback on standard questions during the learning process,
- ❖ generating random combinations of tasks: an advantage for teachers to reach a bigger group of individualized assignments.

By Grimaldi and Rapuano, (2009), multimedia technology based on new hardware and software technology plays an important role in the management and organization of the lessons. This technique brings new

opportunities to learn in a flexible and interesting way what is taught in a boring and tiring way. From the perspective of the teacher this allows to bring a dynamic relationship into the learning, to accelerate learning, to go into greater depth of knowledge and thoroughly explain learning materials. Even from the perspective of a student ICT brings diversified conditions for learning: the learning process in an environment with ICT is different from learning in a traditional classroom or lab environment.

ICT in education, however, are also negative sides. Labašová and Kozík (2011) in the use of electronic presentations on lessons set out the following drawbacks:

- ❖ the perception that knowledge gained by students by watching a presentation is more superficial than when students are making notes by hand
- ❖ creating a slide show demands more time from a teacher than writing his training in points,
- ❖ creating a slide show for a single topic (lesson) is uneconomical,
- ❖ technical problems: failure of equipment (projector, computer, ...) and so on drains the attention of teachers and students.

The use of digital technology in teaching has resulted in pushing out practical activities and exercises from the lectures course, even in subjects in which until recently classroom experiments and show cases had a dominant position.

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.

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)

1.3 Simulated experiments/simulated laboratories

1.3.1 Simulated experiments

A simulated experiment is not a real experiment, but a computer-calculated experiment which is used to visualize theoretical formulas and processes. Simulated experiments range from game-like small applets and animations to very complicated engineering software (e.g. Finite Element Analysis).

Educators, who in recent years implemented 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 an increase in the level of achieved knowledge and skills. Applets help a lot in the development of analytical thinking (observation), implicational skills (formulation of assertions, reasoning), logical thinking and the ability of applying the observed and learned phenomena in education. Using 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. Sometimes the time-

consuming and complicated construction of physical experiments is removed from the lessons.

It is easily feasible to integrate simulated experiments in the teaching units, mainly for lessons of natural science and technical subjects. Created simulations (applets), which are available on the Internet, or created by the teacher him/herself, which demonstrate the physical principle of the particular phenomenon have as such an added value to demonstrate on the phenomena. The web page of specific applet contains mostly the accompanying text, theoretical ground, formulas, derivations, manual tasks, questions, etc.

The appearance of the applet mostly depends on the intuition of the software engineer during the preparation phase of the specific applet. Some applets are demonstrated from a graphical side relatively easily, because the author of the applet put more emphasis on the professional side of the actual problem. Such an applet contains more formulas, theoretical explanations, and often, the simulation is not so dynamic. Such applets on the other side contain more particular figures; possibly monitor the interaction of several physical parameters (in the case of simulation of physics).

There are other types of applets, which do not put the emphasis on the theoretical explanation of a specific problem. Their goal is to instruct common users, to whom is adapted the graphical outlook of the simulation. Sometimes, these applets look like simple computer games.

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

1. <http://physedu.science.upjs.sk/ejs/index.htm>,
2. <http://www.compadre.org/Physlets/index.cfm>,
3. <http://phet.colorado.edu/index.php>,
4. <http://webphysics.davidson.edu/Applets/Applets.html>,
5. <http://www.walter-fendt.de/phys.htm>,
6. <http://hockicko.utc.sk/>,

7. <http://physics.bu.edu/~duffy/classroom.html>,
8. <http://fem.um.es/EjsWiki/index.php/Main/Examples>,
9. <http://www.cabrillo.edu/~jmccullough/physlets/>,
10. <http://acme.highpoint.edu/~atitus/physlets/>,
11. <http://lead.mst.edu/scienceteacher/lets/physlets/>.

1.3.2 Simulated experiments

Simulated laboratories (often referred as virtual laboratories) are created as simulated imitations of real experiments. The entire laboratory infrastructure is simulated on computers. Simulated laboratories allow for the use in the educational process of various prepared simulated or 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 Java. (Christensen et al., 2008)

Applets and animations are designed to clarify and clearly show the phenomena 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 instruments (Virtual Instrument). In general, there are two methods of using virtual instruments (Grimaldi and Rapuano, 2009):

- ❖ The first way is to use virtual instruments as sophisticated graphical user interfaces (GUI) to manage real instruments (step motor, temperature sensors and the like).
- ❖ The second possibility is the use of a computer simulation of the behaviour of a 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 Rapuano (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,
- ❖ the level of reality is higher than in just simulated labs,
- ❖ time-consuming and ease of use is optimized and the difficulty of acquiring the curriculum is minimized,
- ❖ it is possible to perform dangerous experiments without risk to the student or the installation,
- ❖ 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.

The condition for the user for a simulated/virtual laboratory is a high-speed access to the Internet.

Domingues et al (2010) after the first year use of the virtual laboratory referred to improvement of 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 Abdulwahed and Nagy (2011) concluded - despite the many advantages of computer simulations and virtual laboratories - that teachers and students generally agreed that simulation cannot and should not replace every experiments and by 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.

1.3.3 Virtual laboratories in Education

Combining simulations with real data gathering and management of remote processes enables 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 having technical issues and parameter settings. Thanks to this, experimenting 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), (Figure 1). This model was created using the Virtual Reality Modeling Language (VRML)

and the application Blaxxun Contact VRML Browser1. Students received the model with the necessary applications on an installation CD. This allowed the students to become familiar with the laboratory structure and equipment at home. When they come to the real laboratory they have acquired the necessary knowledge for using the real laboratory equipment.

This kind of flipped classroom approach in laboratories can be very effective to save valuable time in the laboratory.



Figure 1 Environment of virtual chemical laboratory from the perspective of 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 a combination of real and virtual machines. In their experience, the system is very attractive to students. For a realistic presentation of the experiment over the Internet several visualization methods were used. 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 2.

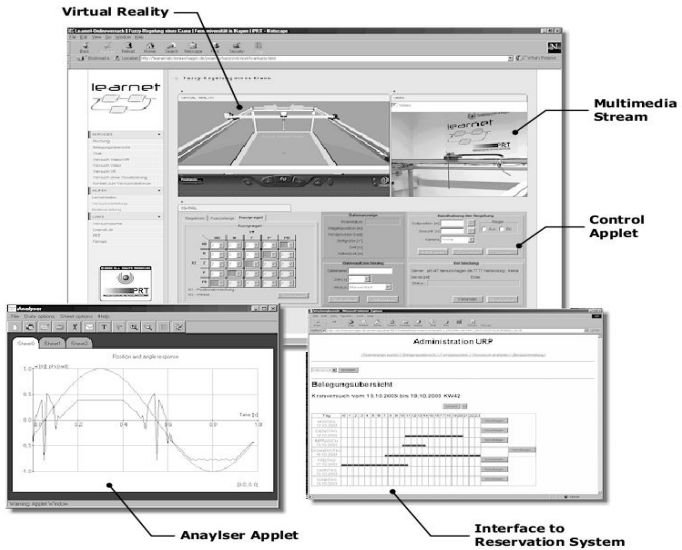


Figure 2 Web interface of the student who access the virtual laboratory (Masar et al., 2004)

Jara et al (2011) reported good experiences with two conducted consecutively teaching modules of the course "Automatics and Robotics". The first module was a virtual one, in which students programmed a simulated robot in a virtual environment. In the second module was use a real remote lab, in which students sent their robot program that they previously created and debugged in the virtual environment, Figure 3.

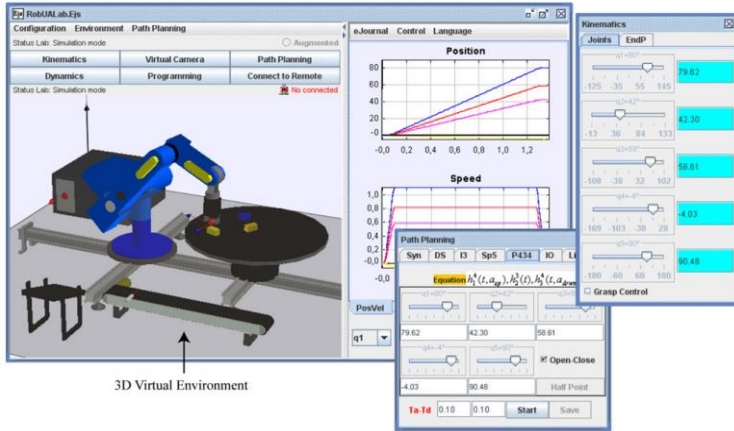


Figure 3 Controlling virtualized robotic arm by student (Jara et al., 2011)

This teaching method helped students to 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 the LAN (Local Area Network). The teacher explains the issue in a virtual lab environment and students can observe the progress of the experiment on their screen. Where it is somewhat unclear, so called "chalk" mode is activated. This mode allows to manipulate shared objects in the virtual laboratory. This enables possibilities to show exactly what the student 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.

The benefits of lessons with a real (physical) experiment, in addition to other benefits also develop skills in the handling of devices and measuring instruments. Blaško (2011) provides the following key competencies that students acquire by carrying out school experiments in real labs. These are the following:

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

In virtual experiments obtaining the above mentioned competencies is significantly affected by the setbacks of computer simulation. For example, the development of communication competences is limited because of the isolation of student working somewhere else than in the lab, and his dependence on electronic communication. This is related to personal and social competences.

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 a remote or a simulated experiment.

The experimental environment in a simulated lab or a remote lab is different from a real physical lab in the way it addresses the senses of the student. In a real lab all sense (view, taste, smell, sound, touch) are addressed, in a virtual or remote lab only view. The reality feeling of the environment can be improved by supporting sound. Computers (laptops, netbooks, tablets and smartphones) from which students visit

the virtual/remote laboratories are equipped with sound cards. By changing the inputs (by adding sound) on the lab-side the quality of the environment will be altered and it will be more credible for the learner.

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, tele-presence and virtual presence. Physical presence is linked to the real laboratories and understood as "physically be there". Tele-presence 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 the 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 goes 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:

1. presence as a social richness is related to two important notions originally applied to the impossibility of mediation of interpersonal communication: intimacy and immediacy,
2. 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,
3. 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,
4. presence as immersion, sensory and psychological immersion, which can be measured by the number of connected/disconnected user's senses,

5. 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,
6. 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.

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

The main information about some virtual laboratories are highlighted below:

Virtual laboratory Walter Fendt, Germany

Website: <http://www.walter-fendt.de/html5/mde/>
<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.

1.4 Remote experiments (laboratories)

1.4.1 Remote laboratories

The idea of implementing Internet-controlled laboratories 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/Intranet.

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 industrial applications work, in which it is needed to identify the remote user and to record his activities. 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 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.

A “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 experiments 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.

1.4.2 (Real) Remote experiment

The term "Real Remote Experiment" means that we are dealing with a real physical experiment which we can actually observe and control from a distance (via a computer connected to the Internet). In comparison to a virtual experiment which is only a simulation (1.3.1).

A remote educational experiment is based on the real laboratory experiment with as a difference, that physicals or technical tasks are not made directly within the teaching process of natural science or technical subjects by students in the classroom, but only observed or in some cases controlled via PC connected to the Internet/Intranet. 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. The user follows the progress of the 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 the 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 – instead of wasting time on learning definitions there is 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 the Intelligent School Experimental System (ISES) to develop remote experiments. On the web pages of ISES (<http://www.ises.info/index.php/en/ises>) there is at disposal not only the technical support (instructions for installing hardware and optimizing system), but also the software (free demos and upgrades of the software at disposal for 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)

The following experiments can be observed or controlled via PC connected to the Internet on the ISES website and the list is continuously growing:

- ❖ Water level control,
- ❖ Meteorological station in Prague,
- ❖ Electromagnetic induction,
- ❖ Natural and driven oscillations,

- ❖ Diffraction on micro-objects,
- ❖ Solar energy conversion,
- ❖ Heisenberg uncertainty principle,
- ❖ Meteorological station in Prague,
- ❖ Magnetic field in coil axis,
- ❖ Photoelectric effect,
- ❖ Polarization of light,
- ❖ Radioactivity
- ❖ Spectra,
- ❖ Faraday phenomenon,
- ❖ Rectifier,
- ❖ VA characteristics of LED (Measurement of Planck constant).

As an example, the real remote experiment “Electromagnetic induction” was used in the draft lesson on electromagnetic induction (Figure 4).

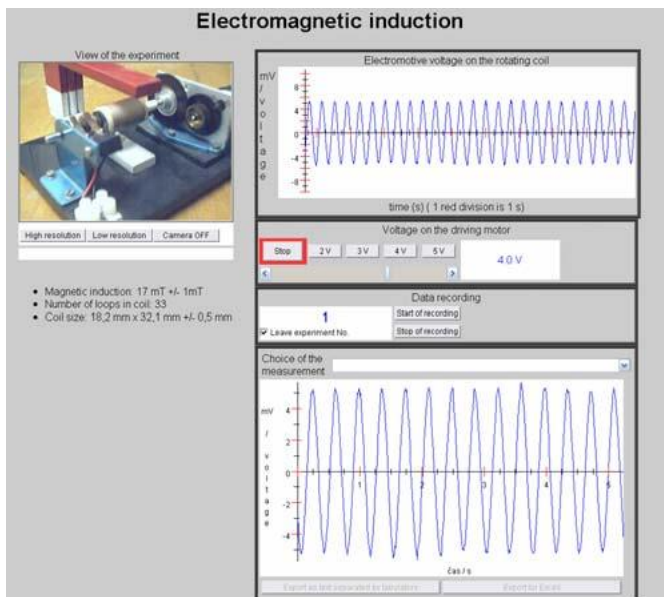


Figure 4 Remote lab on magnetic induction (Client web application – Elektromagnetic induction, 2016)

The “Electromagnetic Induction” experiment is freely available on the web page www.ises.info in four language versions (English, Slovak, Czech and Spanish).

Remote Experiments
Motivation
Introduction
Physical Background
Experiment
Assignment
Experimental Arrangement
Run Experiment

Figure 5 Entrance page of the experiments (Client web application – Elektromagnetic induction, 2016)

Each experiment of the list is built in a uniform way (Figure 5):

- ❖ Motivation page: an eye-catcher to grab the attention of the learner.
- ❖ Introduction page: short introduction of the phenomenon.
- ❖ Physical background: theory behind the phenomenon of electromagnetic induction.
- ❖ Experiment: schematic overview of the construction and setup of the experiment.
- ❖ Assignment: what should the student do to successfully complete the lab.
- ❖ Experimental arrangement: the actual construction of the experiment and the user guide
- ❖ Simulation (optional): if possible, a simulated version of the lab.
- ❖ Run experiment. The user can control the experiment over the Internet. In case of the electromagnetic induction experiment, the user is able to control the amount of voltage on the engine, which determines the speed of the rotating coil in an homogeneous magnetic field. Via the ISES-system, the induced voltage is scanned and in real time the time-dependence of the amount of induced voltage on the coil is displayed. 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 (Figure 4) is a view of actual experiment (The user can view the rotating coil of engine).

ISES is only one of many collections and methods. But as there is already several experiments developed on ISES, it has become more or less a development standard.

1.5 Comparison of hand's on, simulated and remote experiments

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 a 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) analyzed a 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. The principal source of confusion lies in the inconsistency in the 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.

In teaching practice the Comenius principle is commonly known according to which the success of education depends on how a teacher can actively involve the senses of their students in the learning process when teaching (J. A. Komenský, 1646). The merits of the Comenius principle has been verified in the 400 year history of education. In contrast to this pedagogical principle would be the full replacement of real experiments with simulated experiments. Total replacement of real experiments (practical exercises) in the education, whether remote experiments or simulations does not make sense for a number of pedagogical and educational reasons (especially in the case of teaching natural sciences and technical subjects). The unsuitability of a 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 systems of teaching. Systems 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 the application of a suitable connection or a combination of hand's on, remote and simulated experiments it 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.

The next paragraph describes a research project which searched for an answer to the impact and expectations of users and teachers of real, remote and simulated laboratories.

1.5.1 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 knowledge about the benefits of the application of real remote and

simulated experiments in the process of education by students in university study programmes. And how the experiment can increase the level of knowledge in students and to find out the benefits of using this kind of experiments in to anchor their knowledge.

The secondary goal of the research was to find out the influence of the experiments on the level of motivation and activation and the interest of students in the topics during the classroom teaching with remote and simulated experiments.

The research was done with the method of a natural pedagogical experiment. The representative sample consisted of 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 a preliminary test on cognitive knowledge, so that the groups were homogenous. The control group was 47 students and the experimental group was 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 done with the draft methodological model with the support of ICT, especially with real remote a simulated experiment. In the control group teaching was done in a traditional way: lectures with a discussion. The main topic of curriculum was the electromagnetic induction for both groups. This topic was chosen with respect to:

- ❖ Previous knowledge from secondary school,
- ❖ importance of the problem of electromagnetic induction in technical applications, in the further study and the knowledge application in professional practice,
- ❖ accessibility of the real remote experiment on the Internet,
- ❖ availability of a simulated experiment concerning the topic.

The level of students' knowledge was tested with a non-standardized didactic test of cognitive knowledge at the beginning and at the end of this natural pedagogical experiment. The durability/anchoring of knowledge (which is acquired in the school

teaching the electromagnetic induction) was tested with the same test, after changing the order of the questions. This durability test was done after time with the students both of groups.

Attitude and perception of students and the future teachers to the draft school teaching program was surveyed in a questionnaire.

The primary goal of the school teaching in the experimental group was to design the methodology of teaching with the purpose to strengthen the phase of deepening and consolidation of knowledge on a particular topic in the curriculum. The teaching was focused on the repetition of theoretical and practical knowledge.

From the perspective of the individual phases in the educational process the attention was centered on the fixation phase, which has as main objective to consolidate knowledge and practice. This is mostly done in the form of solving theoretical and practical tasks. This consolidation in the designed model of teaching was done by means of simulated experiments in combination with real remote experiments.

For this reason, the research was not focused on observing the influence of experiment in the individual phase of the school teaching unit. In our methodology, the process of education was constructed using the method of fixation (questions and answers) to support the interest of students to the particular topic, to arouse curiosity and to avoid passivity. This means that the goal of the research project was to create the methodology, with which the educator should achieve an efficient impact on deepening and consolidating the knowledge, which the students acquired in the previous study.

The significance of differences in the results of the didactic tests of knowledge, which were taken from students of both groups, was evaluated by student's two-sample test with 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 a 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. The higher level of cognitive knowledge was statistically confirmed by students in the experimental group in comparison with students in control group, which were educated in traditional way.

Through the questionnaire, focused on attitudes and perception of students, we found that students consider our methodology (based on real remote experiment in combination with simulated experiments) as attractive and suitable for teaching 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 phenomena. Students do not waste time in the 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.

Halusková (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.

Kocijančič (2009) came to the similar conclusion in his research as the other authors and he focused his research on the 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 the use of progressive methods of education supported by ICT to achieve a 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 an 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 inter-curricular relations in the school teaching.

The research project was focused on considering the suitability of the application of real remote and simulated experiments, in the university study programme of teaching vocational subjects and practical training. The results showed the importance and relevance of the application of ICT in subjects, which are not very attractive and favourite from the students' point of view.

The topic of Electromagnetic induction belongs to the topics, which students perceive as a theoretical one. They just consider it to have a high proportion of definitions and formulas that are necessary for various calculations, without deeper understanding of the basis of the physical phenomenon and its use in practical applications. Therefore, the projects' main goal was to pay attention to the ability of students to achieve a higher level of deepening and consolidation of the basis of a particular curriculum in a topic that is more theoretical than practical. The results of our group of students - future teachers of vocational subjects – showed that we achieved the targeted goals.

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 a positive influence on increasing the level of durability in acquired knowledge.

1.5.2 Remote experiments 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 orienting on physics, chemistry and biology. Nevertheless, the prevalent type of laboratories is oriented in the area of electrical and control 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-meters 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 nodes.

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).

1.5.3 Surveys on Remote experiments at Universities

Despite the fact that the popularity of applications of real remote experiments (RE) in education is increasing, their educational effectiveness is questionable. According to authors (Nedic et al, 2013) a significant part of the students does not perceive RE as real. They do not see the difference between remote real and simulated experiments, regardless of the fact that the RE provide them with real data.

Abdulwahed and Nagy (2011) draw attention to the absence of the teacher in tutorials and communication with students, resulting in the isolation of a student from the real learning environment. The cited authors regard the lack of feedback as a major disadvantage of RE.

A particular problem is raising funds to build and operate a RE. Some experiments are able to be activated automatically, regardless of the time of connection to the user (such experiments are usually from the field of electrical engineering), other need permanent human intervention in place (this is typical for chemical and technological experiments). In terms of the use of RE by particular users, the limiting

condition is the network bandwidth and the network connection speed. High-speed Internet access is necessary. Another lack of remote real experiments is unilateral sensory involvement (only sight) of users/students in working with RE in comparison to real experiments (feeling, hearing).

The first survey

To find out about the opinions of university teachers about the benefits and problems in using RE in education of environmental and technical subjects, in 2012 were questioned 44 university respondents from all continents. In this research 94 universities were asked to complete a nonstandard attitude questionnaire. Returned answers of questionnaires were 47 %. Respondents were chosen according to information from scientist magazines focused on RE and from Internet RE laboratory databases.

Questionnaire consisted of four items.

In the first item respondents identify the place where RE are used most often in education. Results show that the most frequent place of use of RE in education is traditional classroom equipped with projector, computer with Internet connection (48%), 23% of respondents identify special IT laboratory as the most frequent connection of users and 29% classified different way of connection (Figure 6).

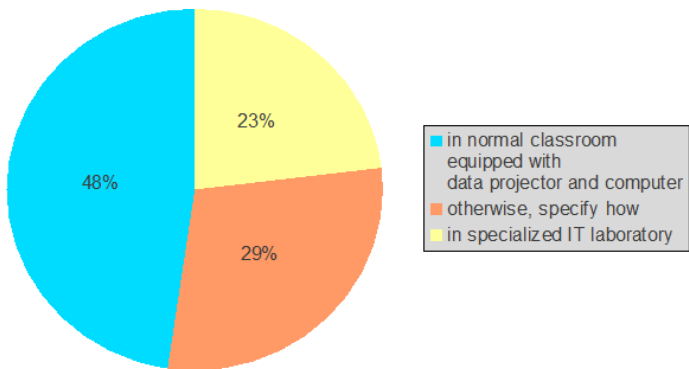


Figure 6 The place of execution/physical space for using of RE

Respondents confirm with their answers that a classroom with computer and Internet connection, projectors and recorder are suitable for teaching with RE. This technical equipment is common in mostly all education (class) rooms at universities. In the item “otherwise” respondents could write different environments than appeared in questionnaire. They usually wrote the answer “*anywhere on the Internet and from mobile devices*”.

By this response, they stressed the advantage of RE from the perspective of student. Students prefer and make the connection to RE at the time and from the place that consider the most suitable for their own learning (Figure 6).

In terms of achieving positive results of RE application in teaching, it is important to know the attitudes of respondents to the use of RE in various stages of the education cycle. It is clear from the opinions of respondents that RE are mainly used in the initial phase of teaching, to motivate students (31%). This phase of a lesson is very important for the overall success of the course, as an educator in this phase strives to stimulate and rise the interest of students in educational topics (Figure 7). This conclusion corresponds to the knowledge on the use of RE described in published research studies according to which students are first acquainted with the examined action through RE and then they implement the experiment in a (real) laboratory.

At the stage of teaching, interpretation/presentation of the subject matter it was 28 % of correspondents used RE, at the stage of revision of the subject matter 21 %. For testing the knowledge level a good 20% of teachers indicated they used RE.

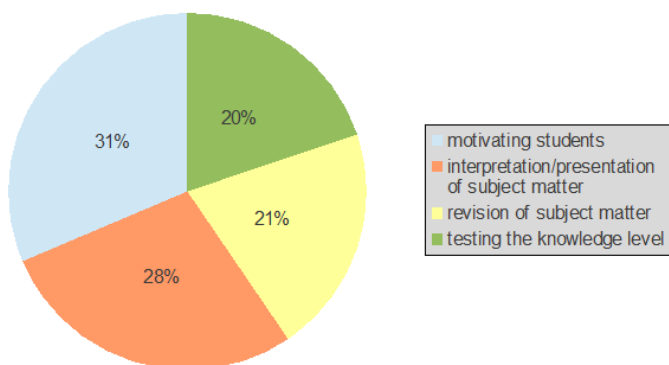


Figure 7 The frequency of use of RE by teachers in dependence on the phase of the lesson

Common attitudes of respondents to remote RE in comparing with real experiments were searched in item 3. The most frequent answer in 51 % was answer *“Remote experiment suitably complements a real experiment”*. The second most frequent answer in 26% was *“Remote experiment can fully replace a real experiment.”* 14% of respondents have different opinion than offered answers.

An interesting view was expressed by one respondent: *“... here I would calmly mark all the four options”*. Even more respondents argued in similar terms: *“Really depends. We consider them complementary in general, but some cannot be modified (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 *“it depends on the particular phenomenon”*.

An interesting view of respondents (9%), according to which *“remote experiment cannot replace a real experiment”*.

The general attitude of respondents to the remote real experiments in relation to the real experiments is expressed in Figure 8.

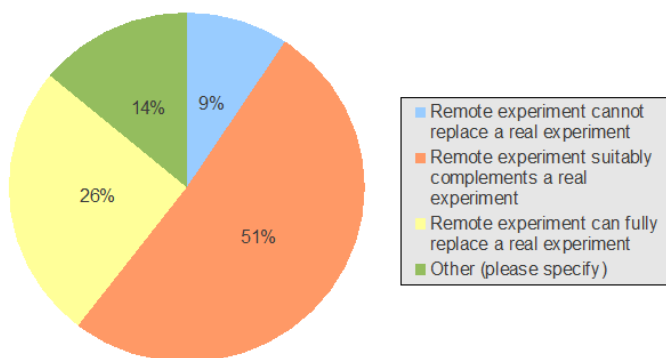


Figure 8 General attitudes of respondents to the RE

An analysis of the responses to each item of the questionnaire proved, that remote experiment has its place in education. In specific cases, it is even more appropriate than real experiment (for example, in distance education in various scientific fields, etc.). In general, however, it is not possible to compare the real and remote experiments, as in comparison, the training and educational objectives of the institution which carries out educational activities should be taken into account.

The second survey

In the year 2014 authors researched once again with a similar focus in a group of 28 respondents. The group was created from university teachers concentrated on environmental fields, technologies and engineering and ICT from east European countries. In a similar questionnaire as the previous research respondents answered to 4 items. Results of respondents' items are in graphs written for each item, respondents answered to these items:

Remote experiment is appropriate to carry out (you can select multiple items) (Figure 9):

- ❖ in normal classroom equipped with data projector and computer,
- ❖ in specialized IT laboratory.

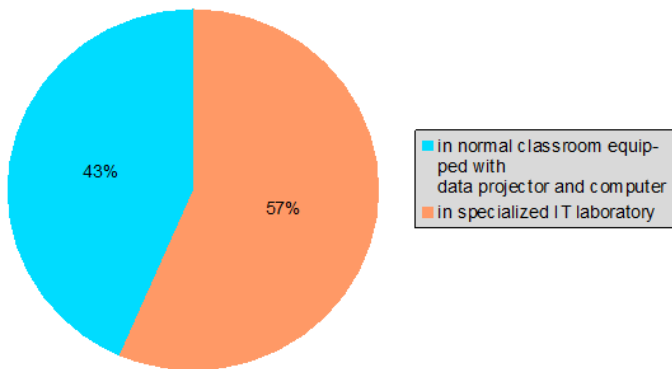


Figure 9 The place for application of RE in education

Remote experiments should be used for (you can select multiple items) (Figure 10):

- ❖ motivation of students,
- ❖ interpretation/presentation of subject matter,
- ❖ revision of subject matter,
- ❖ testing the knowledge level.

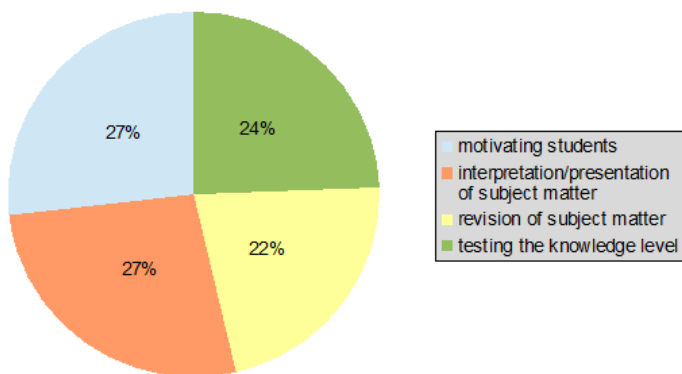


Figure 10 Application of RE in education

Remote experiment is advisable to use (you can select multiple items)(Figure 11):

- ❖ an individual assignment,

- ❖ a task for group work,
- ❖ a homework assignment.

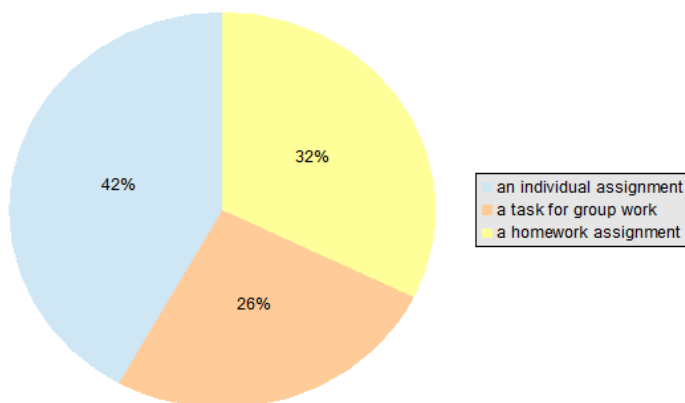


Figure 11 Suitability of using of RE in teaching

Express your approach to the use of remote experiments in education (Figure 12):

- ❖ remote experiments cannot replace a real experiment,
- ❖ remote experiments suitably complements a real experiment,
- ❖ remote experiments can fully replace a real experiment.

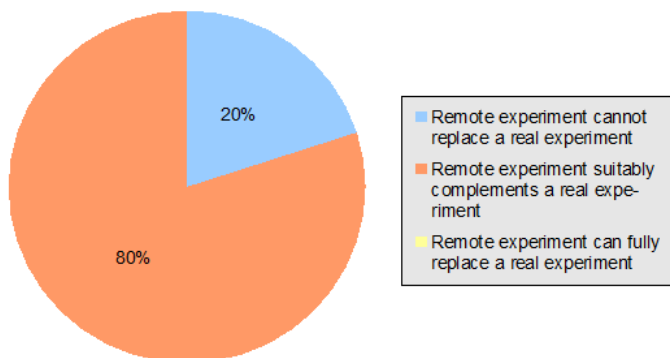


Figure 12 Relation between the real and remote experiment

Attitudes of respondents seem to be similar to the first survey. However, when we look in more detail we can find out several differences. Respondents in the first research marked traditional classrooms equipped by projector, computer with Internet connection, as the most frequent place to share remote experiments in education process. In the second place was chosen special classroom, IT laboratory. In the second research the order was opposite. In the first place was special classroom, IT laboratory and in the second place were traditional classrooms equipped by projector, computer with Internet connection. We assume that the difference in opinions is based on specifications of technical equipment in classrooms at universities and on respondents in each research. In the first research in the group were teachers who had tried remote experiments but in the second they had not such experience.

In the second item of the questionnaire we wanted to know the opinion of the respondents on a way of using remote experiments in education. Opinions of respondents in both researches were the same. They opinion is that remote experiments are most frequently used to motivate students and to facilitate the interpretation/presentation of subject matter, less to revision of subject matter and testing the knowledge level.

As the respondents we can say that all four answer possibilities in the questionnaire allow using of remote experiments by teachers in education.

Opinions of respondents are in agreement with the experience of that authors that remote experiments can be used in giving tasks to solve.

Respondents consider as the most suitable the use of remote experiments in individual tasks (an individual assignment 41,9 %), less at home (a homework assignment 32,2 %) and as the least suitable the use of remote experiment is for group works (a task for group work 25,8 %).

Interesting is the opinion of respondents about relationship of remote experiments to real experiments. In both researches they consider remote experiments as a suitable addition to real experiments (51% and 80%).

In the first research 26% of respondents shared this opinion: "Remote experiment can fully replace a real experiment" while in the second research nobody has this opinion (0%). In accordance with the information are respondents' answers to the statement: Remote experiments cannot replace a real experiment. While in the first research only 9% agreed, in the second agreed 20%.

1.6 Backgrounds of application of remote experiments in education

1.6.1 Application conditions for applying innovative teaching with remote experiments

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 20th and at the beginning of 21th century. As a consequence of quick and massive development of ICT applications, new information regarding advances in sciences, 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)

Unfortunately in the last 20 years there is an obvious decrement in the interest in the 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 trend visible also in other European countries. It is generally known that subjects like mathematics, physics or chemistry are not very much preferred and favorite among 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 information technologies much scientific knowledge is accessible to wide layers of inhabitants in the early decades of the 21st century. E-technologies and their continuous improvement 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 to teach it. The philosophy of education itself changes constantly. There is a tendency to divert from the philosophy of education orientated to the skills needed in a lifelong occupation/job. Consequently the philosophy of education takes into account the constantly changing conditions on the Labor Market. This leads to lifelong learning skills, necessary as a condition for success in a changing society.

What we know as lifelong education is more and more being emphasized nowadays. Our society starts to realize the meaning and the importance of real fulfillment of a term “knowledge society” or so called “learning society” as a condition for sustainable development. (Clough, 2002)

In the abovementioned social-economic environment there educational systems should have as a fundamental aim to provide people with an educational level that has the potential to create preconditions for future development.

In teaching technical subjects and engineering, a whole range of creative methods for solving every particular technical or technological problem should be provided. Getting familiar with this approach from the very beginning (ideally already from pre-school education onwards) creates positive predispositions for further successful understanding of more complicated technical principles during further studies and the mastering of various technically orientated activities in everyday life.

This consideration on the necessity of life-long learning leads to innovative educational methods in which a teacher is more a coach: his is a partner for students and at the same time he represents authority.

The basic role of a teacher in this model of educational processes is the activation of learners towards the subject of learning, in comparison to traditional teaching in which the teacher was the source of knowledge. Individual activities of learners will be oriented on the already mentioned attributes (abstract thinking, spatial imagination, logical thinking etc.).

1.6.2 Remote experiments and the didactic cycle

A creative approach is the substance for an innovative method of education where a teacher stands in the position of a partner while keeping his authority. For a pedagogue/teacher to reach the required educational aim, he must be able to attract the attention of learners to the particular topic. And the implementation of experiments (hands-on, remote, and simulated) in education is a 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 the creative application of remote experiments in the teaching process that would enable a pedagogue to design and create own educational experiments supported by e-technologies.

There is also a common definition of didactic demands for this type of experiments missing, which should be taken into consideration in the process of the design, construction and running of remote experiments.

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 learning outcomes 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 self study.

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

- ❖ motivational (supporting interest in learning),
- ❖ expository (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 favorite way of teaching among pedagogues worldwide and it is positively accepted by students themselves (Choi et al. 2009, Corter et al. 2007, Aburdene et al. 1991). This fact itself supports the 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 fulfill following:

- ❖ easy accessibility on the Internet,
- ❖ simple navigation on the web site of the experiment,
- ❖ easy to understand user guide for operating the experiment,
- ❖ assignments with clear definition of educational aims,
- ❖ corresponding theory to the theme of an experiment at the appropriate educational level of the 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 secured from misuse.

It is obvious that the deployment of a 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 a safe and economical functioning of the labs shall also be one of the topics of the research.

2 CONSTRUCTION OF REMOTELY CONTROLLED EXPERIMENTS (RCE)

The construction of a remotely controlled experiment should be well prepared from both pedagogical and technical point of view.

Preparing a RCE consists of following steps:

- ❖ idea, intention, topic, learning outcomes,
- ❖ pedagogical approach,
- ❖ technical solution of the experiment and its application,
- ❖ creation of educational contents and its visualization,
- ❖ innovation of technical solving and educational contents
- ❖ a long term operational ability of RE. (Kozik and Simon, 2012), (Arras et al, 2015)

2.1 Pedagogical considerations of Remote Controlled Experiments

The experiment is defined as the basic method of scientific knowledge. An experiment is used for 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. Student will understand an experiment only if he experiments himself. Therefore it is important that every student participates actively in the control and evaluation of an experiment. The ideal solution would be to make several identical experiments in parallel in groups. Students would have more space for personal practice in the implementation and control of the experiment. At the same time students could compare the achieved results to each other and analyze 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 Thornton (1999)) a didactic suitability of demonstration of the natural science and technical effects and principles in teaching. The outcome of such

teaching shows that 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 students of many schools do not have any possibility to confront their theoretical knowledge with practice. A large range of science lessons theory leads students to memorize only the knowledge. (The authors reached this conclusion on the basis of discussions with teachers of primary schools at workshops). This approach does not allow students adequately to understand the discussed topic. The result is an inability of students to apply the acquired theoretical knowledge in practice. Under the influence of this approach, students take a negative attitude to the subject which results in a reduced interest of students in the study of natural science and technical subjects. Currently a significant reduction shows in the number of students of natural science and technical subjects what is perceived as a result of the longtime school practice. (Thornton, 1999), (Aburdene et al., 1991), (Corter et al., 2007), (Kozik, 2005), (Kozik, Depesova, 2007)

One of the possibilities for solving the current situation in the teaching of science and technology in relation to the use of experiments is the use of remote control experiments. A Remote controlled experiment (RCE) is a real physical, chemical and technical experiment which is realized in a real laboratory. The difference from „traditional” real experiments is that the observer and executor of the experiment is out of the laboratory and the operation of the experiment is controlled and monitored via a computer network Internet. The design of this type of experiment requires much more time, personnel and financial costs in comparison with the traditional 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. Thornton (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
- ❖ 90% of the respondents were successful at the use of the teaching method with the support of the RCE.

Scores in favor 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 students (respondents) in comparison to 15% of the respondents educated by traditional way without experiments. According to Thornton and others (Ali and Elfesi 2004, Halusková 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 students on the research technique,
- ❖ immediate feedback,
- ❖ reduction of the time need for theoretical calculations in relation to deepening the knowledge of students.

These positive outcomes need to be considered and addressed when building a RCE.

2.2 Technical considerations for remotely controlled experiments

The idea of remote control and monitoring of remote experiment brings special technical requirements.

As a case study we look a remote laboratory built at UKF (Figure 13).

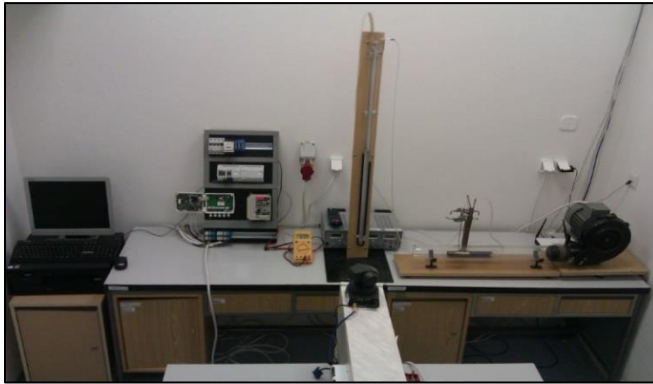


Figure 13 Remote laboratory at UKF

In the experiment is measured the fluid flow and pressure differences in a system of tubes (Figure 14).

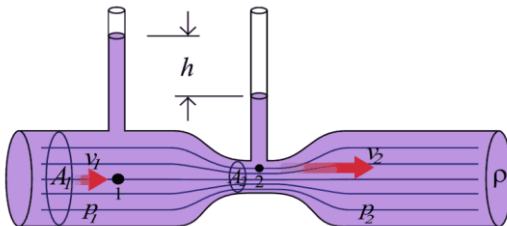


Figure 14 Pressure drop in a Venturi-system

In terms of technical requirements for the implementation, they can be divided into the following groups:

1. Technical means for the natural principle of the experiment

Technical means to carry out or demonstrate the natural or technical principle of the experiment. These 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 a remote control experiment. In this category in case of the RCE (experiment of measuring of fluid flow) these include following components:

- ❖ three-phase electric motor,
- ❖ fan,
- ❖ flow tube,
- ❖ Venturi or Pittot (Prandtl) tube,
- ❖ plastic tubes.

2. Measuring devices for physical quantities

This group of components consist in all the measuring devices for physical quantities which are involved in the experiment. For remote experiments all measuring devices should be connected to the Internet. In the case of a remotely controlled experiment is it necessary to have measuring devices which are equipped with communication ports for sending out the values of measured physical quantities into the control system of the remote experiment. Other possibilities exist in measuring devices and cameras, so that readings can be made visually by the experimenter.

In this category in case of the RCE (experiment of measuring of fluid flow) these include following components:

- ❖ manometer,
- ❖ fan-speed meter.

3. Technical means providing remote control of the experiment

The control 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.

In this category in case of the RCE (experiment of measuring of fluid flow) these include following components:

- ❖ PLC.

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 (students) can be objected 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. In this category in case of the RCE (experiment of measuring of fluid flow) these include following components:

- ❖ camera to view the experiment.

The definition of all of the technical components should be done considering cost, robustness, adaptation to the goals. To assess the usefulness of a certain component, the input of an expert is necessary. Experts in this are engineers for the mechanical construction, ICT and network specialist for the communication over the network.

For each individual RCE this needs to be considered.

2.3 Building remotely controlled experiments

The creation of a real remote experiment that fulfils demands for its reliable and safe running hand in hand with meeting methodical/pedagogical objectives is not a simple task. The challenges and requirements of this task demand for a close cooperation between different experts and specialists (Figure 15).

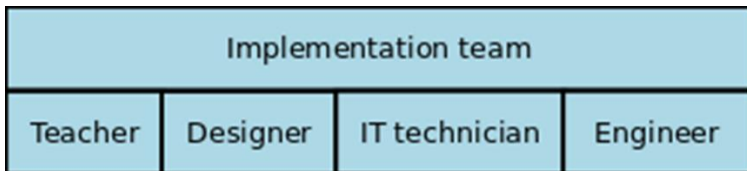


Figure 15 Implementation team of experts

The basic idea for a RCE comes from a designer – a pedagogue, who specifies a task for the experiment from the particular topic of a curriculum and defines the fundamental demands for the creation and running of the experiment from both technological and didactical point of view. These huge set of conditions and demands leads to the 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.

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

Design and application of remote experiments represent two separate troublesome areas.

The first one deals with technical solution and running of remote experiment on the side of the provider who is responsible for:

- ❖ design and construction of a remote experiment on a specific theme,
- ❖ system of management and control of the 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.

The creative approach is the fundament in an innovative form of education where a teacher stands in the position of a partner while keeping his authority. For a pedagogue/teacher to reach the required educational aim, he must be able to attract the attention of learners to

the particular topic. And the implementation of experiments (hands-on, remote, simulated) in education is the mean that enables it. (Schauer et al, 2008)

When working with RE we deal with real laboratory equipment that is perceived indirectly on the side of a user. According to (Halusková, 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. (Kozík, 2005)

In preparation of remote real experiments we see 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 (pedagogical/didactical requirements).
- ❖ The second group of requirements is formulated by the technical solution of remote experiment. Fulfillment of requirements of both groups is a prerequisite for a successful school experiment (technical requirements).

We will have a look at the designing phase of a RCE (Figure 16).

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

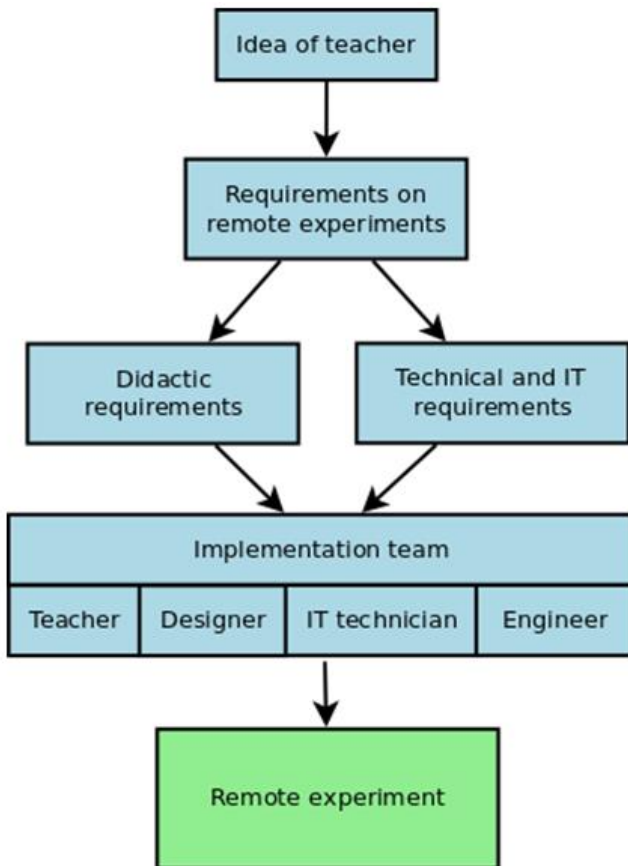


Figure 16 Structure of the designing phase for a RCE

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 (Figure 15). Therefore, we consider the 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 teachers' 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 the technological aspects of the teachers' requirements. S/he solves also the designers' 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 devices 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.

At the end, the teacher must discuss with the designer about the design of the user environment, with the engineer about the proposal of

construction and with the IT technician about remote controlling and monitoring through the computer network (Internet/Intranet).

2.3.1 Design of the remote experiment: technical interfaces

As mentioned before, the use and popularity of the RCE, conceived as a useful tool by the users (teachers/students) is dependent on the graphical representations.

Therefore, the developer of a remote real experiment must solve and pay attention to visualization and the information contents of remote experiment. These 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.

When entering the GUI (Graphical User Interface) of a RCE, it should attract the user's attention by its graphical design and gave him an interest in learning about the topic. Important is level of visualization of the experiment/phenomenon and the quality of image transmission of the experiment and its progress. Similarly, the GUI should include the theoretical background of the experiment, so that the student understands the starting points of experiment and know what its purpose is and why. The complete contents of the remote experiment environment should be simple and direct. Students should not get lost in numbers of non-essential settings.

Technical components for remote laboratories or experiments consist in experimental apparatus with sensors and endpoints, whose

signals are processed electronically in modules connected to the control and check panel. This panel provides communication between modules, sensors and computer through input-output cards of the computer.

In the development 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 selects the website of the remote experiment in his internet browser to download all the graphics to the PC and to display it 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 in some systems of remote experiments imposes constraints in terms of having to allocate to each remote experiment an own web server with its own IP address. In the case of a remote laboratory with several or further experiments, there is a need to install additional web servers with own IP addresses and control panels.

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 build on open and widely used standards. It is thus a greater chance that the laboratory will use a platform that will be available for more years in time.

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 taking images from two video-cameras, then it will require a separate (specific) software solution. Use of IP-cams instead of webcams can help to cut on custom-made software.

In designing a remote laboratory, 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.

The absence of either of both important key-persons will automatically result in poorly designed and difficult to operate labs, which will (usually) not survive for a long period of time.

2.4 Purpose-designed control systems for design remote experiments

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 over the serial ports of their systems. Such a design framework is usually very customized and purposefully designed for a specific task what causes an inefficient handling with time and effort of the designer for maintenance. The custom designed 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 requires financial resources, organization and technical knowledge of designers. From our experience we know that the operation of RCE in a market system is not sufficient to cover even the overhead costs associated with their operation. To keep the operational capability RCE's need to be subsidized. Discontinuance of the operation of several RCE is a result of lack of financial resources necessary for their operation and maintenance. (Kozik et al., 2011), (IEC online)

2.4.1 Industrial automation systems

The word „automation” is becoming one of the most frequent used words at present. 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 industrial devices and processes.

In terms of industrialization it is the next after 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) theoretically the total disappearance of men from the production process could appear. However, in practice this possibility seems to be impossible yet. (Šmějkal and Martinásková, 2007)

From the point of view of the designers it is possible to classify 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 for solving technical problems. The structural design of a remote control automation system with the use of industrial automation has become a challenge and motivation for the 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)

2.4.2 The integrated system of industrial automation

The hierarchical arrangement of the elements of industrial automation in an integrated control system is shown in the form of a pyramid with more levels (Figure 17). (PLC user guide)

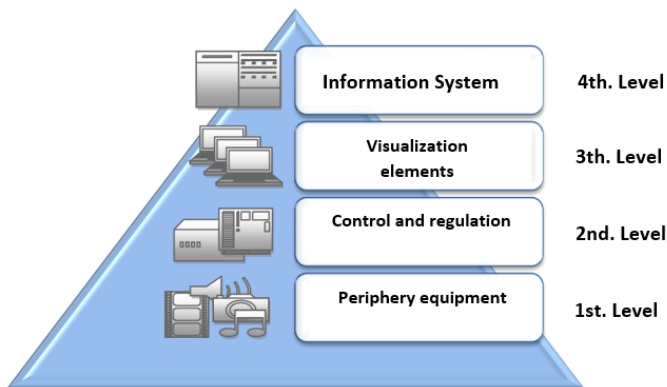


Figure 17 Levels of automation systems

From a functional principle, all automation systems show the presence of devices on the 1st and 2nd level. 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 mostly occur in more complicated control systems. In accordance with the model scheme (Figure 17), 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. (Šmějkal and Martinásková, 2005)

2.4.3 PLC - Programmable Logic Controller

The process control, in the scheme (Figure 17) 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 the working environment (such as resistance to dust or moisture) are an example of it. Another important requirement is compatibility, 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 (Figure 18). (Šmějkal and Martinásková, 2002)



Figure 18 Sample of the PLC system (PLC user guide)

PLCs are used as a solution for automation tasks with different technical difficulty levels. The strong commercialization of this type of products gives a wide range of the PLC's.

Programming of PLCs is realized in a development environment which is specific for every type of PLC. The development environment is software – executable on most computers. The finished control code is at first tested on an offline, simulated PLC system. The finished program is transferred from the 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 programs 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.

2.4.4 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. This is understandable as already in the past the PLC system – mounted in the electrical distribution system or the automation system – had to communicate with computers in the

„control centre“. These control systems were often in a different physical place.

In industrial communication systems not only communication of the PLC system with computers of the control centre are necessary, 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 environments of industrial automation. Massive arrival of the Internet meant also new challenges and opportunities in the 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 proven methods to implement remote control of the PLC systems via the Internet.

2.4.5 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 a simple PLC system is often a more expensive component than the PLC system itself. At the same time the programmer has to comply to a lot of rules in his client application which are related to communication between the PLC and the client PC.

The PLC system with an 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 euro what is an impossible barrier at designing of the RCE.

Paradoxically, the cheapest and most appropriate solution is to bring a traditional 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 other 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 player.

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)

2.4.5.1 Example of a purpose designed control system: Measurement of the Speed of Gaseous Environment

A Remote control experiment was designed to measure the speed of a gaseous environment. The experiment is run and verified by using a PLC control system.

The theoretic basis of this experiment is Bernoulli's' law for fluids:

$$\frac{1}{2}\rho v_1^2 + \rho gh_1 + p_1 = \frac{1}{2}\rho v_2^2 + \rho gh_2 + p_2 \quad (1)$$

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

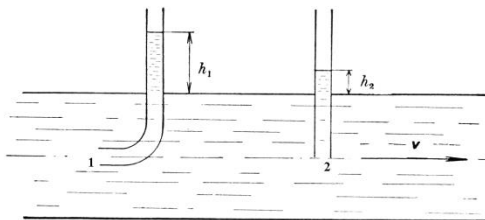


Figure 19 Venturi tube (prutoky.cz)

The measurement of the air flow velocity is done in a plexi-tube with internal diameter D in this experiment. A fan 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 20.

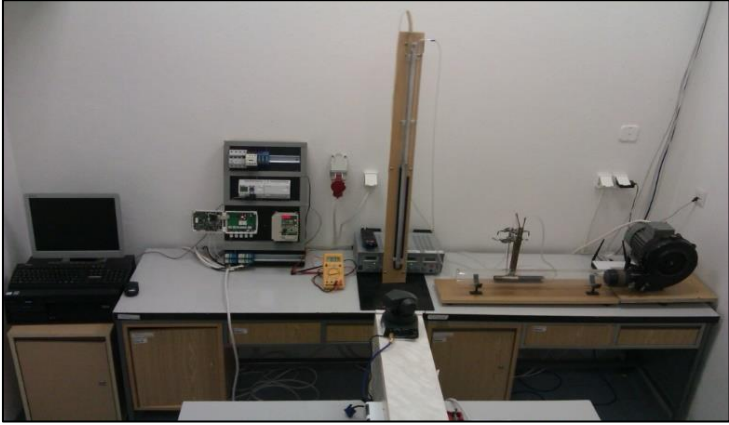


Figure 20 View of realized RCE

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

Pressures are measured by air gauges. Their values are inserted in to formula (2). If air gauges are not available then the pressure value will be calculated as the difference of height level which is shown in figure (Figure 19).

To calculate pressures we can use:

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

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

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

An industrial measurement instrument of the type KIMO CP 300 was used for the validation of the measurement in the tube and the calculated result in this experiment. Principle 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 for physical and technical applications,
- ❖ to understand procedures of physical variables measured in the experiment and to use correctly in calculations,
- ❖ to understand the procedure of validation and interpretation of measured functionalities,
- ❖ to deepen an interest of students in the creative access to solutions for physical and technical tasks,
- ❖ to motivate students towards a positive feeling towards physical and technical subjects.

The design and construction of this remote experiment generated more technical problems:

- ❖ to control and to change of the rpm of the van,
- ❖ to scan the difference of level height in U manometer and at the same time to view all parts of the remote experiment.

The functional block scheme of the Bernoulli experiment is in Figure 21.

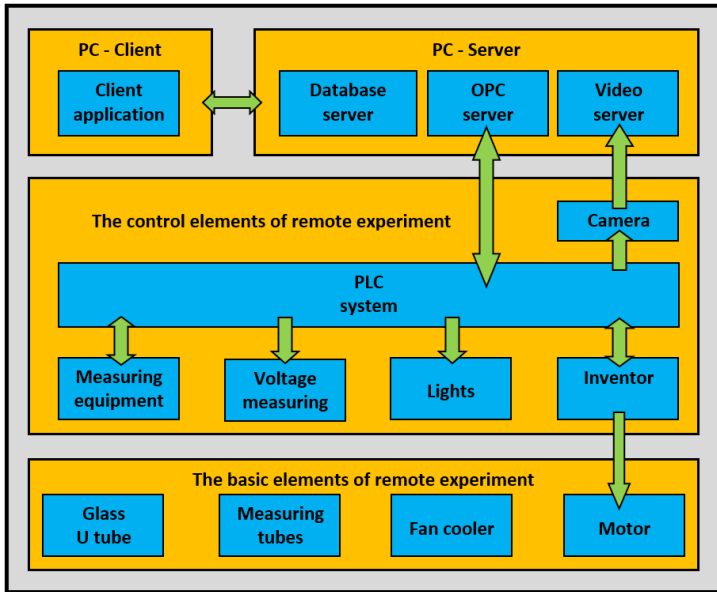


Figure 21 Blocks scheme of RCE

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

Second key aim was to find a solution for the transmission of the video images. The first trial video stream was realized by a VLC video server. Delay time of this solution was not acceptable, because the delay time was 12 seconds. Such delay time are not acceptable for remote experiments. This problem was solved by making a own video server, which was designed and programmed for this solution. Delay time of our own video server was 0.5 - 0.8 sec. which is acceptable. Such a good result was achieved by our video server, which saves the captured picture directly in a data block of RAM memory without saving it on 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.

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

2.5 Managing and maintenance of remote experiments

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 experiments installed at remote 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 a specialized maintenance technician is missing and/or if the funds used for the development and the preparation of experiments are missing, operating a remote laboratory will fail to produce the expected educational and research benefits and the remote laboratory will gradually stop working.

When designing a laboratory of remote experiments it is important to think about the 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 introduce 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 specialized 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 cannot be asked 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. The remote laboratory equipment must operate in a safe and secure environment. There the information system must be protected from malicious (software) attacks.
- ❖ Implementation and maintenance costs. The system of school financing works in such a way that it is easier to find the budget to create a new didactic laboratory than finding budget for maintenance. As a result any equipment is sure to fail at certain moment in time. Limiting access to RCE to own students and making robust laboratories can keep costs under control.
- ❖ Portability. The development of computers, operating systems and software applications are so fast that each application should be both portable and platform independent if 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 and 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.

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 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 (Figure 22).

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.

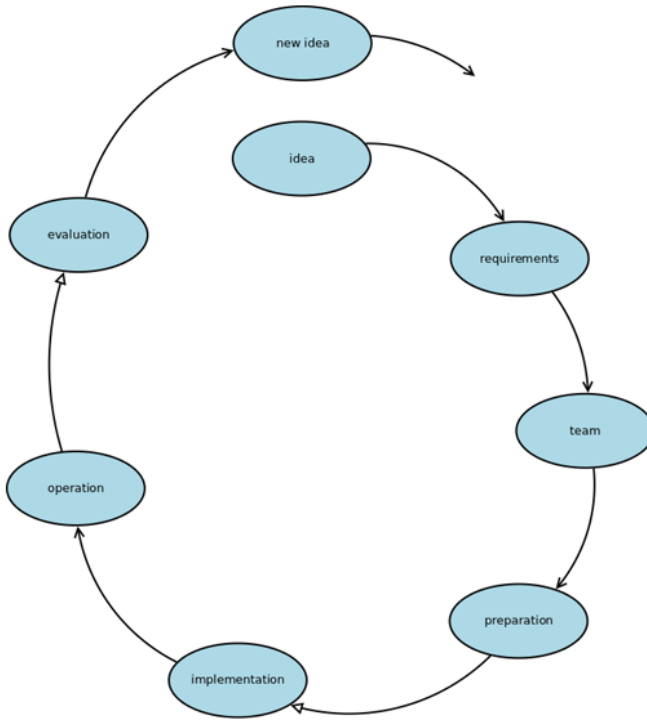


Figure 22 Live cycle of remote experiment

2.6 Security of remote experiments

As far as the computer network is concerned, a remote experiment behaves as a common network service. After the decomposition of the process of work with a remote experiment in the laboratory of remote experiments, the following elements are defined:

- ❖ client,
- ❖ data line,
- ❖ web server – portal of remote real experiments laboratories,
- ❖ web server – computer controlling experimental equipment, connected web camera,
- ❖ experimental equipment carrying out the experiment.

In remote experiments students consciously or subconsciously test (beyond) the boundary values of the experiment. Even though such behavior has a sense from the aspect of education, the issue of the equipment security must be taken into account as well. Salzmann et al. (2007) provide three levels of protection of their remote experiment entitled “inverted pendulum”. The first level consists of the experiment’s controlling software, which sets the regulator’s output to zero if the pendulum reaches the pre-defined limits. The second level is made up by mechanical switches which switch off the drive if defined limits have been exceeded. The last level comprises rubber stops placed on both ends of the pendulum.

Safety issues are also involved in education in many workplaces in the world. (Zuev et al., 2014)

The experimental equipment should be fully remotely controllable by the remote laboratory administrator. The application controlling the remote experiment must be robust, so that potential erroneous parameters of the experiment do not damage experimental equipment. The input data coming from the user must be controlled.

In addition to other requirements, Ferrero et al, (2003) lists also the following requirements for remote laboratories connected with Internet security:

- ❖ **Availability.** The time to access remote laboratory should not be limited. Students thus can carry out the experiment at a time and from a place which most suits them. The need of defined software for the access to the laboratory and processing of outputs must be strictly limited, so that a student is not forced to download and install further applications. No other costs than the costs of internet connection should be expected from students. The remote laboratory system must not be dependent on a particular platform or language. The availability may also include the robustness of the whole system, its resistance against high workload during a peak access of high number of students at the same time.

- ❖ Security. The security of remote laboratory equipment and protection of IT system against malevolent attacks must be dealt with.

A correct functioning of remote experiment requires a good management, i.e. correct and efficient application of used technologies. For the whole process it is important to have well defined plans of management, responsibility, control and evaluation. The control of a remote laboratory is a continuous process which does not end by the implementation of all necessary hardware and software components. The laboratory elements must be constantly monitored and controlled, their hardware and software elements regularly updated through security patches. This process of permanent control is in the IT referred to as configuration management.

The remote laboratories themselves may become objects of an attack. As every network service, they can also become victim of a DoS (Denial of Service) attack. To strengthen a general protection of remote laboratories, it is important to improve their security qualities on all levels.

Three of the main tasks for security issues on a remote lab need to be considered.

The first one is to prevent unauthorized access to the laboratory. A suitable authentication mechanism is the first step in achieving access control. The authentication is usually forced out by the creation of user accounts for the users who after their authentication via username and password may access the experiments. This method represents the most widespread way of authentication. A password is easily transferable and its use is relatively simple and comfortable. At the same time, there is a number of disadvantages and risks connected with its use. Nowadays passwords are considered to be a weak device in providing access. There are many reasons for that. Users mostly choose as a password various forms of their names, initials as well as names from their surroundings, dates of birth, and so on. Various studies have proved that almost a third of passwords may be stolen at the tenth attempt. A password may also be detected during when it is being

entered. Or a user simply forgets it. The basic contradiction then lies in the fact that it has to be long and complicated, difficult to guess, and, at the same time, the user must be able to remember it. Moreover, people let themselves be easily fooled and persuaded to reveal their passwords.

Secondly, since the remote laboratory is connected to the Internet, it is necessary to protect it via firewall. In general, a firewall is a device which separates the protected network from the unprotected one, and, in many cases, one protected part of the network from another unprotected part of the same network. It is thus a kind of constricting place through which all communication from and into the protected network passes. By means of firewall it is possible to force out a certain level of connection security. The sources of protected network which will be made accessible from the external network must be defined, as well as which users from which computers of the protected network may access the sources of the external network.

Thirdly, current sophisticated computer attacks require that the remote laboratory must be protected by another element – an intrusion detection system. The task of the security violation detection system is to identify, possibly in real time, an abuse, non-authorized or incorrect use of the computer system. The intrusion detection issue is becoming very important with regard to the increase in the number of Internet based systems. More systems means more potential attackers and their more difficult identification. The Intrusion Detection Systems, IDS, thus should be included into the security policy as further devices of computer security. The security policy should identify what type of IDS is necessary, where to place it, what type of attacks it should detect, and how to respond to a given attack type.

Due to these security issues and maintenance costs, we have seen a shift of availability of remote labs from the www towards intranet-networks. An intranet application is mostly protected by authentication and adequate firewalling, so that the number of dedicated tasks for the RL-constructions will be easier. Also maintenance costs of the lab drop as protection costs are shared for all intranet applications. Constant monitoring access for new users is

unnecessary, as in the intranet, all potential users is already defined. Availability of the lab for the own users is higher, as there is less users who can connect to the lab.

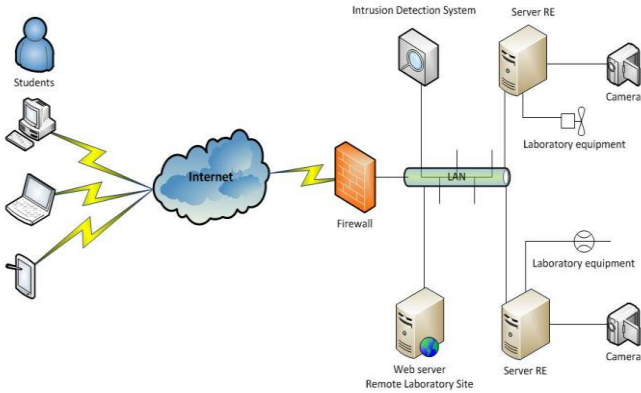


Figure 23 Typical structure of a student’s connection to the laboratory of remote experiments secured by firewall and IDS

A correct functioning of remote real experiments is critically important for their application. As Kara et al., (2011) maintain, it includes not only pedagogical problems, but technical problems and challenges as well. The maintenance and internet security of the laboratory of remote experiments may require unexpectedly great human resources and equipment. This must be taken into consideration already during the laboratory development stage. The remote laboratory manager must realize that the laboratory’s computer systems may become an object of sophisticated attacks. To protect them, it is important to:

- ❖ build a robust security management with a patch application policy,
- ❖ implement a suitable authentication mechanism,
- ❖ apply firewalls and antivirus technologies,
- ❖ apply intrusion detection technologies,

- ❖ include the assessment of security and testing into the process of the development of the system and its regular maintenance,
- ❖ identify and repair potential errors, which decreases the probability of a successful attack.

Security cost can drop if the remote lab is operated over an intranet environment, instead of opening it up to the complete www-world.

3 REMOTELY CONTROLLED EXPERIMENTS IN THE STUDY FIELD OF MECHANICS AND STRENGTH OF MATERIALS

In this chapter we specifically look at remote controlled experiments in the field of material sciences. The study field of material sciences is a field in which traditionally there is a lot of laboratory practice for testing of material properties. We checked if it would be possible to substitute real labs with remote labs in teaching engineering, to make lab-sessions more effective and more cost efficient.

3.1 Experiments in the didactical process of teaching engineering

3.1.1 What is engineering?

The didactical process of teaching engineering is a complex combination of different learning methods. This originates from the definition of an engineer, which makes an engineer a man/woman with a broad knowledge and many skills.

In 1960, the Conference of Engineering Societies of Western Europe and the United States of America defined "professional engineer" as follows:

“A professional engineer is competent by virtue of his/her fundamental education and training to apply the scientific method and outlook to the analysis and solution of engineering problems. He/she is able to assume personal responsibility for the development and application of engineering science and knowledge, notably in research, design, construction, manufacturing, superintending, and managing and in the education of the engineer. His/her work is predominantly intellectual and varied and not of a routine mental or physical character. It requires the exercise of original thought and judgment and the ability to supervise the technical and administrative work of others. His/her education will have been such as to make him/her capable of closely and continuously following progress in his/her branch of engineering science by consulting newly published works on a worldwide basis, assimilating such information and applying it independently. He/she is thus placed in a position to make contributions to the development of

engineering science or its applications. His/her education and training will have been such that he/she will have acquired a broad and general appreciation of the engineering sciences as well as thorough insight into the special features of his/her own branch. In due time he/she will be able to give authoritative technical advice and to assume responsibility for the direction of important tasks in his/her branch.”

Looking at the definition it is clear that an engineer needs a broad knowledge of different topics, but also that he needs a solid base of technical and practical skills.

This broad definition clearly has an impact on the teaching of engineers. Four categories of competences/learning outcomes for engineers were defined (Christensen, et al.):

- ❖ Cognitive learning which is often elucidated as the integration of theory with practice.
- ❖ Inquiry methodology which includes hypothesis forming, experimental design and methodology and evaluation of results.
- ❖ Vocational aims which include awareness of current practice and the inculcation of professional ethics.
- ❖ The development of personal skills such as communications, report writing and team working skills.

This leads to the broad learning outcomes for engineering studies. These outcomes can be found in most engineering degrees. (Sell & Rüttemann, 2014), (UK center for Materials Education, 2011)

- ❖ Ability to apply knowledge of STEM (science, technology, engineering and mathematics).
- ❖ Ability to design and conduct experiments, as well as to analyze and interpret data.
- ❖ Ability to design a system, component, or process to meet desired needs.
- ❖ Ability to function on multi-disciplinary teams.
- ❖ Ability to identify, formulate and solve engineering problems.
- ❖ Understanding of professional and ethical responsibility.

- ❖ Ability to communicate effectively.
- ❖ Broad education is necessary to understand the impact of engineering solutions in a global and societal context.
- ❖ Recognition of the need for, and an ability to engage in life-long learning.
- ❖ Knowledge of contemporary issues.

Implications of these learning outcomes on the learning and teaching system are obvious: engineering studies are both strongly embedded in society on the one hand, and very strongly driven by (evolving) technology on the other. The necessity for engineering students to be able to design and conduct experiments is an important factor to bear in mind in constructing curricula and learning materials.

From this is deduced the necessity of incorporating labs and practice in the engineering curricula.

When looking at different engineering degrees in different universities and different countries, we notice a clear presence of labs being incorporated in the degree curricula. This is more or less independent of whether it is undergraduate or graduate degrees, or from the exact field of engineering study.

The lab is the playground where engineers learn about physical phenomena and get the practical skills they will need in their professional career.

3.1.2 Labs and experimenting in engineering degrees

Labs and experimenting in engineering degrees serve different purposes. This is reflected in the different kinds of lab-setups in education. There are three kinds of laboratories in education: development, research, and educational labs.

- ❖ Instructional laboratory are conceived to practice some practical and technical skills which engineers will need in their future career. Clearly designed learning objectives are needed in an instructional lab to reach considerable benefit.

- ❖ The development laboratory. Students visit the development lab to find experimental data to guide them in understanding the theory. This kind of lab is used to answer questions about natural phenomena and check theory. The second reason to use a development lab is to determine if a design/process performs as intended. Measurements of performance are compared to specifications and if not compliant, experimenting will show how changes need to be made.
- ❖ Research laboratories are used to seek knowledge that can be generalized often without any specific use in mind. The output of a research laboratory is generally an addition to the overall knowledge that we have of the world, be it natural or human made.

Where in undergraduate engineering studies focus is mostly on instructional and development labs, research labs are preferred for graduate studies.

When constructing new labs – real or remote – it is clear that careful thinking about the goal and type of the lab needs to be considered.

Laboratory practice is important to engineering and science students, both for studying theoretical courses, as well as to prepare them for their professional career (Arras, 2011).

Specifically for studying effectively laboratory activities should:

- ❖ Enable students to explicate and understand the questions they are investigating.
- ❖ Enable students to decide what data is (ir) relevant.
- ❖ Learn students the limitations of measurements, sampling and data.
- ❖ Help students to make connections between science concepts and everyday phenomena.
- ❖ Help students to apply mathematical reasoning and techniques to problems.

These ideas make it clear that the laboratory setup should give direction to students, and raise questions; both should not be an automated black box that will calculate all results, nor just present all the solutions. This is important in understanding the setup of the remote laboratory.

3.1.3 Learning outcomes and goals of labs in teaching/learning

The general described goals for laboratory work are (Baillie & Hazel, 2003):

- ❖ Learning scientific information and concepts;
- ❖ Participating in the construction of scientific knowledge, understanding the interplay of theory and methodology;
- ❖ Understanding the processes of scientific enquiry and appreciating and emulating the role of scientists and engineers in enquiry: Observing and measuring; Seeing a problem and seeking ways to solve it; Interpreting data and formulating generalizations; Building, testing and revising a theoretical model.
- ❖ Developing imagination and creativity;
- ❖ Learning manipulative and technical skills and the use of equipment;
- ❖ Developing relevant professional values, attitudes, and interests;
- ❖ Developing an orientation to the social, historical and philosophical aspects of science and engineering;
- ❖ Appreciating the application of knowledge and methods;
- ❖ Developing literature skills;
- ❖ Learning how to communicate verbally and orally;
- ❖ Learning to work co-operatively with colleagues, developing teamwork;
- ❖ Developing scientific or engineering attitudes.

It is clear what the labs are and what the big goals for laboratory work are, but it is more difficult to get the objectives explicated.

The Sloan Foundation, a charitable foundation that has gives support to the development of distance-learning systems, particularly in higher education, organized colloquy in the summer of 2002 with a group of experienced engineering educators to determine objectives for evaluating the efficacy engineering laboratory programs. The question raised in the colloquy was “What are the fundamental objectives of engineering instructional laboratories?” independent of the method of delivery (physical, distant labs). The colloquy converged on a list of thirteen objectives, each consisting of a one-or two-word title to provide easy reference and a brief explanatory statement to help clarify the meaning. The objectives were written using the generally accepted style of using a verb to specify the action that the student should be able to perform as a result of the laboratory experience. (Feisel & Peterson, 2002), (Peterson & Feisel, 2002)

The following objectives resulted from the colloquy:

All objectives start with the following: “By completing the laboratories in the engineering undergraduate curriculum, you will be able to....”

- ❖ Objective 1: Instrumentation.
 - Apply appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities.
- ❖ Objective 2: Models.
 - Identify the strengths and limitations of theoretical models as predictors of real-world behaviors. This may include evaluating whether a theory adequately describes a physical event and establishing or validating a relationship between measured data and underlying physical principles.
- ❖ Objective 3: Experiment.
 - Devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the resulting data to characterize an engineering material, component, or system.

- ❖ Objective 4: Data Analysis.
 - Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions.
- ❖ Objective 5: Design.
 - Design, build, or assemble a part, product, or system, including using specific methodologies, equipment, or materials; meeting client requirements; developing system specifications from requirements; and testing and debugging a prototype, system, or process using appropriate tools to satisfy requirements.
- ❖ Objective 6: Learn from Failure.
 - Identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process, or design, and then re-engineer effective solutions.
- ❖ Objective 7: Creativity.
 - Demonstrate appropriate levels of independent thought, creativity, and capability in real-world problem solving.
- ❖ Objective 8: Psychomotor.
 - Demonstrate competence in selection, modification, and operation of appropriate engineering tools and resources.
- ❖ Objective 9: Safety.
 - Identify health, safety, and environmental issues related to technological processes and activities, and deal with them responsibly.
- ❖ Objective 10: Communication.
 - Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports.
- ❖ Objective 11: Teamwork.
 - Work effectively in teams, including structure individual and joint accountability; assign roles, responsibilities, and tasks; monitor progress; meet deadlines; and integrate individual contributions into a final deliverable.

- ❖ Objective 12: Ethics in the Laboratory.
 - Behave with highest ethical standards, including reporting information objectively and interacting with integrity.
- ❖ Objective 13: Sensory Awareness.
 - Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

Independent of the way of delivering the lab (physical, virtual or remote), any laboratory constructed and used in teaching engineering will need to address several of these learning outcomes/objectives.

In this case we consider the use of remote labs, operated without any staff interference. This choice of lab offers a number of advantages and disadvantages.

The pros of remote labs have been repeatedly described:

- ❖ 24/7 availability.
- ❖ Economical setup of remote labs in comparison to real labs: not only is the cost of the lab lower – due to lower staff cost, smaller equipment – but also indirect costs are small. A remote lab can be set up in any low cost environment, where physical labs tend to be big and need to be installed in expensive classroom environments.
- ❖ Possibilities for students to repeat the experiment many times, which helps their learning process to understand the phenomena.
- ❖ Its advantage to represent the reality. As a remote lab is a real lab it looks and feels like the real lab, in comparison to simulations.

However – remote labs do not only offer benefits.

Some of the major contras towards remote/virtual labs:

- ❖ Difficult to setup from the technical point of view.
- ❖ Rigid setup: except for some parameter changes, users/students can hardly change anything in the setup of the lab.

- ❖ Students lack real connection to the lab: some senses (smell, sound, feeling) are not challenged.
- ❖ Dependent on communication over the internet/intranet which is not always stable and subject to many changes.

Bearing the benefits and advantages in mind and considering the amount of effort to construct a real remote lab, it is clear that the construction of such a lab should be well planned from both the didactical and the technical side.

As important as the good technical functioning of the lab is the definition of the learning outcomes and instructional goals of the lab.

It is also clear that remote labs come closer to development and research labs than to instruction labs, since only a limited amount of previously defined parameters can be changed.

3.2 Experiments in the didactical process of teaching engineering

The basic conditions for setting up a mechanical experiment can be split in two main areas: the pedagogical requirements and the technical requirements.

3.2.1 Pedagogical considerations

Any lab – including remote labs - should offer enough possibilities for students to experiment and offer measurable learning outcomes, associated with experimenting. In other words, care should be taken that the remote lab is more than a demonstration, but a real experiment – although controlled from a distance.

In the real experiment outcome isn't guaranteed, so students need to reflect critically on the concept of the experiment, the variables and the observations. Especially for university students therefore, the (remote) lab cannot be a black-box showing results only. The description and functioning (and resulting measurements) of the remote lab should be comparable to what students experience in a real physical lab, as is confirmed by other authors. (Ferrero et al. 2003)

Furthermore, the lab should come close to (as many as possible) of the outcomes for laboratory work (see 3.1.3).

Finally also the theme of evaluation will need to be considered when using a remote laboratory in the teaching/learning process. For obvious reasons (security, fraud) evaluation on the spot in a remote lab is impossible. Careful definition of what the teacher wants to have evaluated must be part of the plan of construction.

The didactical truth in *“If you don’t know where you want to go, you won’t know which road to take and you won’t know if you have arrived.”* is that it needs to be clear from the start of the educational process what you want to achieve with a course/lab. If not it makes no sense to conceive and build experiments (in this case). Recent history has proven that many remote labs were just build for the sake of proving that it can be build, not for use in education.

Also important to mark out is that remote labs only will not solve all didactical problems. To achieve all learning goals for engineers (see 3.1.3) a mix of hands-on labs (physical real labs) and remote labs is an ideal. All other didactic means besides classroom teaching are an enrichment to the learning process, and each build the knowledge and cognition of the student. This was also recognized by other authors.

We want to state that deployment of remote labs in education does not automatically mean total exclusion of real experiments from the teaching practice. Ideally, the remote experiment should be combined with the real experiments. (Kozik, Simon, Kuna, 2014)

The focus in (remote) mechanical experiments on learning outcomes will be:

- ❖ Objective 2: Models.
 - Identify the strengths and limitations of theoretical models as predictors of real-world behaviors. Validating a relationship between measured data and underlying physical principles.
- ❖ Objective 3: Experiment.

- Devise an experimental approach, specify appropriate procedures, implement these procedures, and interpret the resulting data to characterize an engineering material, component, or system.
- ❖ Objective 4: Data Analysis.
 - Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions.
- ❖ Objective 10: Communication.
 - Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports.
- ❖ Objective 13: Sensory Awareness.
 - Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

The other objectives of the reference list are not applicable in the case of the remote lab because:

- ❖ Some of the objectives (1: Instrumentation, 5: design, 6: Learn from Failure, 7: Creativity, 8: Psychomotor, 9: Safety) are inherent to the lab construction and not changeable by the student/user: safety, design of the experimental setup, use of different techniques
- ❖ Some of the objectives (11: Teamwork, 12: Ethics in the Laboratory) are difficult or not controllable as the users or not under supervision of a teacher when using the lab.
- ❖ Some of the objectives (13: Sensory Awareness) are only partially applicable, as students/users are not physically close to the experiment.
- ❖ Transferable objectives (10: Communication, 11: Teamwork) can be implemented especially when looking for methods of evaluation of the (remote) lab work.

The conclusion is that when planning/building a remote lab, the pedagogical plan needs to be clearly defined first through the definition of the desired (learning) outcomes, before tackling the technical design and connected problems.

A second conclusion is that a remote lab cannot just exist on its own, but needs to be embedded in a learning environment which makes the remote lab blend in with the complete learning process of the student. This often means the construction of an electronic learning environment supporting the remote lab as part of a complete course on a subject.

A remotely controlled laboratory environment embedded in an hypertext learning environment will enable:

- ❖ Students to study the learning content on the phenomena first in the hypertext pages.
- ❖ Be able to experiment on the remote laboratory. Since it is not a simulation, but a real physical laboratory setup that student will control the motivation of students and learning effects are expected to be high.
- ❖ Students to study at their own pace and time. Due to the availability of the laboratory – day and night, seven days out of seven – students can plan their activities in an easy way. From the organizational point of view, care should be taken, when constructing the remote laboratory that tools for blocking time slots are available.

Care should be taken, as indicated in research (Shapiro, 2008), (Cagiltay et. al, 2011) to:

- ❖ Implement systems (scaffolding) that overcome the absence of teaching staff to help the students.
- ❖ Limit the amount of just reading on the internet based platform, but make optimal use of multimedia contents to motivate students and to keep their concentration and attention to the laboratory.

- ❖ Structure the use of the laboratory very well. Not only provide effective manual for the laboratory, but also clearly define tasks and assignments that clarify the use and need of the laboratory.

From the didactics side, the most important thought to bear in mind is that for a good and deep learning process, the teacher must be able to get the attention of the student for a particular topic, without forgetting the global context of the topic in the complete course. The use of exercises and laboratory experiments (physical, virtual or remote laboratories) is an interesting didactic means to fulfill this goal of teaching.

3.2.1 Technical requirements

As a remote lab has the same goals as a physical lab, many of the physical lab problems concerning mechanical experiments reappear. Maintenance, mechanical and physical safety procedures, possibly destructive testing of specimen, big (and expensive) hardware to name some of the problems.

This is also the reason that there is few remote labs around on the internet which are on mechanical topics, with mechanical hardware.

When selecting an experiment for a remote lab we need to take all of this in consideration.

- ❖ Mechanical experiments in which there is destructive testing – which means constant replacement of parts in the lab – are not a good idea, as it limits the up-time of the lab. And it requires human intervention all the time.
- ❖ Using big hardware in a remote lab is costly: so scaling down to smaller sizes is required, but the correct relation and scaling with the real experiment needs to be well guarded. For example anything concerned mechanical stresses is related to the square to linear dimensions. Big hardware means also bigger energy costs, which will be difficult to predict if the lab is available for many users.

- ❖ In comparison to the majority of remote labs which is purely electronic, mechanical installations demand for extra (hardware) interfaces to connect to the internet. These extras complicate the construction and exploitation of the remote lab. This means putting electronic sensors and measurement tools on the experiments which can be read in the computerized environment.
- ❖ Visualization is very important in remote lab, as it is the only sense (sight) which is easy to address. Care should be taken that the experiment can be caught on video to show the user. This makes it difficult to do experiments inside a (small) closed environment. Visualization also means camera's, which will slow down the userinterface.
- ❖ Furthermore mechanical installations are subject to (more) maintenance and more wear than electronic components. The technical solution of the remote experiments needs to be robust and easy to maintain, so that it can serve its' role as an experiment which is available at any time.

For the technical requirements of the user interface for remote laboratory solution, we need to look at arguments put forward by numerous authors (Cagiltay et. al. 2011) (Kozík, Šimon, 2012):

- ❖ user friendliness,
- ❖ simple and clear navigation for the user,
- ❖ clearly defined assignment and tasks of experiments,
- ❖ theoretical background of the experiment,
- ❖ motivation for students to be creative.

3.3 Case study: e-learning environment CALM (Computer Aided Learning Module)

3.3.1 Introduction

In this section we will discuss the e-learning structure CALM (Computer Aided Learning Module) on material sciences at KU Leuven (Belgium) and a remote lab for material sciences which it is embedded in it.

(This learning environment and labs are currently not online anymore, but only available on the intranet of the department.)

After explaining the setup of the CALM and the navigation, in the next chapter (see 3.3.2) we will describe in detail the remote lab and virtual labs embedded in the CALM.

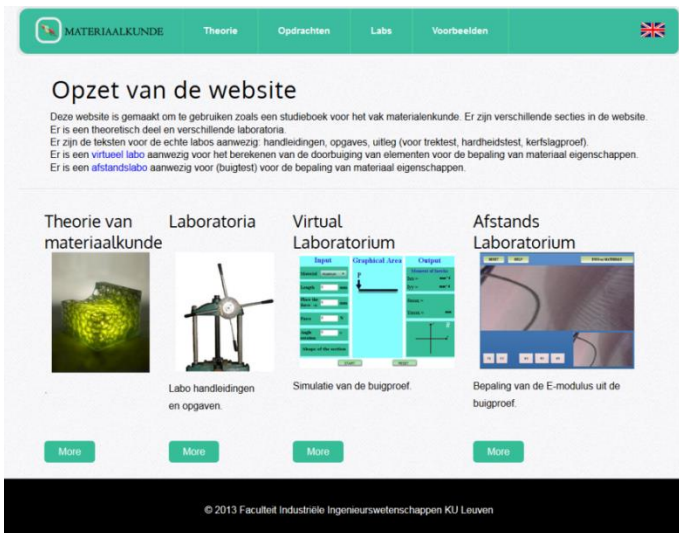


Figure 24 CALM-e-learning environment

This e-learning environment and labs are aimed to be used with second year bachelor engineering students of the faculty of engineering technology at technology campus de Nayer of KU Leuven (Belgium). These second year students have a course on “Material sciences” for 4ECTS, in which they study the basics of material sciences.

The “Material sciences” consist of:

- ❖ Lectures: on the theory of material sciences.
- ❖ Laboratory sessions to explain certain phenomena and to do testing on material properties. These laboratories traditional tensile testing, notch testing, bending testing, hardness testing.

From the past we know that students like doing the experiments, but that due to the cost factor in apparatus and man power, it is impossible to have students doing individual experiments. This setback needed a solution.

The setup of our approach in materials teaching is a blended learning approach. There is an hypertext supported learning environment (CALM = Computer Aided Learning Module) which explains the theoretical basis of material sciences, provides students will all documents concerning laboratory sessions and assignments, shows examples of phenomena, and links to literature on the subject.

The theory on material sciences itself is then supported with real physical lab sessions, virtual laboratories to let students experiment on the phenomena in a extensive way, and remote laboratories used by students to check the theory with real data and to give the feeling of connection to reality.

The CALM also contains instructions, assignments and help for the real life material tests in the lab. (Including tensile testing, hardness tests, microscopy). As such the e-learning part enables students to study the course in one clearly defined manner: the look and feel of classroom teaching is the same as the look and feel of the self-study part. This increases the efficiency of the self learning.

The structure of the CALM can be found in (Figure 25).

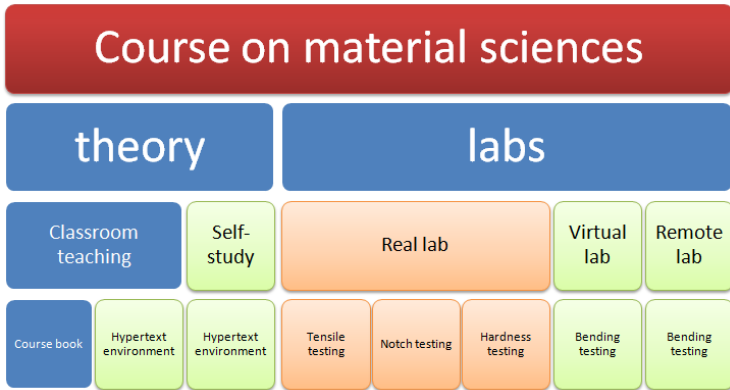


Figure 25 Structure of the course on material science, integrated in the CALM

There is 2 major parts:

- ❖ The theoretical part is used in the classroom teaching and for self-study.
- ❖ The lab part is used to do the lab assignments.

In the lab part is situated the work processes for the different lab assignments and the distant laboratories. We provide virtual labs and remote labs on the same phenomena. As such students can find theoretical values and values from real (if not remote) experiments to compare.

The remote laboratory is an automated real laboratory (experiment) in which students can experiment themselves to find out about the laws of nature of other phenomena. The access to the laboratory is over the internet, with no need for manual interference. The – now present – remote lab is an experiment with a 2-point bending test.

The virtual laboratory is a simulation of a laboratory in which students can experiment with simulated experiments. In the – now present – virtual laboratory, student can experiment with a 2-point bending test.

Assessment of the students is made dependent on the students' role. If student/experimenter is a regular student, evaluation is done based on the reports they turn in on their assignments and by means of a formal exam. The hypertext supported method for them is a way of studying. If student/experimenter is an interested knowledge seeker, he she will be able to use to hypertext supported materials to broaden his knowledge, without any formal evaluation.

3.3.2 Construction of the CALM

The construction of the CALM – and the distant (virtual and remote labs) was a long process and requested a multi-disciplinary approach. From dividing the design and construction in work packages it was clear that many specialists needed to be involved.

Besides the “topic input” which was available – as the course on material sciences existed – all other tasks needed to be defined and thought over.

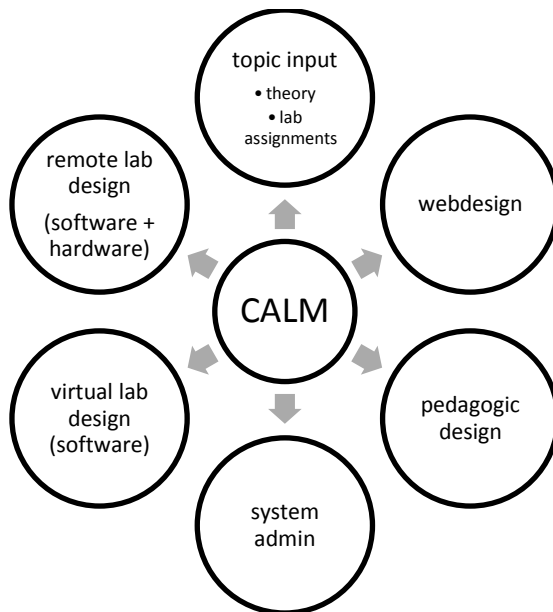


Figure 26 Multi-disciplinary approach

The different tasks required a multi-disciplinary approach:

- ❖ Topic input: this is the task of collecting all necessary academic and scientifically information to put in the e-learning environment. Besides the theoretical content, exercises and lab assignments are structured in this task.
- ❖ The pedagogical design of the e-learning environment covers things like choice of learning outcomes, choice of methods, learning scaffolding, evaluation and assessment. Bearing in mind the four phases of knowledge transfer to students (motivation, the exposure phase, fixation of acquired knowledge and finally evaluation or assessment of knowledge level) it is clear that the pedagogical plan deserves a lot of attention.
- ❖ Web-design: after the definition of the content and the pedagogical approach, the web-design specialists will be able to make the system. Boundary conditions is that it should be appealing to students to motivate and stimulate their learning, and that – where ever possible – it should be technically easy and easily adaptable to new content.
- ❖ The system admin task is to implement the system either on the internet or intranet. Besides the technical (hardware) part of an e-learning system, system admin is also responsible for securing and controlling the system.
- ❖ Design of remote and virtual labs: these subtasks themselves have the same clustering of in a multi-disciplinary approach as the e-learning system with on top:
 - The design of the lab hardware.
 - The design and implementation of sensors and measurements.
 - Digitalization of lab outputs.

This approach brings together a team of specialists, ranging from teachers, over programmers to mechanical and electronic engineers. It is clear that only a joined effort will lead to success.

3.3.3 Navigation in the CALM (Computer Aided Learning Module)

The CALM is constructed with double navigation over the top tabs and through the visualized chapters on the main page.

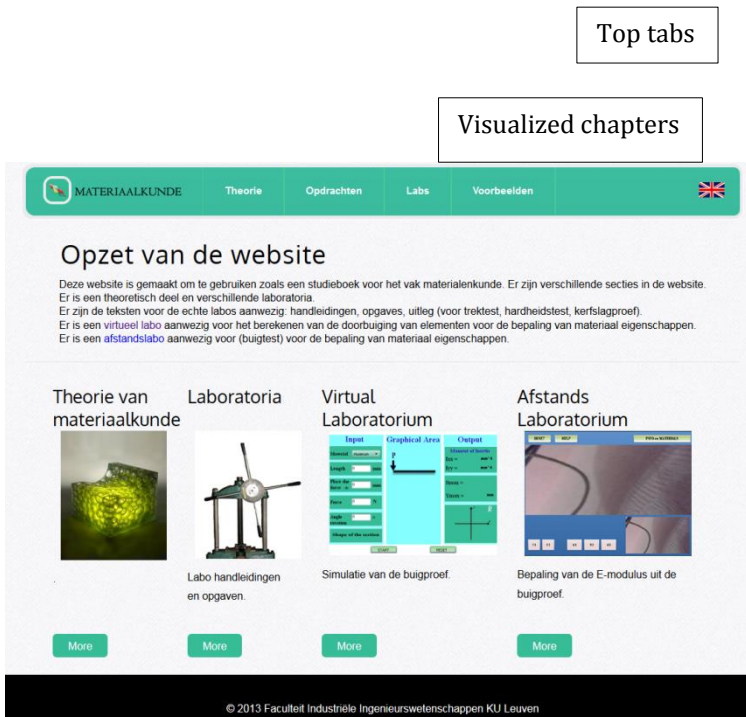


Figure 27 CALM home page

Top tabs:

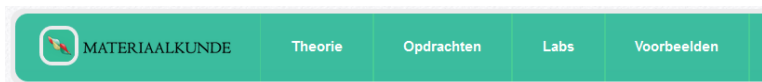


Figure 28 Top tabs

These top tabs contain five clickable items:

- ❖ “Materiaalkunde”: return to the home page of the CALM

- ❖ “Theorie”: section containing the theory about material sciences
- ❖ “Opdrachten”: section describing the assignment for students including the links to the lab-assignments and lab-manuals.
- ❖ “Labs”: section containing description of all labs (physical labs, virtual and remote lab) students have to take. All lab manuals are there and assignments for the lab sessions.
- ❖ “Voorbeelden”: Section containing examples and slides of the lectures off the course on material sciences.

Visualized chapters:

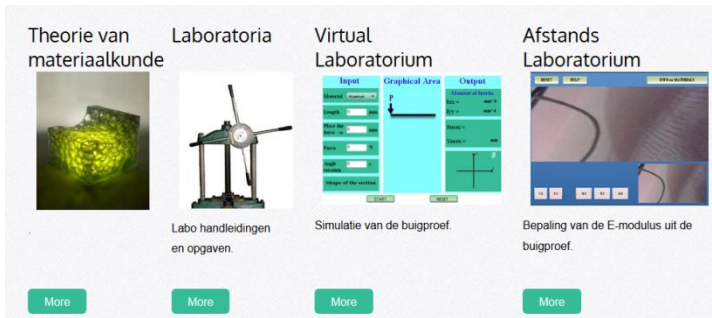


Figure 29 Visualized chapters

The visualization is another method of navigating:

- ❖ “Theorie van Materiaalkunde”: section containing the theory about material sciences
- ❖ “Laboratoria”: section containing description of all labs (physical labs, virtual and remote lab) students have to take. All lab manuals are there and assignments for the lab sessions.
- ❖ “Virtual Laboratorium”: shortcut to the virtual lab (simulation) for the calculation of bending in cantilever beams (2-point bending).
- ❖ “Afstandslaboratorium”: shortcut to the remote lab.

The sections Virtual and Remote lab are separate links, as in future there will be more virtual and remote labs available.

Both the images and the more buttons are clickable to navigate easily and from different places through the materials in the CALM.



Figure 30 CALM navigation

In the next paragraphs we describe in more detail the different sections of the CALM.

3.3.4 Theory section

The theory section of the CALM contains course book materials to explain about material sciences. Navigation is with a left menu bar, linking to all different chapters in the course.

Materiaalkunde

- > Theorie
 - 0. Voorwoord
 - 1. Inleiding tot het mechanisch gedrag van materialen
 - 2. Het statisch gedrag van materialen
 - 3. Het mechanisch gedrag van de verschillende materiaalklassen
 - 4. Het beproeven van het statisch gedrag van materialen
 - 5. Faalvormen
 - 6. De opbouw van een atoom en atoomafhankelijke eigenschappen

De opbouw van een atoom en atoomafhankelijke eigenschappen

6.1 De opbouw van een materiaal.

De opbouw of structuur van een materiaal is hiërarchisch en kan op verschillende schalen (Figuur 6.1) bekeken worden; zo maakt men onderscheid tussen:

- ✓ **subatomaire** schaal, die gedrag en opbouw van de elementaire deeltjes van een atoom beschrijft. De opbouw en de eigenschappen worden onderzocht in de vastestof fysica en is reeds van belang voor een aantal fysische eigenschappen, zoals elektrisch en magnetisch gedrag.



7

atomaire structuur



6

microstructuur



2

macrostructuur

Figure 31 CALM: main navigation in theory section

All chapters contain text, pictures and examples.

The CALM contents is similar to the physical course book available to the students to give the same look and feel.

3.3.5 “Opdrachten” section

The “opdrachten” section contains the assignments and assignments for the different lab sessions.

At this moment it is just another entry to the labs. In future this section will contain other assignments for exercises etcetera too.



Figure 32 "Opdrachten" or assignments section

3.3.6 Labs (laboratory) section

In the lab section is described all lab tests to be taken by students.

The section links to the physical labs, to the virtual labs and to the remote labs: structure of the links is not to an individual lab session but to a lab-test which needs to be taken.

The different lab test which needs to be taken:

- ❖ “Trekproef”: tensile test (physical lab, because it is destructive testing)

- ❖ “Hardheidsproef”: hardness test (physical lab, because it is destructive testing)
- ❖ “Kerfslagproef”: notch test (physical lab, because it is destructive testing)
- ❖ “Buigproef”: bending test, either physical (3-point), either remote or virtual (2-point) bending test.

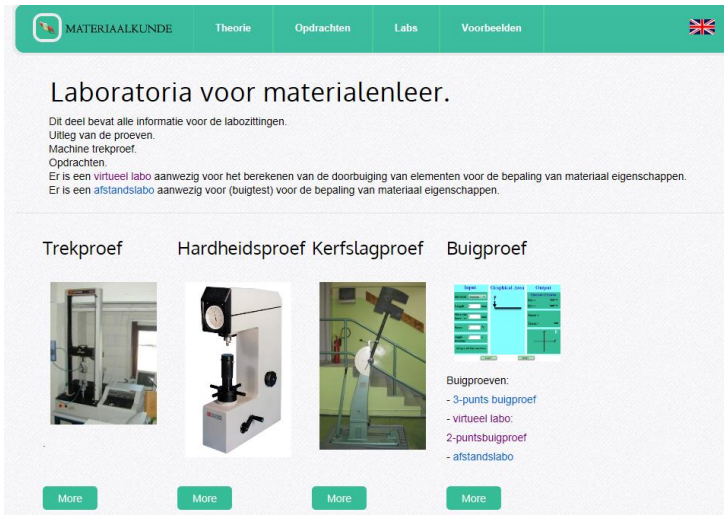


Figure 33 Lab section of CALM

After selecting the required lab-test, left menu navigation links to different methods of measuring and to assignment of the measuring.

As an example underneath we look at the hardness test.

Each lab/test section contains a theoretical explanation and background of the test (see Figure 34).

Measuring hardness of metals according to Rockwell

Course menu

- > Hardheidsmetingen
- > Labozitting
 - > Goals
 - > Voorbereiding van de materialen
 - > Hardheid van mineralen en keramieken
 - > Harheid van metalen
 - > Harheidsmeting volgens Brinell
 - > Harheidsmeting volgens Rockwell
 - > Harheidsmeting volgens Vickers
 - > Hardheid van polymeren.
 - > Omzetten van hardheidswaarden

Hardheidsmetingen.

Er bestaan verschillende methoden om de hardheid van een materiaal te meten. De meeste van deze methoden geven een maat voor de sterkte van het materiaal aan de oppervlakte. Voor een materiaal dat over de ganse dikte van het materiaal dezelfde eigenschappen heeft, is de hardheid een maat voor de sterkte van dit materiaal. Voor materialen die een oppervlaktebehandeling kregen zegt de hardheid enkel iets de sterkte van de oppervlaktelaag. Welke sterkte bedoeld wordt is verschillend voor de verschillende meetmethoden.

Tijdens de labozitting voer je hardheidsmetingen uit volgens vier verschillende meetmethoden:

- Krashardheid van Mohs
- Durometer van Shore
- Brinellhardheidsmeting (HB)
- Rockwellhardheid (HRB of HRC)

Wie materialen met elkaar wil vergelijken op basis van één materiaaleigenschap moet er zeker van zijn dat tijdens de meting alléén deze eigenschap gemeten wordt. We moeten er voor zorgen dat we een meetmethode gebruiken waarbij andere materiaaleigenschappen of omgevingsfactoren ofwel geen invloed hebben op het eindresultaat, ofwel een meetmethode waarbij die andere invloedsfactoren bij alle metingen een even grote invloed uitoefenen op het eindresultaat.

Goals

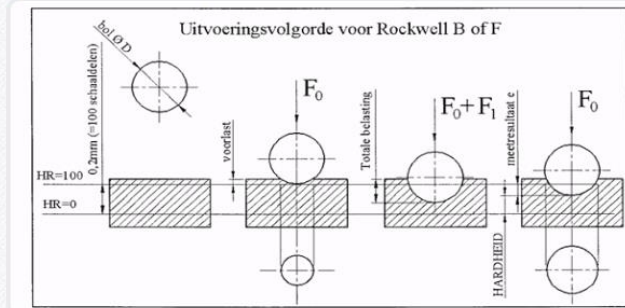
- Je op het einde van het labo de benaming van het materiaal S235 aanvult tot de 'volledige' materiaalaanduiding.

Figure 34 Example in labs: hardness measuring, main menu

Each lab/test section contains the specific details for the testing machines and the required testing conditions (see Figure 35).

Hardheidsmeting volgens Rockwell.

Onderstaande tekst is een samenvatting van de uitvoeringsvoorwaarden voor de hardheidsmeting volgens Rockwell. De proef bestaat uit het in twee fasen drukken van een bol- of kegelvormig indruklichaam in het proefstuk. De Rockwellhardheid wordt dan afgeleid uit het verschil van de indrukdiepte veroorzaakt door de totale belasting, verminderd met de indrukdiepte veroorzaakt door de voorbelasting. Het meetresultaat (h) wordt omgezet in een aantal schaaldelen (e). Een schaaldeel is 2mm ($= 0.002\text{mm}$). Als h de gemeten indrukdiepte is die door de hoofdlast alléén veroorzaakt wordt, gemeten in mm, dan is $e = h/0.002$.



Voor verschillende instellingen van het toestel, zijn er verschillende Rockwellhardheden, met twee verschillende definities. Onderstaande tabel geeft de belangrijkste.

TYPE	indruklichaam	F_0	F_1	Geldig bereik	definitie
HRA	kegel	98,07 N	490,3 N	$60 < \text{HRA} < 80$	$\text{HRA} = 100 - e$
HRC	kegel	98,07 N	1373 N	$20 < \text{HRC} < 70$	$\text{HRC} = 100 - e$

Figure 35 Measuring hardness according to the Rockwell method

Each lab/test section contains the specific lab assignment for the students (see Figure 36).

As such students have the information:

- ❖ To prepare the lab by studying the theoretical background.
- ❖ To do the lab with the testing machine manuals.
- ❖ To make the assignment with the description of the assignment here.

Assignments:
 Doe niets aan het toestel voordat de laboverantwoordelijke een demo gegeven heeft.
 Maak een prinschets van het meettoestel waarin het meetsysteem verduidelijkt wordt.
 Controleer de instellingen van het meettoestel (pas niets aan zonder het te vragen aan de laboverantwoordelijke)
 Beproof alle proefstaafjes met de gepaste instellingen !!!! schuur eventuele onzuiverheden eerst weg.
 Meet ieder stukje 3x en maak het gemiddelde van de gemeten diameter d ,
 Het meettoestel geeft direct het hardheidsgetal. Reken dit echter zelf terug naar de indrukdiepte h .
 Maak een schatting van de sterkte van de materialen, controleer met de opgegeven waarden.
[Ga naar TOP.](#)

Figure 36 Assignment for the lab for measuring with Rockwell method

Putting all information at the same place in the CALM, students have a compact toolbox for making their lab assignments.

3.3.7 “Voorbeelden” (examples) section



Figure 37 Example section

This section contains a lot of illustrating materials (movies, the slides from the classroom teaching session) to help students understand the course materials. As such students have all the materials available to study the subject.

Ondergang van de Alexander Kielland



Figure 38 Links to movies to understand the theory: Alexander Kielland disaster due to stress concentrations. (https://www.youtube.com/watch?v=7QVn3NUW_aQ)

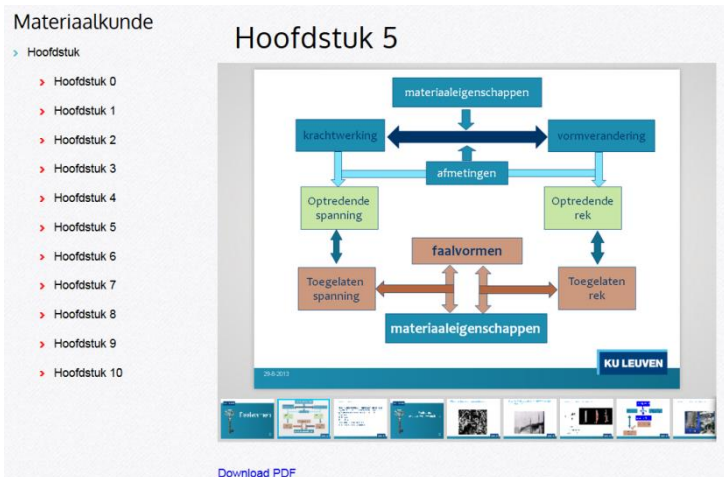


Figure 39 Voorbeelden: slides of the lectures

A lot of the materials is downloadable (as pdf) so that students can also study it offline.

3.4 Remote lab on material sciences

3.4.1 Introduction

The remote lab in the CALM is constructed to substitute a real physical lab with a remote lab to offer students the opportunity to experiment on a real experiment. The goal is to save time, personnel and offer more flexibility in the use of an experiment by students.

The real physical lab is a 3-point bending test, while the virtual and the remote lab is a 2-point bending test.

The hardware design for the remote laboratory is based on the following principles:

- ❖ It should offer the same experimenting possibilities as the real bending test: (approximately) the same set up, the same variables. By making the remote lab react like a real lab, the hope is that students will come to the same conclusions and level in knowledge.
- ❖ It should enable students to have the same learning outcomes: getting the same knowledge out of it. The topic studied in the real physical lab and in the remote is the same. If the method of learning has to be changed, the learning outcomes and level of knowledge reached should be similar.
- ❖ The remote lab could not be a black-box, but offer a real experiment, which means: to set up experiment (choose variables), to measure experimental data, to work with data, to calculate possible error for correct conclusions (learning outcome: the ability to design and conduct experiments, as well as to analyze and interpret data). In a real experiment the outcome can be predictable, but in any case unknown. A real experiment needs to be well prepared by the experimenter and all variables need to be taken into consideration. When the remote lab would act like a black box and measure in an automated manner, or calculate measurements to find the unknown parameter(s), the student loses the sense of the real experiment. So we opted for a simple setup in which all

information is available to the student, but in which student also has to do all the experimental work and calculations.

- ❖ The remote lab should be of a simple robust design. Complex setups need a lot of maintenance, and they have a greater risk of breakdown.

We will see in the lab setup and in the assignment how these conditions are met, and how the learning outcomes are implemented.

3.4.2 Phenomenon studied in the remote lab for material sciences

The strength of a mechanical structure depends on the shape of the structure (see Figure 40) and the strength of the material (see Figure 41). This interaction is difficult to comprehend for students, as we notice all the time. Students can only hardly make the difference between material stiffness and strength (expressed in the material properties called Young's modulus) and structural stiffness (dependent mostly on the surface moments of inertia).

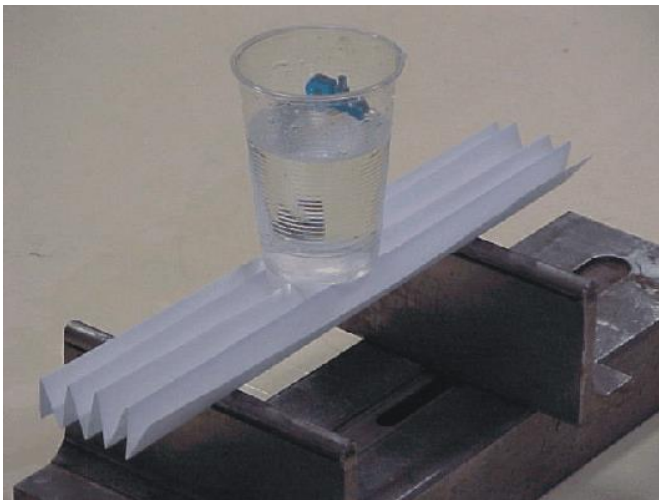


Figure 40 Structural stiffness due to shape: folder paper holding a cup of water

Head markings and mechanical properties



Head marking	Grade, material & condition	Nominal thread diameter size range [mm]	Proof strength [MPa]	Yield strength (min) [Mpa]	Tensile strength (min) [Mpa]	Core hardness [Rockwell]
	Class 4.8 Low or medium carbon steel; fully or partially annealed	1.6-16	310	340	420	B71-95
	Class 12.9 Alloy steel; quench and tempered	1.6-100	970	1100	1220	C38-44

Figure 41 Same shape bolts , stronger and stiffer due to materials

To study the difference different test setups are used.

Young's modulus is a measure for material stiffness and material strength. Traditionally Young's modulus is tested in a tensile tester (see Figure 42), in which a specimen is pulled until it breaks. Typical curve (force versus displacement) for steel in this test is found in Figure 43.



Figure 42 Tensile tester

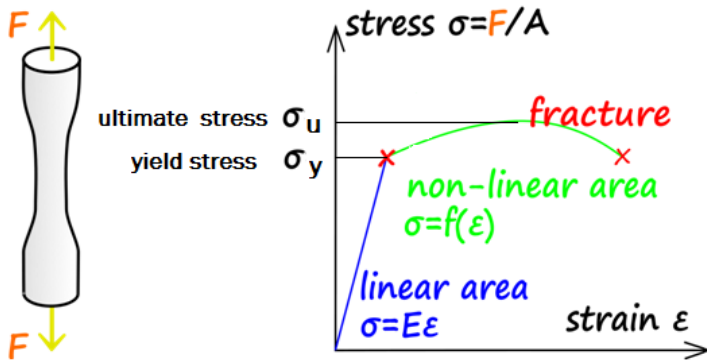


Figure 43 Tension curve (force/stress versus displacement/strain)

A second method of testing to find Young's modulus is the use of a 3-point bending test (see Figure 44). In the bending test the properties of the linear elastic area of tensile curves is used to determine Young's Modulus. With these bending tests one cannot find values for the yield and ultimate stress.

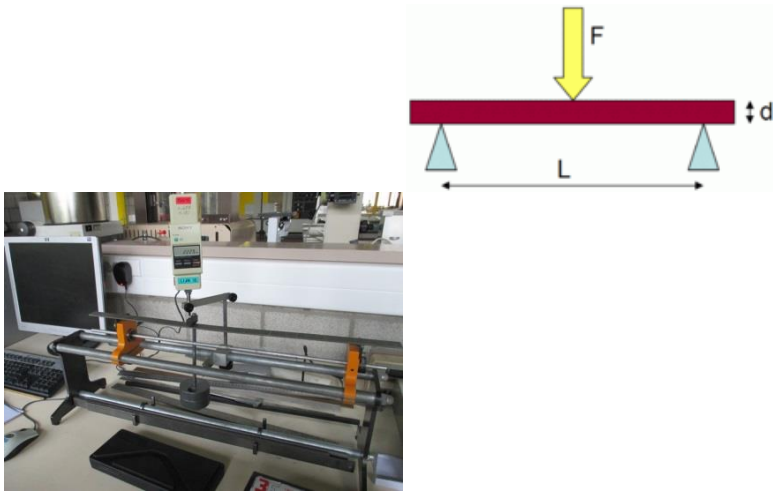


Figure 44 The 3-point bending test in the physical lab

Bending of the beam is function of L (length between supports), force, and shape of the beam-specimen (see 3.4.3).

In the lab we test the bending of specimen to find out the mechanical property of materials named Young's Modulus.

From the point of view of the remote experiment, the bending test is the best option, as it combines material stiffness (Young's modulus) to structural stiffness (shape of the beam-specimen). So the lab setup needs to be a combination of different materials and different shapes to be tested.

The targeted learning outcomes of the remote lab are:

- ❖ Students should be able to deduct materials properties (Young's modulus) from their measurements.
- ❖ Students should be able to calculate the shape stiffness of the test specimens.
- ❖ Students should be able to calculate the accuracy of their results as part of experimenting.

Referring to (3.2.1) we check the learning outcomes desired:

- ❖ Objective 2: Models.
 - Identify the strengths and limitations of theoretical models as predictors of real-world behaviors. Validating a relationship between measured data and underlying physical principles.
 - This objective is met, as students need to measure and deduct material properties.
- ❖ Objective 3: Experiment.
 - Devise an experimental approach, specify appropriate procedures, implement these procedures, and interpret the resulting data to characterize an engineering material, component, or system.
 - This objective is met, as students need to interpret measured data and deduct material properties.
- ❖ Objective 4: Data Analysis.
 - Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions.
 - This objective is met, as students need also to account for the accuracy of their measurements starting from accuracy of measuring devices.
- ❖ Objective 10: Communication.
 - Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels

ranging from executive summaries to comprehensive technical reports.

- Students need to make a report on their assignment.
- ❖ Objective 13: Sensory Awareness.
 - Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.
 - This is not completely met: only vision is used to make decisions on. Students cannot touch the setup, nor smell it or hear it.

So from the pedagogical point of view our remote lab setup should work.

3.4.3 Remote lab setup: principle

The remote lab setup is made with a 2-point bending test. This test is somewhat easier to setup than a 3-point bending, as there is a free end in the test setup (right in Figure 45) where measurements can take place.

The ruling equations for mechanical bending of the cantilever beam (2-point bending) (Hibbeler, 2004):

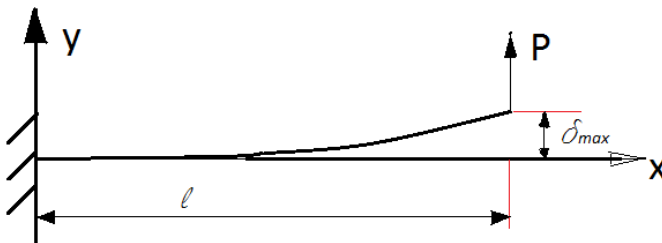


Figure 45 Cantilever beam under bending

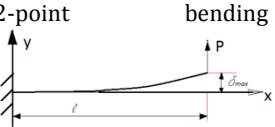
- ❖ Maximal deflection: $\delta_{max} = \frac{P \cdot l^3}{3EI_{xx}}$
- ❖ Deflection (y) at distance x from the reference point $y = \frac{P \cdot x^2 \cdot (3l - x)}{6EI_{xx}}$

- ❖ Bending stress according to the beam theory:
- ❖ Maximal bending stress: $\sigma_{max} = \frac{P*l}{W_{zz}} = \frac{P*l}{I_{zz}/v}$
- ❖ Bending stress at a distance x from the reference point:
 - $\sigma_x = \frac{P*(l-x)}{W_{zz}} = \frac{P*(l-x)}{I_{zz}/v}$
 - In which
 - W_{zz} the modulus.
 - I_{zz} surface moment of inertia.
 - v distance of the outside of the specimen to the neutral fiber.
 - W and I are a measure for the shape stiffness of the specimen.

In the remote lab, students need to measure δ_{max} , while they get the data for shape of the specimen. The exerted force they deduct from measuring the deflection of a known specimen in the lab.

In the real lab, students measure force and shape of the specimen too.

In Figure 46 the difference between the real lab and the remote lab are schematized.

Real lab	Remote lab
3-point bending test	2-point bending test 
6 different test specimens available, test 1 by 1	9 different test specimens available, test 2 by 2
Force increasable in 5 steps by means of weights	2 different forces available by varying the pressure load
Position of force free	Position of force fixed
Students measure deflection	Students measure deflection
Students measure force	Students calculate force from known specimen.
Students measure distance (x) of force to reference point	Distance of force to reference point is given
Students measure dimensions of specimen	Students get all dimensions of specimen

Students calculate possible error	Students calculate possible error
-----------------------------------	-----------------------------------

Figure 46 Features of the physical lab versus the remote lab

All measures and readings are a source of inaccuracy (resolution of measuring tool, inaccuracy of use, faulty readings, and others). So students need to calculate the possible error on their results for Young's modulus with error-theory.

Students get the dimensions of the test specimen, and the accuracy of the measuring tools used to determine these dimensions. From the above mentioned equations, they then calculate the accuracy of their results.

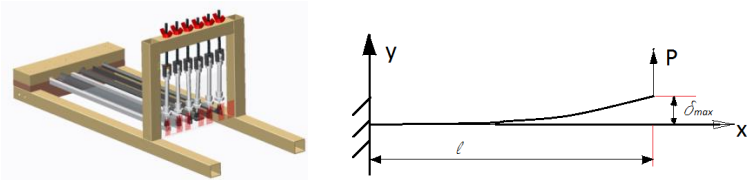


Figure 47 Remote lab: 2-point bending test

3.4.4 Remote lab construction

The construction of the remote lab can be divided in 3 categories. The (mechanical hardware), the control and measuring system and the software.

3.4.4.1 Mechanical hardware

For driving the mechanical hardware there is chosen for a pneumatic system. Pneumatic systems are robust and easy to maintain, can be build with a lot of standard components and are easy to understand in its' functioning by the students. Pneumatic components are also available in a lot of different sizes, to scaling to find an appropriate dimension for the lab was easy.

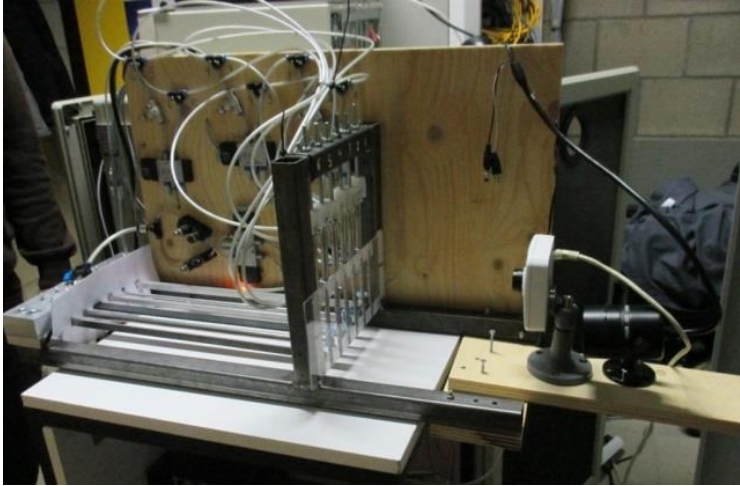


Figure 48 Remote lab: photo of the hardware setup

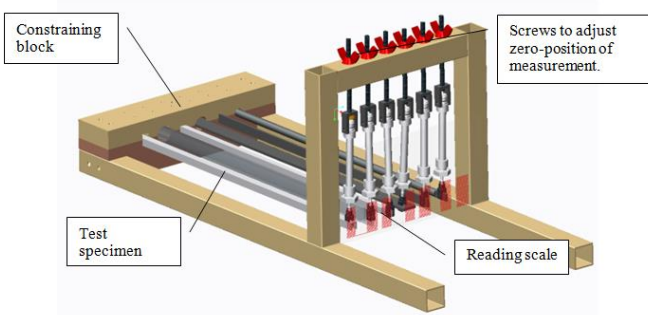


Figure 49 Remote lab: CAD-design

The test specimen are bars of different shapes and materials.

The test specimen are locked at the far end in a constraining block. The block is provided with clamping screws to take specimen with different shapes. As such the test can be altered for different shapes and materials.

The force is exerted by means of pneumatic pistons with a stroke of 40 mm. (Festo DSNU-8-40-P-A, double stroke cylinders). Pressure is regulated with two pressure valves (Festo LRMA-QS-4) to provide two different forces on the test specimen. Force is dimensioned so that material of specimen is only loaded in the linear elastic area of the tensile test curves. Pressured air is delivered with a low noise oil-free industrial compressor (Festo D:ML-S-VD-M).

3.4.4.2 Control of the remote lab

The control of the system is done with electronic controlled valves. Electronic control of the remote lab hardware is realized with a relay board, on the USB-port of the computer. For this, we use a Velleman relay board. This board can be attached to the USB port of the server and contains an USB to RS232 serial convertor, a little controller to interpret the relays commands and the relays. The relays can be attached to a independent power supply. If needed, they can switch 230Vac, 5A. Student-experimenter can activate different valves to control pneumatic cylinders. The relay board switches the electrical controlled pneumatic valves, and also protect the installation by disconnecting the compressor and electrical components from the electrical power lines when the remote lab is not use by a student.

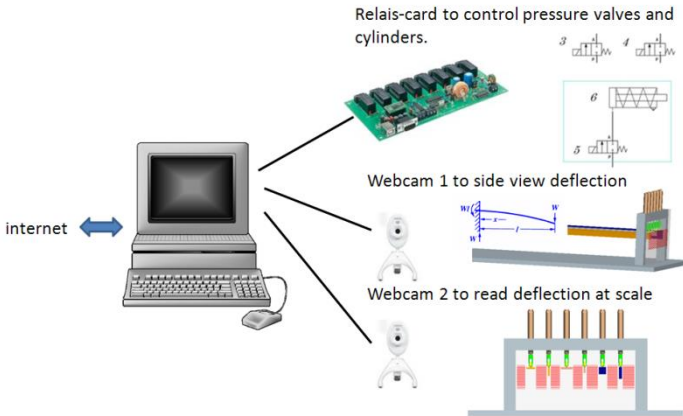


Figure 50 Remote lab general setup scheme

3.4.4.3 Camera system for measurements

Measuring the deflection of the beam is done with a reading scale (see Figure 52) and an IP-camera (ACTi E12 Cube Camera 3MP). The network IP- camera is a power over Ethernet camera.

It is a high definition camera to monitor a more detailed view of the test. Students can view the millimeter scale on the stream and can use these results in their lab report. As it is a network camera, and the stream is embedded (MPEG) in the webpage, the stream isn't processed by the web server. So there is no extra load for the server, as the camera streams its data directly to the internet.

A second camera is attached from the side to have a view on the deflection of the beams. For this, a standard webcam is used. The USB web-camera is a standard Logitech webcam, supported by Linux, and interfaced with VLC (VideoLAN Client). The original camera stream is captured by VLC and streamed across the internet as a MPEG stream. This stream is embedded (real time streaming protocol) in the webpage but can be also viewed in all standard media players.

The images made by the IP-cam offer enough resolution for a measurement with an accuracy of 1 mm.

The network/server part has following characteristics. As central server, we used a HP dl360 server, redundant power supply and the hard disks configured in raid1 (when 1 disk fails, the system keeps running on a second mirror disk).

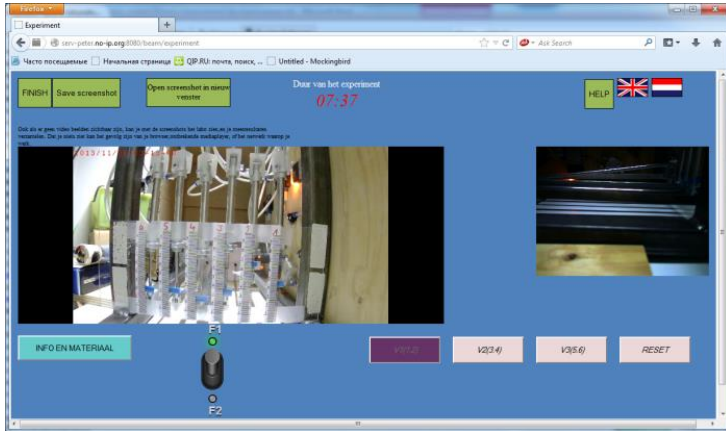


Figure 51 View of the main screen of the remote lab with camera views

Measurements

Measurements of the deflection of the different specimen is made on a reading scale, with a scale resolution of 1 mm.

The camera view can be made in a real time, and screen shots can be taken for the later processing of the data.

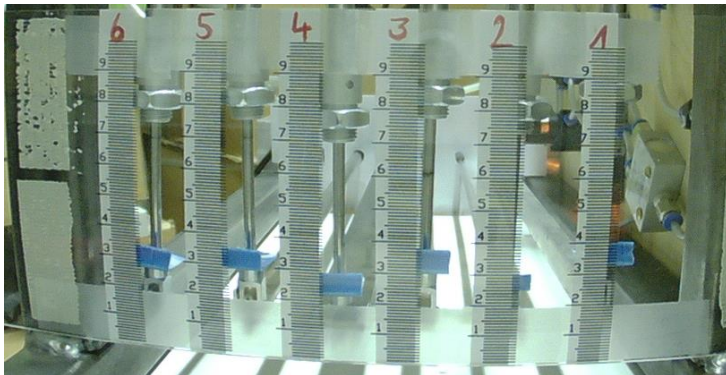


Figure 52 Screen shot of the reading scale for the measurements

There is no automatic calculation of Young's modulus, nor of the forces and moments of inertia in the remote lab. As such students need to work on it as they need to do in the real physical lab.

The specimen in position 4 is given as a steel bar. From this, students can calculate the force exerted on the specimen. With this force, students are able to calculate Young's modulus for the other specimen.

There is a number of test specimen which can be put in the lab. From the series of 10 from (Figure 53) 6 are mounted in the lab.

Students get the dimensions and the order of mounting, and have to experiment to calculate Young's modulus and next deduct the material from a standard list of materials.

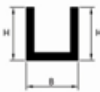
Specimen no	shape	Main dimensions (mm)	Length (mm)	material
1		H=B=9.95, thickness 1.95	400	?
2		Diameter 8.04	400	?
3		7.98x7.98	400	?
4		BxH = 19.44x3.45	400	Steel S235JR
5		diameter 9.95, thickness 1	400	?
6		B x H = 2.90x11.87	400	?
8		15x13, thickness 2	400	?
9		H=8, W=4, flange thickness = 1	400	?
10		8x4, thickness 2	400	?

Figure 53 Sizes and shape of test specimen

3.4.4.4 Software

For the development of the software the Spring MVC Framework was chosen. The basic logic was realized with Java, and for the visualization system we used HTML, CSS, Javascript, JQuery, JSP. The server software for manipulating the valves is Tomcat.

The data and process flow can be seen in (Figure 53 and Figure 54).

The software was divided into different subsystems, depending on the logic in the use of the remote lab.

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

The subsystem for board control task is for switching the relays on the relay board. After getting access to the remote lab student can choose the force applied to the beams and activate the force on the different test specimen (beams).

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 stream in a browser after installing the VLC-plugin. To cope with possible problems on images and video, a section for saving screenshots was integrated for offline working with the experimental results.

Experimenting time is reduced to 10 minutes per student. After leaving the lab, student has to wait 15 minutes before being able to reenter. Security measures are installed to avoid automated/hacked control of the lab.

Architecture of the system can be found in (Arras, Tabunshchik, Kolot, & Tanghe, 2014).

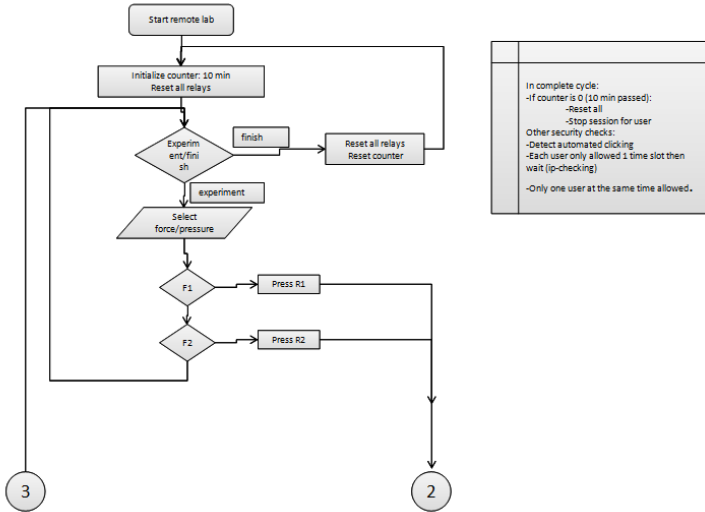


Figure 54 Flowchart of the control system part 1

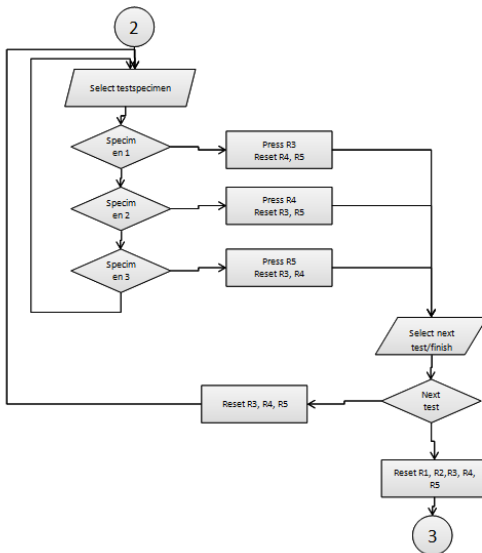


Figure 55 Flowchart of the control system part 2

3.4.4.5 Functioning of the remote lab

The remote lab is part of the CALM (complete e-learning environment) for material sciences. The setup of the CALM is to give students a consolidated single source of knowledge to study the course. It contains all study materials available to students: course book, slides of classroom teaching sessions, laboratory manuals and assignments, and links to extra materials.

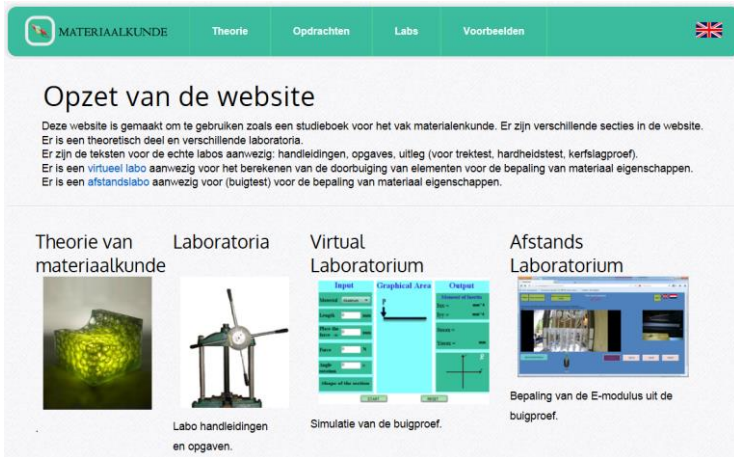


Figure 56 Material sciences learning environment

Students navigate to the remote lab either through the “laboratoria” section or “labs” tab, either directly to “afstandslaboratorium”.

3.4.4.5.1 The remote lab: control

When entering the section on the remote lab, the same structure is presented. Left menu navigation to navigate between the theory/explanation on the bending test, and links to the physical lab (3-point bending test), virtual lab (cantilever beam) and to the remote lab (2-point bending test).

The assignment is described on the webpages, and (extra) in a separate pdf: these enable students to printout the document, prepare the lab, and most essential, to have all texts available without having to switch screens all the time (text is in annexes).

Materiaalkunde

- > 3-puntsbuigproef
- > Virtueel Lab
- > Afstandslab
- > Opdracht afstandslabo
- > Enquête na het gebruik v/h afstandslab

Afstandslab

Run remote lab.

Doel van het labo:

- Verschil leren herkennen tussen materiaalslijfheid (eigenschappen) en vormslijfheid (geometrie) van structu
- Formu
- Nauw

Link to pdf with complete assignment.

Principe:
Om het verschil tussen materiaal- en vormslijfheid te testen maken we gebruik van de buigproef. Deze wordt uitgevoerd op een ingeklemde balk.

$$\delta_{\max} = \frac{Pl^3}{3EI} \quad y = \frac{Px^2}{6EI}(3l-x)$$

Waarbij de buigspanning gelijk is aan

$$\sigma_{\max} = \frac{P \cdot L}{W_{\text{el}}} = \frac{P \cdot L}{(1/12) b^3}$$

Met:

- Wzz het weerstandsmoment

Figure 57 Remote lab: preparation/theory section

When choosing to run the remote lab the first screen is the welcome screen (Figure 58). The welcome screen contains a timer, indicating how long the current session of the remote experiment will last.

There is no reservation system to use the lab. Security on the lab is with user-checking by cookies at present and with a limited time to use the lab. Normal use is 10 minutes. After a session, same user needs to wait 15 minutes before being able to use the remote lab again. This is installed to prevent a monopoly on the system by the same user.

Timer indicating waiting time before being able to use the experiment.

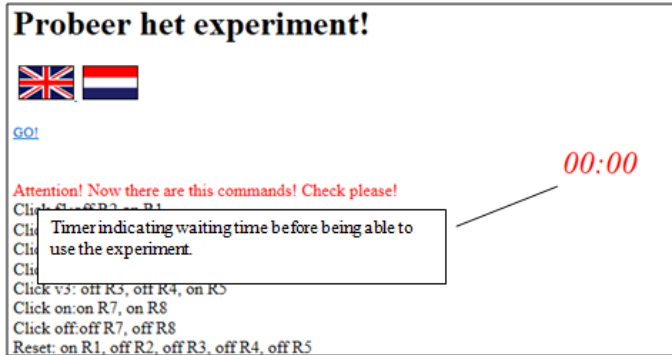


Figure 58 Entry screen of the remote experiment

After entering the lab, user is in control with the GUI in (Figure 59).

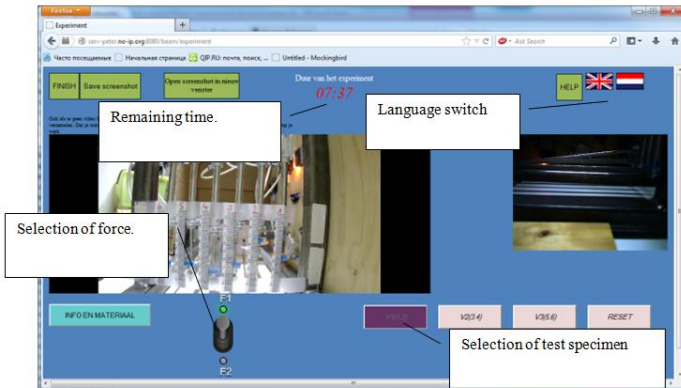


Figure 59 Main screen of the graphical user interface

The remote lab contains 2 camera views:

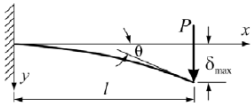
- ❖ Left view to measure the deflection of the test specimen.
- ❖ Right view to have an idea of the bending line.

Control of the lab is underneath: selection of the test specimen which are activated/tested. And the force/pressure switch.

There is a help screen provided (Figure 60) containing the theory (short) of the 2-point bending, and the user manual of the remote lab.

Principe:

Om het verschil tussen materiaal- en vormstijfheid te testen maken we gebruik van de buigproef. Deze wordt uitgevoerd op een ingeklemde balk:



$$\theta = \frac{Pl^2}{2EI}$$

$$y = \frac{Px^2}{6EI}(3l - x)$$

Waarbij de buigspanning gelijk is aan $\sigma_{max} = P \cdot L / W_{zz} = P \cdot L / (I_{zz} / v)$, met W_{zz} het weerstandsmoment, I_{zz} het oppervlakte traagheidsmoment en v de afstand tot de neutrale vezel van de balk. W en I zijn een maat voor de vormstijfheid van de proefstaaf.

Operation:

Het afstandslab bestaat uit een opstelling waarbij 6 proefstaven met een verschillende doorsnede (dus verschillende W of I) door pneumatische cilinders belast worden. Met de gekende afmetingen van staaf 4 en als materiaal (S235JR) kan berekend worden:

- De aangelegde kracht

Met de gekende afmetingen van de verschillende staven (1-6) kan berekend worden:

- Het weerstandsmoment en/of traagheidsmoment
- De E-moduli van de verschillende materialen van de verschillende proefstaven.

Figure 60 Help screen of remote lab

There is also a list provided of the dimensions of the test specimen and of possible materials (Figure 61).

Specimen nr	vorm	hoofdafmetingen	lengte	materiaal
1		H=B=9.95, wanddikte 1.95	400	
2		Diameter 6	400	
3		7.98x7.98	400	
4		BxH = 19.9x3.5	400	Staal S235JR
5		diameter 9.95, wanddikte 1	400	
6		3.10x11.9	400	

Figure 61 List of test specimen and materials

To process the results, on top of the GUI is different possibilities to see and save the camera pictures. The “save screenshot” button makes

it easy for students to do the experiment and collect results for later (offline) comparison and processing.

- ❖ “Finish button”: close the remote lab, and reset all specimen.
- ❖ “Save screenshot”: take a snapshot of the measuring camera view and save it to disc as a *.JPG file.
- ❖ “Open screenshot in nieuw venster”: open a new window in the browser to see the measuring camera view.



Figure 62 Results collecting

Results can be saved on disc in .jpg-format (for offline use) or viewed in a separate window. It is a concern that cameras for live streaming are slow, so the saving possibility is independent of the live streaming. This strategy works and offers possibilities to students to use images in reports and to study results more closely after finishing the online session.

Measuring has an accuracy of 1 mm. This is enough as part of the assignment is to calculate the error on the results (like in a real experiment). As such a small absolute accuracy on the measurement is not necessary.

3.4.4.5.2 Remote lab: protocol

In the protocol is described how the remote lab needs to be used.

Students are advised to run the experiments at least twice and take a mean of their results. As the lab is constructed with pneumatic hardware, absolute repeatability is not obtained.

The short version of the experiment protocol is as follows:

- ❖ Experimenter makes zero measurement first: this is done to compare the results.

- ❖ Experimenter selects known specimen (4).
- ❖ From the measurement of the specimen 4, and with the known material, students can calculate the applied force.
- ❖ Next all other specimens are tested.
- ❖ From the measurements of the deflection and with the known dimension of the test specimen, student/experimenter can calculate Young's modulus, and in this way to find out what material the specimen is made of.
- ❖ (The result can also be simulated in the virtual lab.)
- ❖ Scheme is repeated with another force with the aim to compare results.

After all calculations, the student also needs to calculate possible errors in their results.

In the end, students can compare to values of Young's modulus tested in tensile test in the physical lab-session.

This procedure is described in the text which is available to the students on the CALM-section about the remote lab.

3.4.4.6 Remote lab: evaluation of students

In the curriculum is no separate evaluation of the remote lab.

Students can auto-check their results on Young's modulus with the aid of the virtual lab. For the calculation of errors, a report can be submitted (electronically).

At the end of the lab-sessions, there is a classroom session, in which results of material tests are compared for all tests. A compilation and overview of error-calculations is also presented, so that techniques of error-calculation by students are clear to all.

The level of knowledge of the students who used the remote and virtual lab to study the difference between material and shape stiffness in comparison to students who used the physical lab was tested in a regular exam.

The statistical comparison showed that there was no difference in knowledge level, proving that a remote lab can be as useful as a physical lab for obtaining knowledge on a phenomenon.

The division of students over the control group/test group of the evaluation test is found in Figure 63.

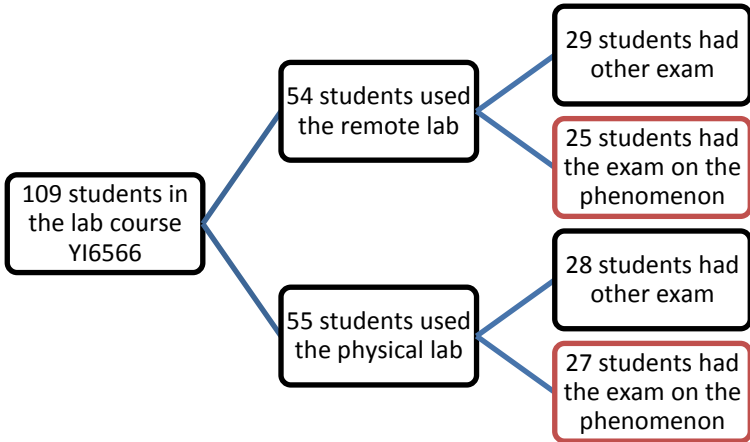


Figure 63 Division of students over the evaluation groups

The fact that there was no statistical significant difference in the knowledge level of the groups of students who studied the phenomena in a real physical laboratory or in the remote controlled lab proves that both kind of labs can be effective in transferring knowledge. This opens up new perspectives for building more RE's as a substitute or complement to existing physical labs.

3.4.4.7 Remote lab: implementation problems

The implementation of the remote lab and of the CALM in the engineering degree showed a number of problems as reported in (Tabunshchyk et. al, 2015)

- ❖ Technical problems both from server and client side make running a remote lab over a longer period of time a real challenge.
- ❖ As the client is dependent on the web and web-browsers, continuously updating of browsers and OS in computers makes it tough to make a solid solution. It means there are a variety of different client-systems: each user has his own configuration, which puts extra stress on the developer to make software which can cope with all these differences.
- ❖ Securing the lab from abuse and misuse is a tough question. Working with a registration system demands for a permanent checking by staff. Using the lab unsecured will lead to destruction and high maintenance costs. Limiting experimental time is a cheap and easy to implement feature in securing the lab, but is not a robust mechanism if the lab is freely online 24/24.

Because of these difficulties, the trend in remote labs is to more and more post it in a controlled environment (intranet) instead of the internet. Advantages are fewer problems with security and with internet issues.

3.5 Virtual lab

In the e-learning module (CALM) is included a virtual lab.

The goal of the lab is double:

- ❖ Provide user with the possibility to experiment on the calculations of cantilever beams.
- ❖ Provide the user with a tool to check the measured values from the remote lab.

There is no separate learning outcomes for the virtual lab.

3.5.1 Setup of the virtual lab

The virtual laboratory is a simulation of a laboratory for material properties study. It was constructed using the basic formulas for a

cantilever beam. The calculation of the deflection and stress in a cantilever beam represents in fact a 2-point bending test. Formulas for the calculation of the cantilever beam can be found in the section on the remote lab (see 3.4.2).

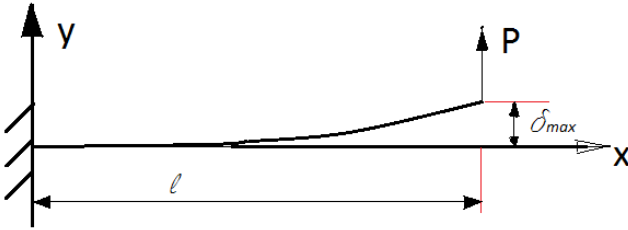


Figure 64 Cantilever beam, 2-point bending, simulated in the virtual lab

The cantilever beam formulas provide theoretical values for the deflection and stress values appearing in the loaded beam. Errors can appear when the beam isn't loaded at the end. Students are warned for this possible mistake, and should study it before using the lab.

In the virtual lab a number of specimen with standard sections can be tested.

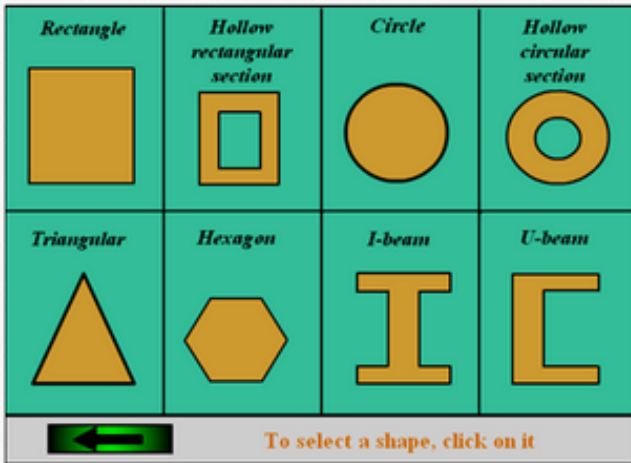


Figure 65 Standard sections for test specimen in the virtual lab

For the programming of the virtual lab a combination of HTML5, ActionScript and JavaScript was used. The component diagram of the developed application is presented in Figure 66.

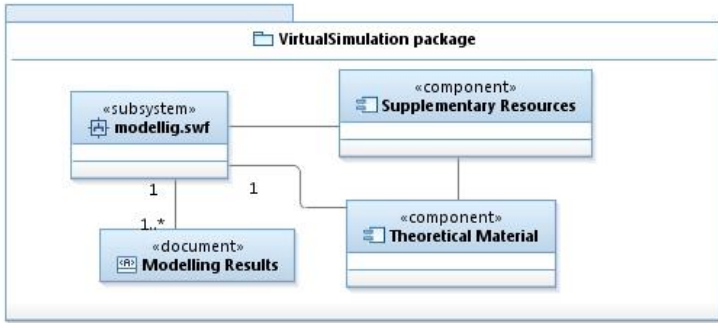


Figure 66 Component Diagram for Virtual Lab

The realization of the calculation for different shapes is realized by classes put in package beam, which is part of subsystem “modeling” shown in Figure 67.

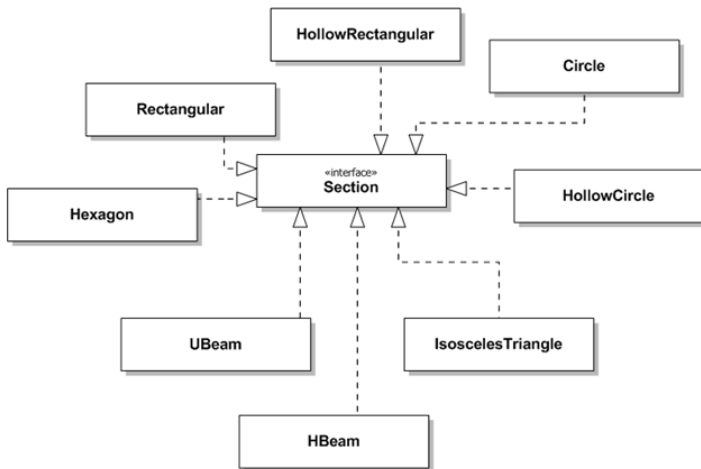


Figure 67 Class Diagram for the cantilever beam calculation depending on the shape

3.5.2 List of functional requirements for the virtual lab

In order to function according to what is expected, this list of functional requirements was put forward:

- ❖ Calculation and visualization of the deflection of a beam, with measurement of deflection at the end and indication of maximum stress and force.
- ❖ The values for different Young's modulus for a variety of materials should be chosen according to reported values (Ashby, 2005). To test material stiffness.
- ❖ For a variety of shapes (rectangular section, H-beams, U-beam, hollow shapes...) to test shape stiffness.
- ❖ For different orientation of the same shape (increment angles 1°) about the principal axes.
- ❖ For a variety of dimensions in the same shape (cross section dimensions and length). The different values should be entered by the student experimenter.

3.5.3 Supplementary Requirements for the virtual lab

For the comfort of the user, a number of requirements concerning the user interface and construction of the lab are listed:

- ❖ Keep it simple: the virtual lab cannot act as a black box. It should be as transparent as possible to give the student the feeling he really understands what happens. No hidden calculations, clearly visible input and outputs, help screen available.
- ❖ The interface should be intuitive. Experimenting student should be able to select all different possibilities with the aid of pull down menus and selection panels, and dialogue boxes for dimensions. If possible on 1 screen only.
- ❖ Readings of deflection, force and stresses should clearly show what is happening.
- ❖ Readings/results 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.

- ❖ Lab needs to be adaptable later: extra materials can be input through XML-files.

3.5.4 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 68).

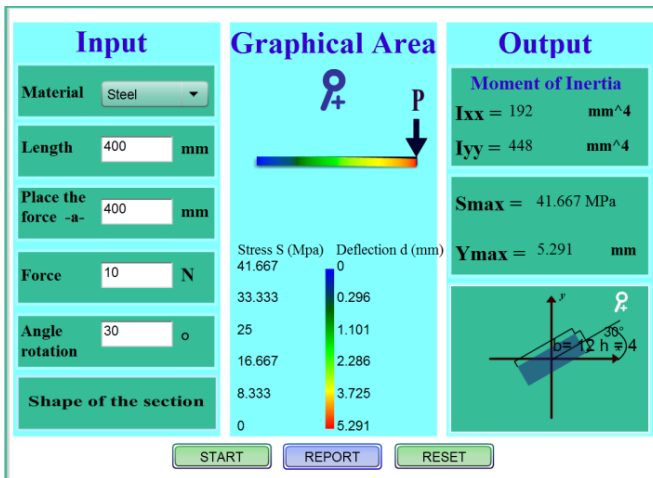


Figure 68 Screen shot of the actual virtual lab

In the input section, user sets the values of material to be tested, physical dimensions of the specimen and applied force. Moments of inertia of the beam are calculated and shown on the output tab.

Pushing start will calculate the values and generate the results, both in the graphical area (showing deflection and maximum beam stress in the specimen), and numerical values in the output section.

The results can be viewed in an additional report window and printed (Figure 69). 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 again.

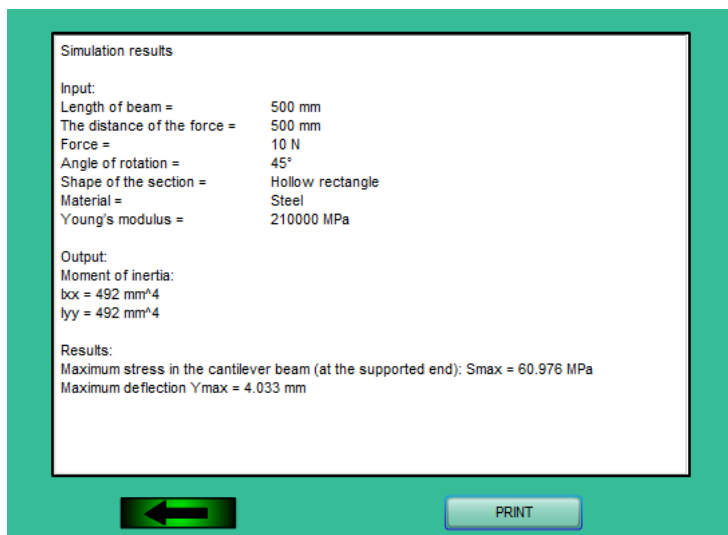


Figure 69 Screen shot of the report screen

In the CALM the virtual lab is presented with an instruction screen, explaining what to do.

3.6 Examples of remote experiments in the field of mechanics and strength of materials

Worldwide over time that have been a lot of initiatives to construct and use virtual and remote labs over the internet.

After time a number of labs have been clustered to offer a greater pool of experiments to users/students.

Now we worldwide see a shift in the accessibility of the labs. Whereas in the past labs were open to the world over the internet, nowadays many labs – especially on mechanics – are only open for a selected number of users, often the students from the university itself. This has to do with cost and cost of maintenance.

Underneath is an overview of labs (on the internet or intranet) as a source of inspiration.

Although most labs are in control engineering and electronics, some nice physical experiments can be found.

In the DistanceLab project, which can be found on: <http://distance.roboticlab.eu> there is an international collection of remote labs. It offers real-time access to different remote labs all over the Europe and pursues the international collaboration between didactic centers, universities and SME-s as well as between students from different countries. (Sell and Rützmann, 2014) Most of the labs are in electronics and robotics. Only the own students have access.

In Slovak Republic a number of remote physics laboratories are available at the University of Trnava Department of Physics. The e-laboratory collection contains one chemistry experiment, and nine physics experiments that are freely available at kf.truni.sk/remotelab.

Other freely available and frequently used are the remote laboratories of the e-Laboratory Project. It is run by a consortium of three universities: the Charles University Faculty of Mathematics and Physics (CZ), the Tomas Bata University of Zlin (CZ) and the University of Trnava (SK). The labs are available at www.ises.info , providing currently eighteen remote experiments.

More labs can be found on www.ictphysics.upol.cz/remotelab/rlab.html, which is a collection of five physics experiments of the Palacký University in Olomouc. (Ožvoldová, Špiláková, & Tkáč, 2014)

Another catalogue of remote labs can be found at <http://unilabs.dia.uned.es>. This is a collection of remote and virtual labs on control engineering and automation.

In TU Ilmenau is a grid of online laboratory devices on control engineering available. (<http://www.goldi-labs.net/index.php>) The user can program and control different virtual and real experiments in the shape of scale models of real installations. Physical models to control include an elevator, a flexible manufacturing cell, a water level control system and an automated warehouse.

At the Universidad de Deusto there is a collection of open labs available. (<http://weblab.deusto.es/website/labs.html>) Here anybody can access a number of experiments as a guest user. There is experiments on robotics and on control systems.

For material sciences and mechanical technology in general, there are very few remote labs available.

At <http://elabs.fe.up.pt> there is a remote lab setup to be found with a 2-point bending test. This system is currently used by the Mechanical Engineering students to calculate experimentally the Young's Modulus of the beam and to evaluate the displacement for the different loads. The setup contains 1 specimen with known dimensions and material. Students need to compare the results with results they calculate in FEA. (Amaral, Santos, & Mendes, 2014)

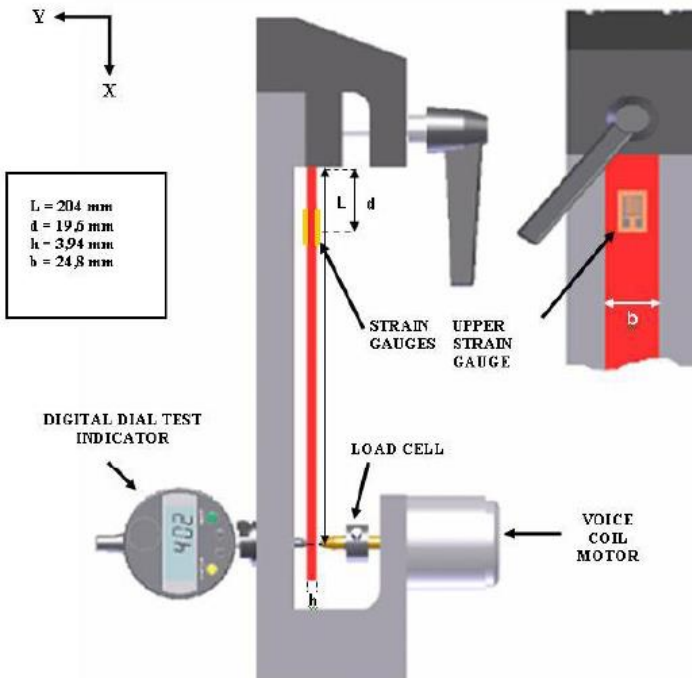


Figure 70 Cantilever beam with single load (Amaral, Santos, & Mendes, 2014)

In the Baumann institute in Moscow, there are different tests remotely available (for registered users only). These include tensile tests, compression tests, twisting and combined tests. Next to it remote access to the robotics lab is also available. (http://lud.bmstu.ru/english_ILIM/index.html)

Another material sciences remote lab was available in the Obafemi Awolowo university experience at <http://ilab.oauife.edu.ng>, as reported in (Kehinde et al, 2011). However it seems that this project is no longer available.

At <http://www.iul.eu/petex/> there is a lab with an uni-axial tensile test for materials. This lab is only accessible for registered users in a MOODLE-learning environment of the Dortmund University. In this remote lab, a selected specimen is loaded in the tensile tester to be loaded until break down. The output is the stress-strain curve of the material. After testing, students can have real-time consulting with the supervising teacher. This lab setup is very expensive (tensile tester + loading robot), and subject to a lot of maintenance. (Pleul et. al, 2011)

CONCLUSION

The research, which results are in the report, shows the importance of carefully planning when conceiving, constructing and practicing remote experiments. They are suitable for each part of education. It is up to teachers how to use and manage RE in educational process.

Information and communication technologies in the last 10 years come in all forms of education and are used in all levels, including universities. The place of using information and communication media is usually called “cyberspace” which gives opportunity to teachers to use new progressive educational methods. In their application we have to pay attention to our aims we want to achieve and avoid their use as a fashion element.

We can expect that RE in the future can fully replace some real experiments in education in situations where manual skills are less important for the outcome of the experiments and in situations where automatic industrial machines are available. We are of the opinion that at present RE represent a useful supplement to real experiments in education, but cannot completely replace it.

In the future we assume an important increase in the application of RE experiments in distance forms of e-learning education. When we take into consideration the information we have, the users of RE experiments should take care not only of the technical and security issues for the application of RE experiments but to achieve success they should prepare study materials (such as a theoretical base), which should be a part of each RE experiment. Study materials in electronic form have to be in harmony with strict didactic rules involving limited personal contact of the teacher with the students. The material has to provide all necessary information for students needed to master their study. Authors cannot avoid the development of hypertext forms of presenting their content.

The use of RE in education is an opportunity, but only when didactic and pedagogy are implemented with the same expertise as the

technical solutions. Without an educational use, an operational RE is no more than a technical solved problem.

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ABSTRACT

In a monograph called Remotely Controlled experiments the authors are focused on the issue of the use of information and communication technologies in natural science and technology subjects by applying social experiment in teaching. The focus is on the application of simulation experiments and experiments installed at remote laboratories. In addition to the description of the basic characteristics of school, simulated and remote experiments with indication of didactic requirements, the authors define the necessary conditions for the planning, construction and exploitation of remote experiments in applications with a view to achieving their long-term operation capability, anticipated innovation in line with achieved progress in science and technology.

One of the parts is an analysis of the results of the survey of attitudes among university teachers to apply remote experiments in university education. Special attention is dedicated to the management and control of remote experiments using PLC (Programmable Logic Controlle) systems, from the view of their design and technical solution to ensure the security in operation of remote experiments.

Moreover, educational and technical issues related to the use of remote experiments in teaching of technical materials and technologies for their production are discussed. This area was long time on the sidelines of interest and so far it has not been given sufficient attention from the part of the pedagogical as well as technical research and development.

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Prof. Tomáš Kozík, graduated in physics of solid states from the Slovak University of Technology in Bratislava, Slovakia in 1969. After defending his Doctoral thesis in condensed matter physics he was granted title PhD. In 1989 he defended his DrSc in technology of ceramic materials processing and was appointed associate professor in branch of physics of condensed compounds and acoustics at the Slovak University of Technology in Bratislava and later in 1994 full professor in branch of electrical engineering materials at the Faculty of Electrical Engineering, STU in Bratislava.

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Since 2006 he is international studies coordinator at the department.

Closely involved in teaching he ran several national and international educational projects for the faculty of engineering. On the national level he organized for 14 years retraining courses for longtime unemployed and for more then 10 years job-trainings for engineers and designers in the use of CAD-systems.

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Remotely controlled experiments

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