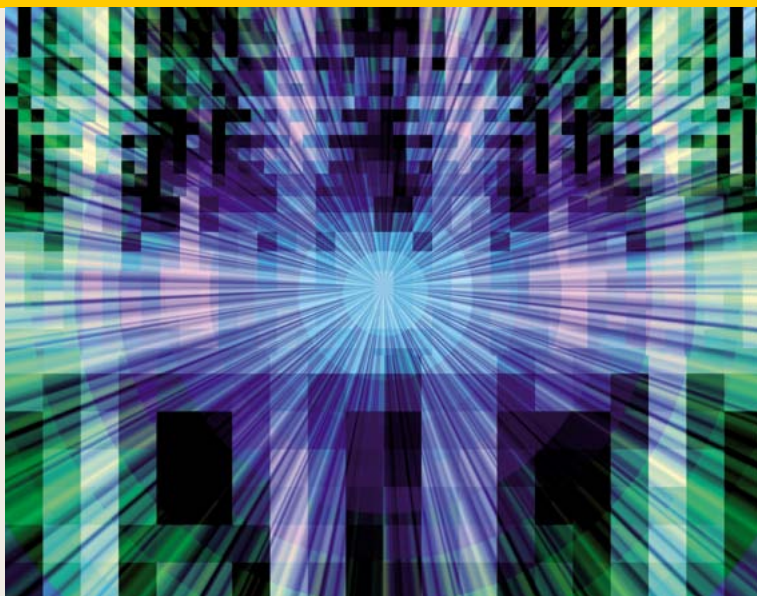Olga Dziabenko and Javier García-Zubía (eds.)

IT Innovative Practices in Secondary Schools: Remote Experiments

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IT Innovative Practices
in Secondary Schools:
Remote Experiments

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Olga Dziabenko and Javier García-Zubía (eds.)

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Preface

Sofoklis A. Sotiriou

In modern e-Classrooms, students and scientists will be able to access Web portals for scientific computer and data infrastructures, thus accessing large collections of data and digital objects using metadata, knowledge management techniques, and specific data services. Students and teachers will apply existing scalable Web and grid technologies to access and share scientific data, using educational and computing resources to run scientific application simulations. Such an approach will allow the creation of enriched interactive and multimedia learning modules that interactively support the exploration of scientific phenomena. Advanced repository and collaboration services will allow students to remotely and securely up- and download science and engineering learning objects. The broader science community will add new learning modules and computer simulation-based learning objects as they become available. An open and Web-based community will capitalize on the 'collective intelligence' of students, educators, and scientists, using Web 2.0 communication and collaboration tools.

The Dawn of Distance Learning e-Infrastructure
By Wolfgang Gentzsch, DEISA and the Open Grid Forum

Powerful new technologies promise to transform science education in ways previously unimaginable. Rapid advancements in educational technologies in the years ahead could produce new learning environments, remote labs and virtual experimentations using simulations, visualizations, immersive environments, game playing, mobile and robotics applications, reusable building blocks of content and many more, which will all address distributed communities of learners.

Rich scientific databases and resources in a variety of fields are publicly available, and can provide a catalyst for science learning (Feni-

chel and Schweingruber, 2010) [1]. Schools, universities and research centres can act as mediators, organizing information –tailored to the needs of their communities– across scientific disciplines and providing tools for understanding complex scientific research, making science understandable and interesting for the public (GRID TALK, 2010) [2]. Attracting students' attention by presenting contemporary ideas and by offering activities that are closely related to new technological achievements is one of the main parameters required to motivate students and contribute to the development of the next generation of innovators. Students are always fascinated by cutting edge and innovative experiments, remote labs and advanced infrastructures and are eager to find out as much as they can about them and to use them. Activities like the use of remote labs that involve such ways of innovative experimentation, give students a chance to witness firsthand how experiments are performed and how data acquired by these experiments are studied in order to reach conclusions and form theories that are scientifically correct and verified. This way of introducing science helps students overcome the idea of it being complex and too difficult for them to understand and helps them to see it as a tool that can be used to explore and understand the world around them. Offering highly stimulating "hands-on" experiences to students which actually involve them in making observations and expressing conclusions instead of offering them occasional tours of such experiments will contribute to the development of their critical skills, as well as enhancing their ability to use scientific language. In order to achieve this, it is necessary to use real scientific infrastructures through corresponding applications specially designed for students.

There are many challenges in the process of educational innovation that must be addressed in order to take advantage of these technological tools and applications to improve learning in science. Advanced technologies developed to meet other purposes must be transformed into affordable tools for learners to use. Technical standards must be deployed to help guide the development of educational content that will be drawn from countless sources throughout the world. The technology community has to form stronger partnerships with the educational community; and educational institutions and their communities need to prepare for rapid technological change.

In this framework, the book "IT Innovative Practices in Secondary Schools: Remote Experiments" aims to bring together individuals and

teams from a wide range of technology and education fields to look into the future and to share their visions and ideas as to what learning experiences and educational technologies could be used in the science classroom of the future. A rich collection of examples of futuristic scenarios, visions, as well as extended pilot implementations are presented and discussed in detail.

The book consists of three main parts:

The first one discusses the potential of innovative tools to transform science education. In the view of the authors, the science classroom should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools. It should enrich and transform the students' concepts and initial ideas, which could work either as resources or barriers to emerging ideas. The science classroom should offer opportunities for teaching tailored to the students' particular needs, while it should also provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is compelling to students.

The second part of the book presents four remote and virtual laboratories and their implementation in real school environments. The authors of the four papers discuss the processes and the methodologies developed in order for the proposed solutions to be integrated into different physics courses, in mechanics, in electricity, in magnetism and electromagnetism. The authors demonstrate how remote labs can expand the capability of a conventional laboratory by increasing the number of times and places in which a student can perform experiments, while also increasing the availability of the laboratory to several students. Moreover, they demonstrate the potential of remote labs to provide affordable experimental data by sharing expensive laboratory equipment within a larger pool of users.

The third part of the book goes a step further and presents a series of more advanced applications that combine the use of remote labs and experiments with mobile applications, sensors, robotics and serious games in order to introduce creative activities in the school classroom. A series of examples are given to show how remote experiments or simulations combined with mobile devices in the framework of game-

based approaches can support science learning. The authors provide evidence that this is an essential way for students to reach high level learning outcomes and thereby develop the basis of fundamental competences for their future personal, school, academic or professional life, as well as tackling attitudes like curiosity, creative self-efficacy, agency and responsibility. If students are allowed to evolve their own research questions, choose suitable experimentation designs and finally perform the experiment; they will be able to develop a kind of "spirit of inquiry and research". This spirit is one important premise for developing original ideas.

I had the honor and the pleasure to read the book in September 2013 just before its publication. I believe that the aim of the editors and the authors is to offer a glimpse of a future in which science learners at secondary schools can explore worlds and cultures beyond their own, both in time and distance, as if they were there. And I hope that their tremendous work, presented in this book, will serve to remind us that we must strive to apply the power of technology in ways that empower young people, enlighten their minds and enrich their lives.

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Introduction

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> *There can be infinite uses of new age technology,*
> *but if the teachers themselves are not able to bring it*
> *into the classroom and make it work, then it fails*
>
> Nancy Kassebaum [1]

Technologies play key roles in transforming classrooms into flexible and open learning spaces that tap into vast educational databases, personalize learning, unlock access to virtual and online communities, and eliminate the boundaries between formal and non-formal education.

Research indicates that in the next five years, six existing technologies have "clear and immediate potential" to be applied for teaching and learning in schools. [2] One such technology involves the use of Virtual and Remote Laboratories, which has been a key trend alongside other technologies such as Cloud Computing, Mobile Learning, Open Content, and 3D printing. Recommendation of any new technology, such as Virtual and Remote Laboratories, should be based on a broad cost-benefit analysis, while recognizing the constraints and challenges schools might face in implementing it. The most important challenges pointed out by the NMC Horizon Report include: (1) the need for ongoing professional development in schools; (2) teachers' resistance to changes; (3) the need to increasingly blend formal and informal learning; (4) the demand for personalized learning that is not adequately supported by current technology or practices; (5) the inappropriate use of digital media for formative assessment.

Information and communication technologies (ICT) receive millions in annual investment in the education sector: research and training is

conducted, software and hardware is purchased. New IT devices and gadgets are making their way into schools, offering unlimited potential to educators. But the key question remains: how have these technologies improved learners' experiences or learning performance? Despite generous contributions, the new technology usually "supports existing teaching and learning practices, rather than transforming those practices" [3]. Therefore the educational impact of a new technology is not *direct*; rather, the impact depends on how teachers and students use it in education: how they use it to learn, teach, communicate, access information, and evaluate student performance.

This book addresses these questions by exploring challenges and solutions, and by presenting a new trending approach in the school sector: online laboratories and remote experiments.

In the last decade, engineering and science communities have been continually complaining about a crisis in science, mathematics and technology education (STEM). STEM standards have been consistently declining. Schools, universities, educators, and policy makers all look for intelligent solutions on how to modernize curriculum frameworks and assessment processes, as well as implementing contemporary technological tools. Applying STEM skills within a laboratory has always been responsible for bridging knowledge and reality. On the one hand, there is no doubt: proper STEM instruction without experimentation is impossible. [4] On the other hand, the expensive laboratory equipment and its complicated maintenance led to a tremendous reduction in its usage within classrooms. Today, a solution to this serious problem involves virtual and remote laboratories where simulated or real experiments can be conducted over the Internet. It makes the lab experiments low-cost, efficient, productive and available almost everywhere, at any time.

Since 1996, the remote laboratory paradigm has been used in engineering education. Usually, an Engineering School would develop one or two remote experiments to support its curriculum. Most of the experiments are not widely known and exist side by side with famous remote labs such as ATLAS (CERN), iLAB (MIT, USA), LabShare (UTS, Australia), VISIR (BTH, Sweden), WebLab-Deusto (Spain) and so on. In the last few years, simple versions of those laboratory experiments have been proposed to the STEM school teachers' community.

This book presents the topic of modernizing the school sector through IT from a different prospective: giving educators access to top-notch

scientific/education resources and instruments, using teachers as facilitators of knowledge, and encouraging their professional development within this new role. Another objective is to introduce the audience to an IT approach of promoting a culture of experimentation and supporting students with interactive experimental laboratories. Online laboratories may prevent the marginalization of practical skills in school science curriculums.

This book is based on the results and discussions accomplished during the OLAREX project [5] and on the presentation of best practices in OLAREX topics all over the world. The structured content presents a huge opportunity for this book to give a broad, well-balanced and comprehensive overview of the problems in STEM education, and discuss teachers' professional development, ICT tools, and case studies of curriculums and assessment connected to remote experimentation. The book consists of three sections: *Transforming* Education through IT, *Engaging* STEM in Secondary Schools with Remote Experiments, and *Inspiring* Education with Remote Experiments.

The role of technology in a contemporary education is highly significant. It improves the equity, quality and attractiveness of educational opportunities for society, builds creativity, leads to free and open intellectual inquiry, helps to deliver study materials, makes learning more student-oriented, and supports teachers as instruction designers. School is responsible for equipping students today to be workers of tomorrow. Therefore, today's best ICT tools should help students ponder real-world problems and prepare them to compete in a globally linked economy.

The first section of the book discusses how technology can transform current STEM education.

In the presented "Discover the COSMOS" initiative, the influence of e-infrastructure in engaging a science classroom is demonstrated. It introduces eScience activities in everyday school practice, promotes inquiry-based learning and comprehension of how science works. Activities like this may transform science education in the contemporary school. Currently about 2000 school teachers from European countries are involved in the initiative. More than 85 000 teacher-designed educational materials for classroom are represented in the eScience repository. Therefore S.A. Sotiriou and A. Lazoudis share recipes of effective community building between researchers, teachers and students. This community is sustained by distributing and employing the collective

power of unique scientific resources –research facilities, scientific instruments, advanced ICT tools, simulation and visualization applications and scientific databases– in meaningful educational scenarios.

Technology Enhanced Learning –a challenge for teachers and schools– is explored in the second chapter. The anticipated changes in technology will enforce the transformation of learning systems and the redesign of teaching instruction by utilizing innovative technology. In the chapter, E. Trepulė, M. Teresevičienė and A. Volungevičienė answer the question about how a teacher can be a catalyst of such transitions; and how technology infrastructure can help schools take full advantage of what software, hardware, computer devices and online assessments, etc. have to offer, how teacher and school leaders can be better prepared in technology and digital learning standards. It shows the necessity of core innovation in creating the learning environment of tomorrow by using the best technology of today (e.g. social network instruments, educational films, serious games, electronics books, remote laboratories, science simulation and online facilities).

In the next chapter, A. Chioccariello introduces new scaffolding for teaching and learning in science. In general, ICT provides tools to explore the physical world, engage in lab activities, collect data in experiments and conceptualize the observations. When providing the learner with appropriate support, inquiry is crucial in order to create a balance between free exploration and guidance to avoid frustration. This chapter uses the experience developed in the UniSchooLabs to argue that an inquiry model template might scaffold the teaching and learning process of science. It becomes the evolving roadmap of classroom activities, encompassing collaborative discourse and argumentation of the investigation at hand, shared by both the teacher and learners.

Knowledge transfer in school-enterprise cooperation is presented in the following chapter, based on the results of the survey done within the framework of the OLAREX project. In the study, organized in Poland, L. Ochoa, K. Kruszyńska and T. Paprocki specify that the future of the labor market depends on the involvement of employers in the preparation of models and training programs, the introduction of practitioners to schools and the creation of incentives for companies to launch internships for school students. The lifelong learning concept can encourage and stimulate employees to pursue continuous intellectual development and employers to continually invest in human capital and labor resources.

ICT could be a beneficial solution tool for the problem presented above. In the chapter, the study on 13 small, medium and large enterprises for school-enterprise cooperation is presented.

The Chapter "Use of ICT in Bulgarian Schools and Museums", written by E. Tsekova and S. Kararadeva, completes the topic of transforming education through IT. During the OLAREX project, the ROMIE-remote robot was designed for the exhibition organized in May-August 2013 at the National Polytechnic Museum, Sofia, Bulgaria. The interactive, non-traditional use of remote experiments in the museum exhibition is an innovative element in STEM education. Such a completely new outreach can pique the society's interest in science, technology and engineering.

The second section, "*Engaging STEM in Secondary Schools with Remote Experiments*", consists of four chapters describing the integration of remote experiments into the school curriculum. These chapters "open doors" towards applying remote and virtual instrumentation in the secondary sector. The reader can become acquainted with case studies of using the Remote Reality Laboratory: BIFI, Spain (E. Cauhé, A. Ferrer, G. Ruiz), which is developed for teaching mechanics in schools; VISIR-BTH, Sweden, which helps to teach and study analog measurements and electricity (L. Claesson, I. Khan, J. Zachrisson, K. Nilsson, I. Gustavsson, and L. Håkanssonat in a Swedish upper secondary school; and B. Igelsböck, A. May, R. Oros, and A. Pester in the Austrian school curriculum); and Integrated e-Learning –INTe-L– TU, Slovak Republic (F. Schauer, M. Ožvoldová, and L. Tkáč), which is devoted to a curriculum in electricity, magnetism and electromagnetism. These laboratories help to transfer theoretical knowledge to practical skills of experiment design, measurements, data processing and their evaluation. The use of modern IT for experimentation, input capturing, fact analysis, and other remote science activities, opens top-notch education up to those for whom such activity would otherwise never be affordable or available for other social reasons.

Benjamin Franklin said: "Tell me and I forget, teach me and I may remember, involve me and I learn". This is the paradigm that highlighted the significance of experimenting and practicing in learning. Encouraging, involving and inspiring students is a tough job for teachers of the 21st century. Nowadays, the online (virtual and remote) laboratory is a leading instrument in STEM experimentation with which we can continue to

inspire tomorrow's scientists, engineers and mathematicians. It is no wonder that the experiments developed for students and available remotely worldwide can also provide pupils with cultural experiences, linking science with the humanities. The last section of the book explores the role of remote and virtual concepts in a student's creativity and inspiration.

The first paper in this section introduces a conceptual framework needed to foster the inquiring mind in secondary STEM education. These days, three trends to support creative STEM education through ICT-based learning technology development are clearly recognizable: remote labs, personal learning environments and portable devices. The authors argue that, in addition to promoting inquiry, the science laboratory can help students acquire higher-order cognitive skills such as thinking critically, applying, synthesizing, making decisions, and being creative. The integration of remote labs and e-Portfolio into mobile learning environments has been studied. The results of this research can be seen in Chapter 10, presented by C. Terkowsky, T. Haertel, E.Bielski, and D. May.

The next chapter –introduced by J. Bento da Silva, W. Rochadel, R. Marcelino, V. Gruber, S. Sommer Bilessimo– formulates the main principles of a mobile remote experimentation when applied to education. The project developed by RExLab (UFSC, Brazil) and co-executed by the Maria Garcia Pessi School of Basic Education covers access to teaching contents on mobile devices, complemented by access to remote experiments in physics at a public school from the municipality of Araranguá, in the state of Santa Catarina, Brazil. In this case study, it was noticed that proposed educational models may motivate and invigorate the students in the STEM subjects.

Serious Games allow the instructor to avoid lecture-based materials. Instead of tedious reading, these games propose an interactive content that also conveys learning in the context of entertainment and fun. In Chapter 12, I. Iturrate and I. Angulo present the readers with the research work carried out by the WebLab-Deusto group. They combine the remote experiment based on the mobile robot platform with game flow. The educational value and several possible instruction scenarios are presented.

The final work discusses a valuable contribution to the acquisition of higher-order experimental skills in science, technology and engineering. This provocative chapter presented by T. Restivo and G. Alves emphasizes that, despite the great and promised opportunities of applying online

laboratories in the school curriculum, the recognition of the acquisition of experimental skills through informal and non-formal learning activities is necessary. Although the offer of online laboratories is increasing, there is still a long way to go, namely in pedagogical and didactical terms, to take full advantage of remote and virtual instrumentations in open education.

We are eager to invite you to read the book as a whole and hope you will enjoy reading it as much as we enjoyed editing it. We encourage you to contact the authors to discuss further opportunities of using their research, science facilities and online labs in your classroom.

Finally, and most of all, we thank the Lifelong Learning Programme [5] of the European Union for financial support without which this book would have been impossible.

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SECTION 1

Transforming education

Discover the COSMOS: e-infrastructures for an engaging science classroom

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1. Introduction

The *Discover the COSMOS* initiative aims to demonstrate innovative ways to involve teachers and students in *eScience* through the use of existing e-infrastructures in order to spark young people's interest in science and pursuing scientific careers. It aims to *demonstrate effective community building* among researchers, teachers and students, as well as empowering the latter to use, share and exploit the collective power of unique scientific resources (research facilities, scientific instruments, advanced ICT tools, simulation and visualization applications and scientific databases) in meaningful educational activities. These activities should promote inquiry-based learning and appreciation of *how science works*. It also intends to *promote effective integration of science education with e-infrastructures* through a monitored-for-impact use of *eScience* activities, which provides feedback for the take-up of such large-scale interventions in Europe. This paper presents the main areas of action of the *Discover the COSMOS* initiative and discusses the approach used to introduce *eScience* activities in everyday school practice. Currently, about 2,000 teachers from every European country are involved in the initiative and they are developing practice scenarios that integrate the unique resources of the *Discover the COSMOS* repository (portal. discoverthecosmos.eu) into the school curriculum. The repository

includes about 85 000 items of user generated educational sets of material for classroom use.

There are currently numerous education reform initiatives under way in Europe as policy makers try to make schools more effective and provide students with an education that prepares them for life in the 21st century. Schools are being asked to improve the quality of education, notably by providing more students with advanced skills than in the past and the ability to be flexible thinkers and problem solvers. These reform initiatives vary and include: programmes to develop educational portals with certified content; professional development opportunities to in-service teachers; networked laptop computers for all students; classrooms with interactive whiteboards to help make lessons come alive; wireless Internet access points in schools (e.g. current governmental initiatives in Greece, Austria, Spain, Portugal); large scale ambitious plans to remodel schools and create learning environments which inspire all young people to unlock their hidden talents and reach their full potential; 21st-century work places for teachers; and finally, providing access to facilities which can be used by all members of the local community. All these efforts clearly serve –at different levels– the vision of *Re-Schooling*, towards schools as "Focused Learning Organisations" and "Core Social Centres", that is, dynamic establishments in strong cultures of equity and consensus about their value which follow system-wide, root-and-branch reform. This vision was elaborated back in 2004 by the International Schooling for Tomorrow Forum [1]. At the core of these reforms is an emphasis on 21st-century teaching and learning in which an ICT infrastructure is not merely present, but is used in the most effective ways possible. In the OECD scenarios, schools are revitalized around a strong "knowledge" agenda, with far-reaching implications for the organization of individual institutions and for the system as a whole. In the process of Re-Schooling [2], the ICT infrastructure is a fundamental support tool enabling educational establishments to comply with their central social function. Technologies are present in different teaching and learning environments, both as access stations to networks and as tools for information or data analysis and processing. They are starting to be used in quite common ways across disciplines to maximize learning results (tools for analysis, development, processing, etc.), and for specific roles in the learning process. They also encourage the development of competences and the application of relevant knowledge in simulated situations, while at other times they permit assessments, or self-evaluations, for diagnosis of aptitudes. They also

provide efficient tools for drawing up reports, portfolios and presentations of research results and projects, etc. Students and teachers are able to communicate with their peers, have access to quality databases and archives and publish in digital educational academic magazines. Working networks –with other schools and also with higher education institutions and research centres– are becoming the norm in many cases. In this context, e-Infrastructures could play an important role in supporting communications and knowledge management through shared databases, access to unique resources and archives (e.g. virtual experimentations and scientific databases), advanced instruments and tools (remote laboratories and advanced facilities). e-Infrastructures could provide powerful tools for scaling-up and transferring current pilot implementations to large scale deployments to take full advantage of the opportunities new technologies present.

In the near future, such solutions will form part of the basic infrastructure of schools, which will be transparent "resource centres" open to the community, operating under a management structure geared to organizing teaching and learning activities for and with the community. ICTs will be used in different ways for everyday school activities. There will be reconditioned PCs in theme classrooms to promote creative writing, terminals in some classrooms for consulting and searching for the information required by students for their homework and projects, mobile and wireless devices for developing defined and structured curricular activities, and sophisticated environments for creative activities and remote communications. Learning about the use and application of technology will be part of the activities focused on creation, discussion and reflection. Students will develop projects with teachers, not merely guided by them, as part of an educating community; to this end, they will use the technology available in the school to present their arguments, communicate their ideas, search for information and develop products in a co-operative way. ICTs will play a fundamental role in socialization and the students' contact with the world. Internet discussion groups at different levels (courses) will be a prominent feature of different national and international establishments, creating open spaces in which other society members will be able to participate. ICTs will help broaden the range of experiences and horizons of the actors involved in learning and the education of students. Schools will be considered spaces that are subject to physical boundaries, but *open in virtual terms to the community and the world, strongly supported by ICT*.

This will be possible through quasi-instantaneous and very broad transmission bands that are ubiquitous, invisible, specialized, and hyper-medial. ICT will be so integrated that it will not appear as an explicit element of the schools' resources and methods of work. The effective use of ICTs will enable *distributed* knowledge communities to collaborate and communicate *across* disciplines, distances and cultures. Research and education communities beyond traditional brick-and-mortar facilities will become *virtual organizations* that transcend geographic and institutional boundaries.

There are many challenges involved in the process of innovation that must be addressed if we are to take advantage of these technologies to improve learning. Technical standards must be deployed to help guide the development of education and training content that will be drawn from countless sources throughout the world. The technological community has to form stronger partnerships with the education community. Advanced technologies developed to meet other purposes must be transformed into affordable tools for teachers and learners to use. Our schools and teacher training organizations need to prepare for rapid technological change.

2. **Involving educational communities in eScience: The vision for the science classroom of tomorrow**

The publication of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report [3] brought science and mathematics education to the top of the member states' educational goals (following similar actions in the US in 1996 NRC, [4], EDC Center for Science Education, [5]). The authors argue that school science teaching needs to become more engaging, be founded on inquiry based and problem solving methods and designed to meet the interests of young people. *According to the report, the origins of the alarming decline in young people's interest for key science studies and mathematics can be found, among other causes, in the old fashioned way science is taught at school.* The crucial role that positive contact with science at a younger age has in the subsequent formation of attitudes toward science has been emphasized in many studies (e.g. PISA [6]). However, traditional formal science education too often fails to foster these, thus negatively affecting the

development of adolescents' attitudes towards learning science. Also, as [7] has pointed out, the tension created between objectivism (the objective teacher-centered pedagogy) and constructivism (the constructive and student-centered pedagogy) represents a crucial classroom issue influencing teaching and learning. The TIMSS (Third International Mathematics and Science Study) 2003 International Science Report [8] specifically documented that the three activities accounting for 57 percent of class time were: teacher lecture or teacher's explanation (24%), teacher-guided student practice (19%), and students working on problems on their own (14%) in science classes in the European countries participating in the study.

Therefore, it appears that the current science classroom learning environment is often a mixture of divergent pedagogies and diverse students' orientations or preferences ([9], [10]). The fact is that there is a major mismatch between opportunity and action in most education systems today. This revolves around the meaning of "science education," a term that is often misappropriated in current school practice, where *rather than learning how to think scientifically, students are generally being told about science and asked to remember facts* [11]. This disturbing situation must be corrected if science education is to have any hope of taking its proper place as an essential part of the education of students everywhere. In addition, recent research on learning and instruction has substantially advanced our understanding of the processes of knowledge and skill acquisition [12]. However, school practices have not changed in ways that reflect this progress. Moreover, modern technologies (e.g. advanced visualizations, simulations, virtual worlds and shared collaborative environments), which go beyond the use of simple applications and the Internet, have not been fully integrated/incorporated into the current science learning environment. According to the recent report "Science Education in Europe: Critical Reflections" [13], the most serious problem in science education is one of fundamental purpose. Schools, the authors argue, have never provided a satisfactory education in sciences for the majority. Now the evidence is that it is failing even in its original purpose: to provide a route into science for future scientists. *The challenge, therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students, those who will go on to work in scientific and technical subjects, and those who will not* [14].

In our view, *the science classroom* should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools. It should enrich and transform the students' concepts and initial ideas, which could serve as either resources or barriers to emerging ideas. The science classroom should offer opportunities for teaching tailored to the students' particular needs while it should also provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and produce a record of competence that is compelling to students.

ATLAS Student Event Challenge
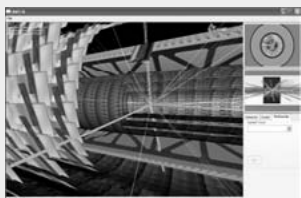
The ATLAS Student Event Challenge (ASEC) project (www.learningwithatlas.eu) makes it possible for students and teachers to explore the particle collisions taking place in the ATLAS detector at the highest collision energies available in the laboratory. ASEC melds together several state-of-the-art capabilities. The main activities of the project include: a) analysis of particle collisions (events) from the ATLAS experiment through the use of an educational Data Analysis package, b) detector and physics process animations (2D and 3D) and Virtual Reality event display. The students are able to analyze the events using the analysis package and the virtual reality event and detector display. The project uses the best aspects of technical animation by allowing students and others to manipulate 3D images of the detector, and then look to see how particles are detected as they pass through. In addition, students observe 3D animations of events representing new physics processes and analyze them to see if they recognize patterns of new physics processes.

There are already numerous educational eScience activities that use remote research databases, scientific instruments and data analysis tools and advanced infrastructure for collaboration and communication purposes. This field has huge potential for engaging students in scientific inquiry and debate and thus to contribute to the teaching of the skills required to participate in or follow public debates on scientific issues. It also promises new IT-based authentic assessment instruments and higher

standards in science education. The field of *eScience* could support the vision for the development of a more challenging science classroom environment through:

- access to research data and archives (e.g. data from CERN detectors, telescopes);
- access and use of scientific instruments such as telescopes;
- use of advanced tools for data acquisition and analysis;
- presentation of computer models of objects, processes or phenomena being studied;
- remote and local communication and collaboration on scientific topics and data;
- flexible and commonly understandable instruments for authentic assessment of learning results.

As a result, teachers can easily choose to use a constructivist approach each time it is most appropriate. The *eScience* applications help to structure educational processes around students' growing abilities to take on increasingly larger and more significant projects and also to design feasible interesting student projects at different levels.

3. The role of research infrastructures and of the outreach programs

Research infrastructures play an increasing role in the advancement of knowledge and technology and their exploitation. Because of their ability to assemble a 'critical mass' of people and investment, they contribute to national, regional and European economic development. They are therefore at the core of the knowledge triangle of research, education and innovation. The *eResearch2020 –The Role of e-Infrastructures in the Creation of Global Virtual Research Communities*– study [15] was carried out on behalf of the European Commission, Directorate General Information Society and Media, in order to better understand the organizational, collaborative and technological developments in e-Infrastructures which are effective in supporting virtual research organizations in different fields. It concluded with four scenarios for the future, promoting as the ideal one the *Research Revolution*, in which change takes place at all levels, including schools. In this framework, the

Discover the COSMOS initiative aims to add its contribution to the efforts for the realization of the Europe 2020 strategy, which announces a re-focusing of research and innovation policy for building Europe's innovative advantage by: a) demonstrating the key role of e-Infrastructures in the development of highly motivating and flexible learning environments, b) demonstrating *how science works*, c) implementing a series of innovative *eScience* scenarios (the *Discover the COSMOS* Demonstrators) for school practice that provides teachers and students with access to unique scientific resources organized under a systematic pedagogical framework, and d) providing a model for the coordination of educational and outreach activities of major research infrastructures.

A. *Developing more conductive, highly motivating and flexible learning environments*

There are many educational and outreach initiatives that aim to introduce the work of the scientist in the school classroom. *Hands on Particle Physics Masterclasses* (http://www.physicsmasterclasses.org), initially implemented at a European scale in 2005 in the framework of the *World Year of Physics*, is demonstrating to the students *how science works* and the *Galileo Teachers Training Programme* (http://www.site. galileoteachers.org/), initially proposed in 2009 in the framework of the *International Year of Astronomy*, offers training to science teachers on how to use the scientific methodology in their classrooms. Both these initiatives are regarded as extremely successful in the field worldwide. The *Discover the COSMOS* initiative aims to build on these successful initiatives and to go a step further, by proposing ways that (through the effective use of existing e-infrastructures) *could scale them up to include more students and teachers worldwide*. By utilizing the existing e-Infrastructures, the *Discover the COSMOS* initiative brings into the classroom activities that are based on real-world problems and involves students in finding their own answers and solutions, testing their ideas, receiving feedback, and working collaboratively with other students and researchers beyond the school classroom. For example, following the model of Hands on Particle Physics Masterclasses, *a series of virtual collaboration activities*, called *e-Masterclasses* has been designed and implemented, *promoting inquiry based and problem solving processes in virtual and blended learning environments*. In this case

students can perform the assigned tasks from their schools and allow more schools to be involved in the process. Collaboration in the framework of e-Masterclasses demonstrates the potential of e-Infrastructures to meet the large computational demands of the on-line collaborative learning processes. For instance, the extended computational capabilities of GEANT could enable the exploitation by teachers and students with limited ICT resources (e.g. school communities in remote or disadvantaged areas) of the advanced *Discover the COSMOS eScience* applications that provide innovative ways for teaching and learning. To this end, the *Discover the COSMOS* Communities Support Environment offers innovative, interactive, collaborative and context-aware functionalities, which are student-centred and focused on contextualized and adaptable learning experiences.

Hands on Particle Physics Masterclasses (http://www.physicsmasterclasses.org/)

Each year about 6,000 high school students in 23 countries come to one of some 110 nearby universities or research centres for a day in order to unravel the mysteries of particle physics. Lectures from active scientists give insight into topics and methods of basic research into the fundaments of matter and forces, enabling the students to perform measurements on real data from particle physics experiments themselves. At the end of each day, as in international research collaboration, the participants come together in a video conference for discussion and compound of their results. The Hands on Particle Physics Masterclasses is a powerful illustration of how an *eScience* experience can provide rich and meaningful opportunities for people to participate in and learn about science. With the appropriate guidance from the research teams, students can use tools of science as they learn the practices, goals and habits of mind of the culture of science. Similarly, in the framework of this initiative, the scientific community responded to participants, modifying their project design as a result of feedback and continued interest in the project [16]. Through this fruitful collaboration, the relationship between scientists and students evolved, resulting in all members contributing and gaining valuable scientific knowledge.

B. *Demonstrating how science works*

The *Discover the COSMOS* activities simulate the work of real scientists who have access to facilities and resources regardless of their location. In this way, our approach is focusing on the presentation of new working methods and models based on the shared use of resources across different disciplines between researchers in virtual research communities in all *eScience* fields. The *Discover the COSMOS* approach aims to demonstrate a series of educational activities in which *students will be engaged in "border crossings" from their own everyday world culture into the subculture of science*. The subculture of science (collective set of norms, practices, language and tools) is in part distinct from other cultural activities and in part a reflection of the cultural backgrounds of scientists themselves. By developing and supporting experiences that engage learners in a broad range of science practices, we can increase the ways in which students identify with and obtain meaning from their science learning experiences. The educational context of the *Discover the COSMOS* is not transmitted in a theoretical way but rather in a biomatic way in the form of a real life experience. It provides ICT tools and scaffolds that enhance learning, support thinking and problem solving, model activities and guide practice, and which allow the representation of data in different ways. In the framework of the activities, students are able to personalize a set of resources for reference and problem solving. A great variety of learning activities are supported from the *Discover the COSMOS eScience* applications: browsing and querying Internet resources from different research centres and laboratories; virtual visits to advanced research infrastructures where the experimental settings are presented to students as 3-D visual objects and representations (e.g. walking in a visualized magnetic field); realization of remotely controlled experiments using advanced experimental instruments (e.g. telescopes and particle detectors); communication with fellow students, teachers and experts; experimentation with everyday phenomena; visualization of complex physical phenomena or mathematical problems (e.g. performing geometrical calculations in 3D environments). A rich collection of technical tools, appropriately orchestrated in the *Discover the COSMOS* learning environment, are available to teachers and their students. During the activities students' initial predictions can be compared with data from

the different experiments that they will have the chance to carry out. The consortium believes that the proposed approach will improve everyday teaching for several reasons:

– *Increasing motivation:* Students are more likely to feel a sense of personal investment in a scientific investigation as they will actively participate in the research procedure and will add their own aesthetic touches to the different tools they are using for experimentation. Such an approach could help to make science "fashionable" among students. It has to be also noted that inquiry based pedagogy (supported by the use of ICT tools) addresses a variety of learning styles and strengthens higher order thinking skills essential for success in mathematics, science, engineering and technology related courses.

– *Extending experimentation possibilities:* The use of advanced experimental infrastructures (like telescopes) and the access to data from frontier experiments (like ATLAS and CMS) can serve as spurs to the imagination, promoting the interest of the students to become involved in scientific investigation. They personally experience the procedures involved in an authentic research project and thereby gain a far better understanding of science and engineering. The proposed procedure is freed from the pressing time limitation of the teaching hour. Therefore, their classroom is transformed into a scientific laboratory. We believe that students can come to view the astronomical observations or the data analysis procedures as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression.

– *Developing critical capacity:* Too often students accept the readings of scientific instruments without question. When students are involved in the proposed activities, for example, by performing their own experiments and observations, they should, as a result, develop a healthy scepticism about the readings and a more subtle understanding of the nature of scientific information and knowledge.

– *Making connections with underlying concepts:* Our working hypothesis is that amending the traditional scientific methodology for experimentation with visualization applications and model building tools helps students and learners in general to articulate

their mental models, make better predictions and reflect more effectively. Additionally, working to reconcile the gaps and inconsistencies within their mental models, system models, predictions and results provides the learners with a powerful, explicit representation of their misconceptions and a means to repair them with.

– *Understanding the relationship between science and technology:* Students gain firsthand experience in the ways that technological design (and mainly e-Infrastructures) can both serve and inspire scientific investigation. The *Discover the COSMOS* learning environment offers the option of teaching students as individuals, in small groups and in large groups, while it provides links to other schools and research facilities in their country and abroad. The versatility of the tools that are integrated is one of the most compelling factors of the *Discover the COSMOS* learning environment.

A sustained school-research experience like Hands on Particle Physics Masterclasses provides an ideal opportunity for students to familiarize themselves with the process and culture of science and even to become engaged participants in the scientific enterprise. Through participation in such *eScience* activities, students can develop a greater appreciation of how scientists work together and the specialized language and tools they have developed. In turn, students also can refine their own mastery of the language and tools of science. For example, students participating in the "Higgs Boson Hunt" mission come together as a community to solve a particular problem (see Figure 1). Using the tools of science to analyze data and to select the best candidates, students become more familiar with the means by which scientists work on their research problems (e.g. selection of a small number of candidate events out of extremely large amounts of data through the development of effective filtering mechanisms). The repertoire of the selected *eScience* applications (see Table 1) facilitates various patterns of group working. Flexibility is the key, because whatever visions of education we design our systems around, we can be sure that they will need to perform in a very different way in a few years' time.

The *Discover the COSMOS* learning environment allows students to work through material at their own pace, with different levels of support
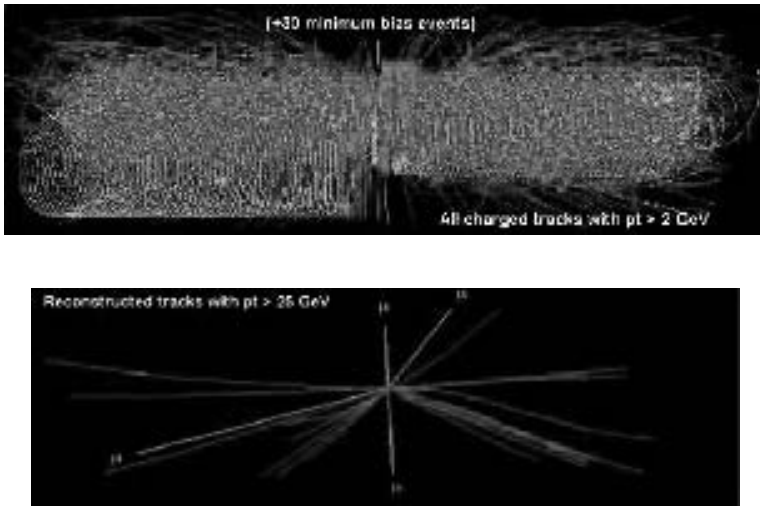
Figure 1

Students are involved in activities like "The LHC Data Challenge": Starting from the event on the right we are looking for the "signature" on the left (images from CERN). By involving students in such activities and problems in eScience, we can demonstrate the need for significant computing power and the importance of e-Infrastructures in such scientific process.

according to their own preferences. Inevitably, different students embrace technology to greater or lesser extents and in different ways through the complementary interfaces the system offers. By engaging in scientific activities, students also develop greater facility with the language of scientists; terms like *hypothesis*, *experiment* and *control* begin to appear naturally in their discussion of what they are learning. Students thus begin to gain entry into the culture of the scientific community and start to change the way they think about themselves and their relationship with science. They see themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science. When a transformation such as this one takes place, young people may begin to think seriously about a career in a research laboratory.

C. *The Discover the COSMOS repertoire of escience resources –*
   developing authentic educational experiences

The *Discover the COSMOS* pedagogical framework highlights and
promotes exemplary educational and outreach activities for schools. Such
a process will help to chart the course into the future. By building on the
best of current practice, the *Discover the COSMOS* approach aims to take
us beyond the constraints of present structures of schooling (pedagogical,
organizational and technical barriers) toward a shared vision of excellence.
The *Discover the COSMOS* approach presents a series of exemplary
practices, resources and applications (analysis tools, data repositories,
simulations and advanced visualizations) which provide students with
experiences that enable them to achieve scientific literacy, criteria for
assessing and analyzing students' attainments in science and learning
opportunities that school programmes afford.

The Discover the COSMOS Demonstrators are the window onto live
scientific experiments and phenomena, ongoing research and the
personalities and stories of working scientists across Europe. The *Discover
the COSMOS* initiative brings together key players in the field of Particle
Physics (e.g. CERN in Europe and LBL in US) and Astronomy outreach
that have invested major efforts to introduce frontier research issues into
the school classrooms in Europe and beyond. *The CERN High School
Teachers Training Programme* (http://teachers.web.cern.ch/teachers/), *the
HandsOnParticlePhysicsMasterclasses*(http://www.physicsmasterclasses.
org/), *the Galileo Teachers Training Programme* (http://www.site.
galileoteachers.org/), *the Hands On Universe initiative* (http://*www.euhou*.
net/), the National Schools Observatory (http://www.schoolsobservatory.
org.uk/), *the SkyWatch Contest* (http://www.discoveryspace.net/
skywatch2007/) are some indicative examples of successful initiatives that
make use of large scale research infrastructures (detectors, accelerators and
telescopes) and advanced *eScience* applications. Fig. 2 presents the
Discover the COSMOS backbone infrastructure that facilitates the
deployment of the proposed inquiry based activities in European science
classrooms. The *Discover the COSMOS* infrastructure consists of user-
friendly interfaces which abstract service provision from the underlying
research infrastructure complexities, while they provide environments for
virtual access to (remote) instruments, as well as user-driven "composition"
of virtual facilities and test beds.

The necessary link to the school science curriculum will be implemented using a multilingual *Science Education Vocabulary* that has already been developed by the consortium members ([17], [18]). The goal of the *Science Education Vocabulary* is to associate the users, the educational activities and pedagogical models. Such an approach also addresses the multilingual and multicultural issues arising from this project. The *Discover the COSMOS* applications and the proposed scenarios of use offer a "feel and interact" user experience, allowing for learning "anytime, anywhere" by employing advanced and highly interactive visualization technologies and also personalized ubiquitous learning paradigms in order to enhance the effectiveness and quality of the teaching and learning process. These materials have been tested in different educational settings (schools, teacher training centres, outreach programmes, workshops and summer schools) in Europe and beyond, and they have proved their efficiency and efficacy as inquiry based resources.

In the framework of the *Discover the COSMOS* initiative we are proposing value-added services to increase the utility of these resources through coordination, systematic dissemination and effective teachers' community building. Table 1 presents the main research infrastructures and applications integrated in the *Discover the COSMOS* repository.

The *Discover the COSMOS* Demonstrators are treated as case studies and they are tested in different environments (teacher training and professional development institutions, schools) across Europe during the life cycle of the project. The process of observing and reflecting on teachers' actions and on students' learning and thinking can lead to changes in the knowledge, beliefs, attitudes, and ultimately, the practice of teachers. Teachers can extend and apply knowledge presented in the case studies, formulate questions and ideas, learn from one another, become aware of alternative perspectives and strategies, reflect on real problems faced by practicing teachers, and increase their knowledge of science, as many science topics are covered in the selected case studies.
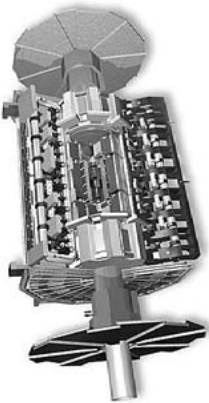
Figure 2

The *Discover the COSMOS* environment contributes to the access to and sharing of advanced tools, services and learning resources for schools. The service aims at the deployment of a virtual science thematic park that connects schools, universities and science museums with a network of robotic telescopes around the world. The system is based on the use of Grid technology to facilitate fast and reliable access to the network of the telescopes and the databases of the participating observatories. The aim is to bring to students, teachers, researchers and individuals (amateur astronomers, visitors of science parks) all around the world the opportunity to use remotely controlled robotic telescopes in real time giving accessibility to unique resources as the sky is a vast and unique laboratory of science, always in operation, accessible at all times from everybody from everywhere, where all sorts of interesting physical phenomena take place most of which is impossible to reproduce in any scientific laboratory. Finally it supports the provision of key skills to the future citizens and scientists (collaborative work, creativity, adaptability, intercultural communication).
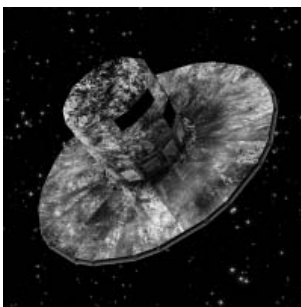
Table 1

Advanced Research Infrastructures and eScience applications that will be used in the framework of the Discover the COSMOS educational activities
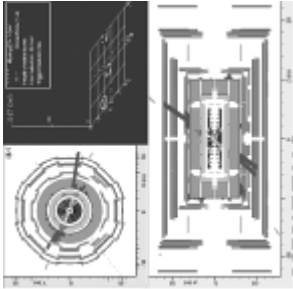
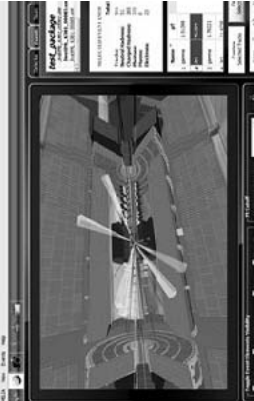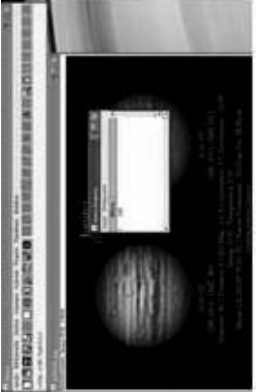| Research Infrastructures	
ATLAS (www.atlas.ch) is a particle physics experiment at the Large Hadron Collider at CERN. The ATLAS detector is searching for new discoveries in the head-on collisions of protons of extraordinarily high energy. ATLAS will learn about the basic forces that have shaped our Universe since the beginning of time and that will determine its fate. Among the possible unknowns are the origin of mass, extra dimensions of space, unification of fundamental forces and evidence for dark matter candidates in the Universe.	
CMS (http://cms.web.cern.ch/cms/) is a high-energy physics experiment in Cessy, France, part of the Large Hadron Collider (LHC) at CERN. CMS is designed to observe a wide range of particles and phenomena produced in high-energy collisions in the LHC. Like a cylindrical onion, different layers of detectors stop and measure the different particles and use this key data to build up a picture of events at the heart of the collision. Scientists then use this data to search for new phenomena that will help to answer such questions as: What is the Universe really made of and what forces act within it? And what gives everything substance? CMS will also measure the properties of previously discovered particles with unprecedented precision and be on the lookout for completely new, unpredicted phenomena.	

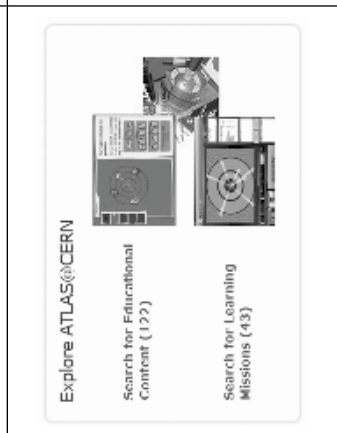|	
The Large Hadron Collider (LHC) is a particle accelerator used by physicists to study the smallest known particles: the fundamental building blocks of all things. It will revolutionize our understanding from the minuscule world deep within atoms to the vastness of the Universe. Two beams of subatomic particles called 'hadrons' –either protons or lead ions– will travel in opposite directions inside the circular accelerator, gaining energy with every lap. Physicists will use the LHC to recreate conditions just after the Big Bang by colliding the two beams head-on at very high energy. Teams of physicists from around the world will analyze the particles created in the collisions using special detectors in a number of experiments dedicated to the LHC.	
Gaia (http://www.esa.int/science/gaia) is an ambitious ESA mission to chart a three-dimensional map of our Galaxy, the Milky Way, in the process revealing the composition, formation and evolution of the Galaxy. Gaia will provide unprecedented positional and radial velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars in our Galaxy and throughout the Local Group. This amounts to about 1 per cent of the Galactic stellar population. Combined with astrophysical information for each star, provided by on-board multi-colour photometry, these data will have the precision necessary to quantify the early formation, and subsequent dynamic, chemical and star formation evolution of the Milky Way Galaxy.	

	The Faulkes Telescope Project (http://www.faulkes-telescope.com/) is the education arm of Las Cumbres Observatory Global Telescope Network (LCOGTN). LCOGTN operates a network of research class robotic telescopes. Currently there are two telescopes, one in Hawaii and the other in Australia. These telescopes are available to teachers for them to use as part of their curricular or extra-curricular activities and are fully supported by a range of educational materials and a team of educators and professional astronomers.
	The Liverpool Telescope, http://telescope.livjm.ac.uk, is a fully robotic astronomical telescope (located on the Canary Island of La Palma) owned and operated by the Astrophysics Research Institute of Liverpool John Moores University in north-west England. It was designed and built by Telescope Technologies Limited, a spin-off company of the University, as the prototype of their production-line range of two-metre class telescopes. The LT was therefore the "first off the line". The telescope itself is a two-metre Cassegrain reflector, with Ritchey-Cretien hyperbolic optics, on an altazimuth mount. Up to nine different instruments can be mounted at the Cassegrain focus, one in the "straight through" position and eight more on side ports accessible by a rotating "science fold" tertiary mirror.

***eScience* Applications**
(2D and 3D interfaces and analysis tools, Scientific data repositories and archives, educational repositories)

HYPATIA http://hypatia.phys.uoa.gr/ (Hybrid Pupil's Analysis Tool for Interactions in Atlas) is part of the ATLAS Student Event Challenge (ASEC), a contemporary educational project regarding Particle Physics. HYPATIA is focused on high-school education and engages students to work with the most advanced techniques used by modern particle physics. It enables students to obtain a better understanding of the interactions between fundamental particles of matter by studying "events" detected by the ATLAS experiment. The deployment of such tools simplifies the teaching of physical principles and eliminates the idea that physics and Science in general is too complicated to understand.

MINERVA http://atlas-minerva.web.cern.ch/atlas-minerva/ is an interactive analysis tool for students to learn more about the ATLAS experiment. It is based on a simplified setup of the ATLAS event display, Atlantis, which allows users to visualize what is happening in the detector by using 2D animations. Minerva has currently developed two main scenarios of use which are both based on identifying particles produced from collisions. Students have the chance to get a glimpse of how scientific experiments are performed in particle physics and how new discoveries are made.

Description	Screenshot
AMELIA http://amelia.sourceforge.net/index.html is a 3D application with focus on particle physics processes in ATLAS. It allows students and other users to acquaint themselves with collision events that are produced within ATLAS, analyze their data and study the tracks of particles. AMELIA is the only tool that provides 3D representations of the collision events enabling students to see how particles are detected as they pass through. It allows the user to rotate, zoom and select virtual pieces of the ATLAS detector and events. Videos, animation, sound, interactive visualization and data analysis are integrated in a single framework, making AMELIA a very useful and effective tool in the hands of students.	
SalsaJ http://www.euhou.net/ is a student-friendly astronomical images analysis tool. It works with FITS image format thus making it suitable for analyzing images from most professional telescopes. SalsaJ is designed to be easy to install and use. It allows students to display, analyze and explore real astronomical images and other data in the same way that professional astronomers do, making the same kind of discoveries that lead to true excitement about science. SalsaJ is available in 25 European languages and it is widely used by teachers in many European countries.	
LTImage http://www.schoolsobservatory.org.uk/astro/tels/ltimage is a simplified image processing tool specially designed for students. It is developed by the National Schools' Observatory and it aims to facilitate educational activities that require analysis of image data from astronomical telescopes. LTImage works with FITS image format, thus making it suitable for analyzing images from most professional telescopes.	

	The **"Sun for all" scientific archive** http://www.mat.uc.pt/sun4all/ includes over 30,000 Sun images captured over the last 80 years. It aims to promote Science in general and astronomy in particular among students. "Sun for all" focuses on the exploration of the Sun's properties by students when using real scientific data and tools and thus implements the teaching of mathematics, sciences and elementary informatics.
	The **Discovery Space Portal** (www.discoveryspace.net): This portal offers access to 6 robotic telescopes seamlessly incorporated into one virtual observatory and provides the services required to operate this facility, including a scheduling service, tools for data manipulation and access to related educational materials. The portal gives students the opportunity to use remotely controlled telescopes in real-time. In this way it enables students to increase their knowledge on astronomy, astrophysics, mathematics and other science subjects and also improve their computer literacy while strengthening their critical thinking skills. Students are able to graphically view all quantities under study and the data correlations. The service has 1,100 registered users (teachers and students).

COSMOS Portal (www.cosmosportal.eu): The COSMOS portal is an experimental laboratory for students and teachers aiming to improve science instruction by expanding the resources for teaching and learning in schools and by providing more challenging and authentic learning experiences. The COSMOS Portal offers tools and templates that help teachers to design their own inquiry based activities using numerous resources (photos, videos, animations, exercises, graphs, links). Additionally, it offers tools for community building and collaboration. The COSMOS portal currently contains more than 100,000 items of Educational material and Learning Activities, while it is frequently used by the 3,000 active registered teachers.

The Learning with ATLAS@CERN Portal (www.learningwithATLAS-portal.eu): This portal contains educational resources, such as access to near real-time data and interactive analysis tools (e.g. AMELIA, HYPATIA tools allow users to explore the ATLAS experiment in an intuitive way, which is much friendlier to students, http://atlas.ch/students.html), 3D and 2D animations of physical processes in a game-like approach, teacher resources (e.g. professional development materials, lesson plans, projects and activities, http://teachers.web.cern.ch/teachers/), student-centred materials (e.g. data library, communication area, student magazines), applications for educational projects and collaborative activities.

4. **Discover the COSMOS educational content**

The *Discover the COSMOS* educational repository currently (mid 2013) includes over 85,000 science education learning objects and activities connected to the science curriculum. It includes data and tools (e.g. databases of numerous observatories across the world, simulations of physical phenomena), teacher resources (e.g. learning scenarios and lesson plans, professional development materials, exams), student-centered materials (e.g. data library, communication area, student worksheets), as well as applications for observations and collaborative activities. Additionally, the *Discover the COSMOS* repository includes high quality applets simulating important astrophysical phenomena, such as eclipsing binaries, stellar evolution on the H-R diagram, lunar phases, planetary orbits, planetary motion and planetary obliquity, as well as simulations of interactions performed at high energy collisions of particles taking place in accelerators and numerous real data from the CERN detectors. Instructions, simulations and explorations are offered for both the student and instructor, including assessment. A series of movies (solar and lunar eclipses, meteoroids collapses on lunar surface, how LHC works) are also part of the collection. Table 2 presents the profile of the science education content currently stored in the repository.

Table 2

Discover the COSMOS Educational Content and Learning Activities
(as of 31/07/2013)

Content Type	Current Population	
Science Education Content	Educational Scenarios, Lesson Plans, Presentations	766
	Images/Graphs	83 847
	Movies and Simulations	405
Discover the COSMOS Learning Activities		1428
Discover the COSMOS Learning Activities (for Mobile Devices)	50 (in English and German)	

5. **Coordination of Educational and Outreach Activities**

By bringing together outreach groups from Particle Physics and Astronomy who have developed unique *eScience* applications and educational and training programmes for teachers and students, the *Discover the COSMOS* action aims to propose a generic framework for the design, development, implementation and evaluation (both short and long term) of effective Educational and Outreach activities. The aim of the consortium is to formulate a common set of guidelines and recommendations on how scientific work can be used to provide an engaging educational experience through the exploration of "real science". Research on learning science makes it clear that it involves the development of a broad array of interests, attitudes, knowledge and competences. Clearly, learning "just the facts" or learning how to design simple experiments is insufficient. In order to capture the multifaceted nature of science learning, the *Discover the COSMOS* approach proposes a roadmap that includes a series of "strands for the design of the Educational and Outreach Activities" and articulates the science-specific capabilities supported by the environment of a research infrastructure. This framework builds on a four-strand model developed to capture what it means to learn science in school settings[4] by adding two additional main strands incorporated for informal science learning, which reflect a special commitment to interest, personal growth and sustained engagement, the hallmark of informal settings.

The strands will provide a framework for thinking about elements of scientific knowledge and practice. The proposed framework will also describe a series of support functions that have to be deployed for the long-term impact of the proposed activities to be safeguarded. Such support actions could include support for: the integration and coordination of educational and outreach activities between groups across different research institutions; the science community and scientists interested in educational and outreach activities; the education communities interested in scientific content and applications; special events and activities that provide means and tools for web-based communication and collaboration. This framework, shown in Table 3, provides a useful reference for helping teachers and outreach groups in the informal science education community to articulate learning outcomes as they develop programs, activities, and events, and further explore and exploit the unique benefits of introducing *eScience* in schools.

Table 3

The main strands and the Educational Objectives for the design and implemen-
tation of Educational and Outreach activities for involving students in eScience

Strands	Educational Objectives
Sparking Interest and Excitement	Experiencing excitement, interest and motivation to learn about phenomena in the natural and physical world.
Understanding Scientific Content and Knowledge	Generating, understanding, remembering and using concepts, explanations, arguments, models and facts related to science.
Engaging in Scientific Reasoning	Manipulating, testing, exploring, predicting, questioning, observing, analyzing and making sense of the natural and physical world.
Reflecting on Science	Reflecting on science as a way of knowing, including the processes, concepts and institutions of science. It also involves reflection on the learner's own process of understanding natural phenomena and the scientific explanations for them.
Using the Tools and Language of Science	Participation in scientific activities and learning practices with others, using scientific language and tools.
Identifying with the Scientific Enterprise	Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses and sometimes contributes to science.

Furthermore, such an action implies an integration of knowledge
areas, effective and close cross-institutional collaboration and organi-
zational change in the field of science education. It has to be noted though
that the achievement of high quality science teaching requires the
combined and continued support of all involved: researchers, policy
makers and curriculum developers, science teacher educators, teachers,
students and parents.

6. **Impact Analysis**

The *Discover the COSMOS* environment has been designed to facilitate science teachers' search, retrieval, access and use of both scientific and educational resources. It introduces teachers to an innovative methodology for designing, expressing and representing educational practices in a commonly understandable way through the use of user-friendly authoring tools. In order to understand its practical functionalities and to validate its use, the *Discover the COSMOS* environment was studied in detail in real conditions for a period of 2 years. The tools were presented to the user communities on different occasions (training courses, workshops). The *Discover the COSMOS* initiative is supported by a very active community of 2,000 science teachers from many European countries. The content of the repository is available in English, German, Greek, Finnish, French, Spanish, Portuguese, Swedish, Bulgarian and Turkish.

According to our findings from the large scale implementation, by deploying easy-to-use uploading and search mechanisms, the *Discover the COSMOS* initiative seems to provide a major support tool for its users in their professional work. The use of the advanced infrastructures, and more specifically the robotic telescopes and the use of real data from the CERN detectors, are highly motivating activities for the students. In addition, the use of an effective and efficient classification scheme, one that proposes the organization of the available user-generated content according to curriculum needs, and the offer of structured learning materials for classroom use based on the most popular teaching strategies seem to encourage users to re-visit the portal regularly. The data collected demonstrate that the *Discover the COSMOS* repository is able to retain them long enough to substantiate high growth rates. The exponential growth in the number of contributors to the repository is accompanied by an exponential growth of uploaded content. COSMOS users contribute numerous educational materials (about 50 learning objects per contributor) while they repeatedly visit the *Discover the COSMOS* environment.

For a deeper analysis, a series of additional parameters were studied, comparing the initial phase of the operation of the repository with a subsequent phase. These parameters comprised the total number of the repository visitors (all, new and returning unique visitors); page-views;

pages per visit; and a series of parameters that demonstrate visitors' loyalty, such as the average time spent on site per visit and the depth of each visit (number of pages visited). According to the data obtained, a significant behavioral change has been identified as returning users access the repository more and more frequently in after-school hours, presumably during the preparation of lessons, just as the educational design of the *Discover the COSMOS* environment had expected.

Furthermore, we benchmarked the *Discover the COSMOS* web usage against the law of surfing [19]. As the quantitative results demonstrate, new users follow a typical surfing pattern. However, returning users (who comprise more than 50% of all *Discover the COSMOS* visitors) outperformed this pattern substantially by "foraging" frequently, deeper and longer for the science education content offered by the *Discover the COSMOS* repository (see Fig. 3).

The graph shows the equation:
$$P(L) = \sqrt{\frac{\lambda}{2\pi L^3}} \exp\left(\frac{-\lambda(L-\mu)^2}{2\mu^2 L}\right)$$
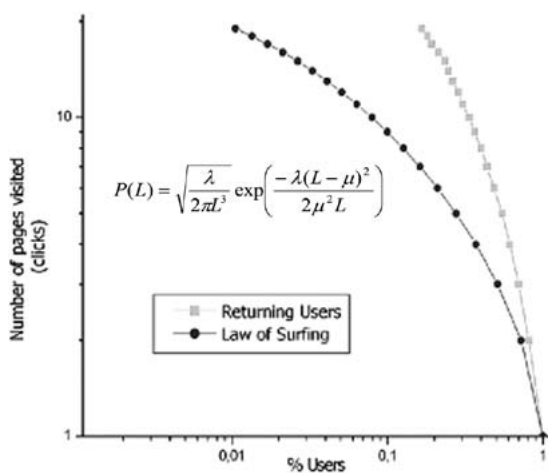
Figure 3

Returning repository users show high levels of loyalty, stay longer on site, make more page views. They are benchmarked against the law of surfing and outperform it. About 15% of the repository users visit more than 20 pages per single visit. The graph presents the probability P(L) of the number of pages L that a user follows in the portal. This model was verified by comparing its predictions with detailed measurements of surfing patterns. These quantitative results indicate that the Discover the COSMOS enviroment exhibits patterns of offering substantial value to its users in the science education community [20].

The presented study may enrich our understanding of the most effective ways of organizing and using scientific resources in teaching practices. It may also provide a more comprehensive basis for designing more efficient educational digital repositories that could support innovative teaching practices and support the development of effective links between research and school education. Such findings also play a critical role in informing the next design cycle for such systems. Moreover, by focusing on teacher practice, this work is advancing the role of *eScience* applications in supporting teacher collaboration and context-building activities. In particular, involving teachers as the designers of learning activities that are relevant to their classroom needs helps them participate in the emerging education cyber infrastructure: first they become users of online resources and eventually close the loop by contributing new learning activities to education digital libraries using online resources. This method can also be used for a number of interesting web applications. Because of the web's digital nature and great use, it is relatively easy to obtain online data that could reveal more novel patterns of information foraging, and one could extend the method to determine the distinct characteristics of different user communities.

7. **Acknowledgements**

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Technology enhanced learning: challenge for teachers and schools

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1. Introduction

Seeking success in a global economy and society that is becoming more and more varied means that young people need a wider variety of skills than ever before. Most young people will do jobs that do not exist nowadays, most of them high-skilled and related to computers that do not exist yet. Technologies will change the world in the way we cannot possibly imagine at present. The anticipated technological changes will make it necessary to change the teaching curriculum, as the skills needed to use the most updated information and communication technologies (ICT) are becoming as important as reading, writing and counting skills.

2. Teacher – as a catalyst for change

The problems of a changing society and education put great pressure on teachers. As [3] has already pointed out, building a learning society requires teachers to become professional learners. The teacher, as a citizen of a learning society, must have personal skills such as openness to novelty, creativity, cooperation skills and readiness to update existing knowledge. On the other hand, adequate professional training is also crucial. A teacher has to comprehend the goals of a learning society, as well as master new teaching methods and tools.

There are two major reasons –those most often mentioned in theoretical work– for introducing information technologies in schools:

– *Pedagogical*. Educators have pointed out that technology enhanced learning fosters better and quicker acquisition of skills. Research has proved that test results of students who use computers are 10-15 % higher than those of their peers. On the other hand, ICT may help to implement new education goals and fill the gap between education and realities of economy and society. Computers and ICT help to create a new, ICT-enhanced learning environment that supports acquisition of critical thinking skills, integration of different topics, application of active methods, employing individual skills of a child, autonomous and group working skills. Specialists in educational change and ICT solution developers see the need for the implementation of modern technology enhanced didactics.

– *Social*. The information explosion and the rapid development of communication networks have brought about new possibilities to receive and spread information, communicate, express opinion and actively participate in social and political life. Citizens' ability to participate and create society will depend on the ability to use modern ICT, to receive and spread information [6].

3. **Teacher ICT skills**

While planning and improving the teaching curriculum, it is important to prepare interesting and attractive teaching and learning materials that include ICT. Contemporary youngsters are the children of technologies – they are "digital natives", naturally born into the existing and developing ICT environment. They take technologies for granted naturally. Therefore, employing the media that is natural and interesting to them may lead to very effective results. "Digital native" is defined by [6] as a native speaker of technology, fluent in digital language of computers, video games, and Internet. The presentation [1], entitled "Capturing the Imagination of the Digital Native", stated several new different skills of the digital natives:

1. parallel thinking
2. visual-spatial skills
3. multi-tasking skills

4. response times
5. mental mapping

To avoid stereotyping and labelling, "digital natives" will simply be called "students" in this paper. The difference exists between students and teachers in the way students and teachers receive, treat and use information (Table 1).

Table 1

Student and teacher preferences, according to [1]

Students prefer to	Teachers prefer
– receive information quickly from multiple sources – multitask and parallel processing – receive information in the form of pictures, sounds and video – use hyperlinked sources – interact in "real-time" – create and use user-generated content – learn instantly, relevantly and in a fun context	– a controlled release of information from limited sources – single or "focused" tasks – information transferring in the form of text – a greater need for private and personal space for introspection – presented linear, logical and sequential information

The importance of ICT competences in pedagogical activities has been emphasized by many authors [9]. Today, teachers need to be ready to open up to possibilities of technology enhanced learning for their learners. The ability to use ICT and knowing how these technologies may support learners have both become vital skills in professional teaching activities. Teachers have to be ready to offer their students all the benefits of technology enhanced learning [9]. The contemporary education environment requires teachers to adequately master ICT competences.

4. Quality issues for educational software

The technology enhanced education process is not value free. The values that are encoded in the learning curriculum have an important

influence on learners. It is always vital to consider the quality of learning software before starting to use it. Educational computer programs have to correspond to the teaching and learning goals and expectations. Therefore, before choosing educational software, it is important to make sure that it will be appropriate for the learners, correspond to the learning goals, correspond to the curriculum and satisfy the requirements of the learning environment. If a training program meets these requirements, then it is acceptable to analyze other qualitative aspects.

Authors in [4] suggest different software quality assessment criteria. on assessing educational software quality, paying attention to:

– the educational software design, as it determines understanding the application of this software;
– the attractiveness of teaching material: adequately chosen audio and video elements may increase learning motivation;
– interactivity of teaching material: learner inclusion in task and activity formation may inspire learning;
– the applicability of the training program: it must be possible for educational software to have its parameters changed according to learner needs and existing knowledge.

5. ICT as a tool for learning motivation

Students browse the Internet in order to meet certain expectations. They are often not able to name their own expectations, but a survey performed by [2] emphasizes 4 major motivational criteria to search Internet for:

– communication: students use social networks, communicate, cooperate, share comments, express their emotions and seek approval and understanding.
– excellence: students seek to expand their knowledge and understand things that others do not know yet and to be the first to share and demonstrate them; they seek to manage information that could be applied in different life situations.
– self-realization: students need activity to give sense to their existence.

– fitting-in: students do not want to stand out from the others and are therefore, creating social networks, blogs, etc. A fear of standing out from the others forces students to join different social networks.

These are the motivational criteria that drive students to use ICT. [5] suggests very similar criteria that refer to students' motivation to learn (Table 2). It is evident that it is basically the same criteria that motivate students to use ICT and to learn:

Table 2

Criteria that motivate students to learn [5]

Motivation criteria	Learning needs
Social relationships	Need for communication, association and membership
Personal achievements	Higher status / position at work, professional development, decrease in competition
External expectations	To comply to requirements, meet management expectations / recommendations
Stimulation	To break routine, avoid boredom, to provide contrast to other life details
Interest in learning	To seek knowledge for personal interests, learning for the sake of learning, in order to feed curiosity

Things that motivate to learn also motivate students to use ICT. Therefore, it can be stated that by using ICT, students improve their learning. In certain aspects, students are more advanced than their teachers or parents. The level of ICT proficiency is also influencing teacher authority: a teacher who is not ICT literate is not respected and is underestimated. ICT proficiency demonstrates mutual interrelationship between the teacher and learner: a student is learning from a teacher and a teacher is learning from a student. Students often do not want to accept information from a teacher who is not ICT literate as they feel more advanced in ICT. Then teachers are not able to contact with the students, who also feel underestimated and not understood because their ICT skills are treated as almost illegal and negative extracurricular activities. A teacher is not satisfied with student' preparation for classes as his/her

achievements are not related to the learning curriculum or values. A student is willing to search the Internet and to meet his/her expectations. In a nutshell, for a student there are clear differences between the sites to search, while the key point here is whether his/her expectations are met.

Students informally learn things that are new and attractive to them. It is not true that using only traditional methods may secure an attractive lesson design. Traditional learning is valuable for its face-to-face contact, which is especially important to each person, including both teachers and students. Traditional teaching should be combined with technology enhanced teaching and this blended form will be called "traditional method" in the very near future.

If we agree that students are motivated by using ICT because their learning needs are met, then it is evident that formal and traditional education needs to blend them in technology enhanced learning, because ICT is closely related to learner needs and motivation. Using ICT is based on the same motivation criteria as learning. Using ICT is learning in itself. Research reveals many advantages of ICT application in the teaching process:

– Internet is a more widely acceptable learning tool and world cognition media for students;
– Internet allows students to learn after school;
– Dangers of surfing/using the Internet may, in many cases, be anticipated by the teacher-encouraged and targeted surfing of educational sites;
– Internet learning may include values. The process allows inclusion of family and friends;
– The learning process becomes more community-based and encourages inclusion, belonging to a certain group, decreasing social exclusion and allowing task discussion among family and friends.
– The learning process allows inclusion of each student's opinions and inclusion of feedback as well, which is not always possible in class due to time, human resources and other restrictions.

In their educational process many teachers use such ICT tools as e-mail, forums, discussions, video material, real-time communication, social networks, wiki pages, etc. This also includes e-journals. These tools are most often used simply for communication and, at least in

Lithuania, reveal a substantial deficiency in using technology enhanced learning.

6. **Application of Internet technologies in teaching process**

A. *Forum, discussions*

Forums and discussions are designed to facilitate debates on various topics in asynchronous mode. Google searches sometimes lead to discussion forums, where people are asking and answering each other's questions and discussing different topics. Different types of forums exist and their popularity varies from one country to the next. Each one is peculiar and has its own audience, so when certain information is needed each individual has to decide which forum is the most suitable to choose. The popularity of forums is best judged not by the number of registered users but by the number of posts. In a teaching process, forums are suitable for counseling, projects and explanations.

Subject teachers may create a forum in Moodle environment (Fig. 1) for the students to communicate the problems that they encounter when learning one topic or another. A teacher is able to answer questions, thus offering ICT supported counseling. Another positive aspect is that a question a person encounters has very often already been answered by others. Thus, both teachers and students save time as there is no need to explain the same things several times. Discussions on different topics and issues may be initiated by teachers for students or the school administration for parents.

For example, in a class of a native language, there is a group-work task for students to write an essay on a certain topic. A forum may be created for this purpose so that group members can express their opinions on the choice of the topic, each member's contribution and other aspects of preparation (Fig. 1). Each member may express his/her opinion at a time that is convenient to him/her, reach certain decisions and prepare a group paper for the next lesson.

Another example could be a situation in which a school administration is discussing a trip with the parents. The parents log-in in their own time and express their opinions regarding planning the destination, organization, time, duration, etc. Discussion results can be summarized and a final decision taken about the trip.

Figure 1

Forum in Moodle environment

B. *Creating video learning material*

There are online tools that can be used for the creation of recordings and storing of video materials. The most popular example could be YouTube (Fig. 2), followed by TeacherTube, Vimeo, etc. Each registered member can put video recordings online, watch other videos or share them with others or record videos using an online camera and a microphone. The YouTube data base has over 5 000 000 categorized video records, including films and TV shows, music video clips, homework records, etc. Each record can easily be downloaded to a website or blog. By using this tool, it is also possible to record a video, a song, a lesson, etc.

This tool can easily be used in music, art, history and other lessons. A YouTube tool can be applied in informative method, narrative, demonstration, illustration, creative task decisions and problem-based learning (Fig. 2). This tool can be very effective in different subjects of school teaching. A teacher can make recordings related to the subject topic using this tool. One

possibility is that of taking students out for a field lesson in the woods and then asking them to watch a lesson recording on a given link at home.
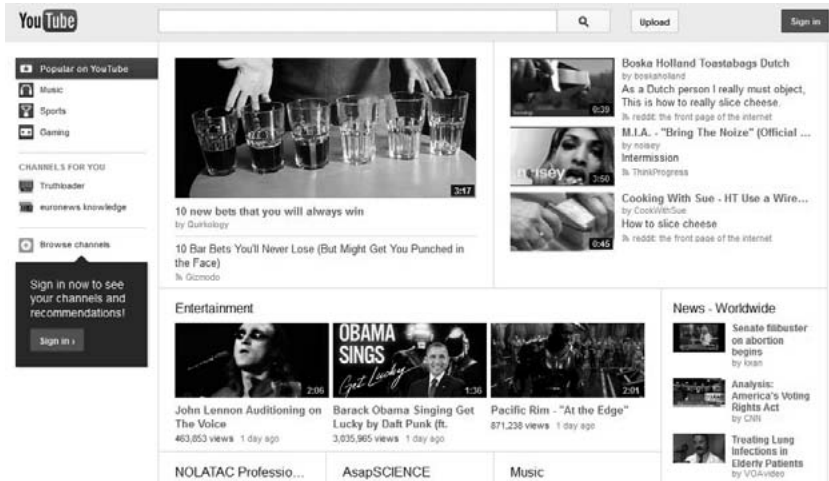

Figure 2

YouTube window

Another way of applying this tool could be in a history lesson. A teacher gives each student a task to analyze a different historical personality and record a story on YouTube. The students get acquainted with a chosen historical personality and prepare a presentation in a special area of YouTube related to history and historical personalities. Students may replay the topic at anytime and watch video recordings, thus being motivated to learn in a technology enhanced environment.

C. *Creating animation*

There are ways of creating video cartoons online using Xtranormal, Goanimate or MeMoov tools. Previously, creating animation was a very complicated procedure. However, nowadays there is an abundance of different online tools for non-complicated creation of animation. There is even no need to download or install additional computer programs. It is possible to create cartoons or to watch animation created by others. The

activity is simple, fun and free. Animation can be enriched by different functions that enable the creation of unique animation. Afterwards, it is possible to send a link to the created cartoon to friends, students, teachers or parents. This tool also allows users to:

– create animation;
– choose scenes, characters, emotions, etc.;
– add voices to each character;
– add a variety of effects;
– search for and view animation created by others.

This tool can be used to employ methods of illustration, demonstration and practical training. In the illustration method, each student can create animated reports on summer vacations, etc. Creation of animation is possible in each subject lesson, but it is especially suitable for art lessons. Animation can be used not only in the learning process but also in administrative activities, e.g., visualizing the school's vision or creating a promotional cartoon, etc.

D. *E-mail communication*

E-mail communication allows interpersonal communication. There are free e-mail options on the Internet provided by Yahoo, Gmail and other providers. There are different companies worldwide that offer e-mail post possibilities for personal and professional needs for a charge as well as for free.

E-mail offers possibilities for writing essays, counseling, explaining and doing other different tasks. E-mail is/can be used for student counseling in different lessons. Electronic mail is a communication tool that can also be used in school administration to reach teachers, staff members and parents. It can also be used to connect parents, social partners or alumni in order to invite them to different activities or events.

E. *Real time communication*

Real time communication tools enable personal or group communication in real time, regardless of geographical location. Programs like

Skype, Messenger and others allow real time communication. One of the most popular real time communication programs is Skype (Fig. 3), which also offers Internet telephone so that recipients all over the world can be called online. Internet calls connect computers for free, while calling from a computer to a phone is charged. Skype also provides video connection, which requires use of a webcam.. Skype allows talking, writing, sending files to friends, students, co-workers or school community members.
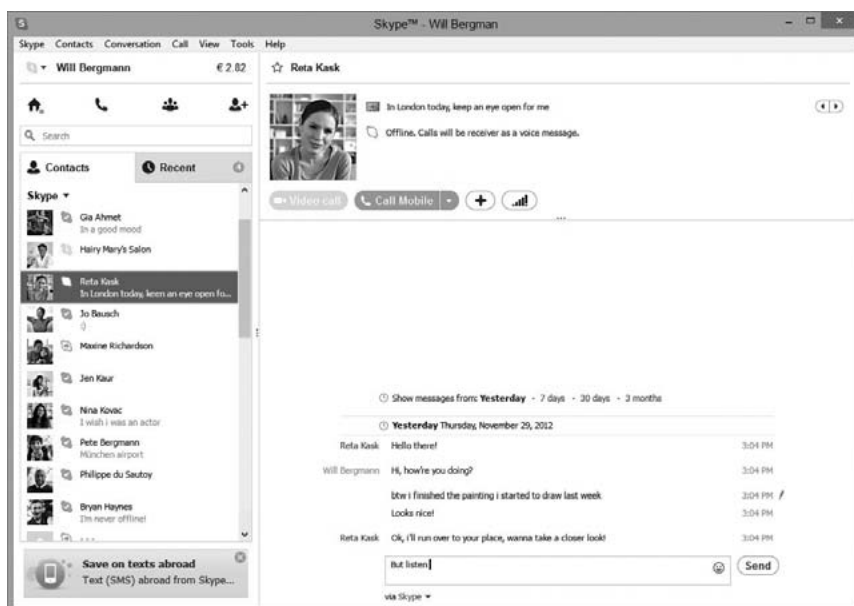

Figure 3

Skype program window

The chat program can be used for explanations, repetition or counseling. This tool allows teachers to advise students on different topics. Skype may be integrated into the study process as a real-time communication tool for student counseling, communication on school topics and after school. Students and teachers may connect after school and offer or receive counseling regarding the tasks. Teachers may also connect with parents and discuss their children's achievements through

texting or video conferencing. It is also possible to organize a video conference with several parents at a time. Another advantage is that of connecting on Skype video for a lesson with a pupil who is sick and has had to stay at home.

F. *Social networks*

Social networks are interactive Internet allowing the networking of individuals or groups with similar interests. Members of social networks may create Internet projects of different complexity using automatized tools. Some of the most popular social networks are Facebook, Twitter, etc. Take Facebook as an example, where each member has his/her own profile and can restrict viewing to "friends", that is, individuals who are allowed to be connected. Personal approvals provide possibilities to create social networks. Depending on the tool, the members of the network may communicate in real time or with asynchronous messages, share links, pictures, video clips, play common games, etc. Before using Facebook, it is important to instruct the students about Internet security, i.e., data safety, sharing information, etc.

Social networks have different application options and may be employed for various activities in different teaching subjects. It is also possible to analyze security rules by asking students to study what information they may find about their friends and other individuals who have profiles on the social networks, and what conclusions may be derived from this information.

G. *Blogs*

The term is derived from the phrase web log, where web is a net and log is a diary, Blogs are used for diaries or different stories on the Internet. In general, a blog is a tool created to form news posts in an automatic way. Blogs may be created using http://wordpress.com/ and similar websites. Blogs allow users to create stories, give descriptions or present hobbies in a form of a diary. Blogs are also widely used to present recipes, travel experiences and the like, and are usually prepared by one particular author, although other visitors may write comments and share suggestions.

H. *Wiki pages*

Creating Wiki pages is similar to creating an Internet encyclopedia or making notes. A topic is developed by several authors. Wiki pages may be created using MediaWiki, coWiki (Fig. 4) or other tools.

Figure 4

Wiki page example

Creation of Wiki pages may be used in history lessons to describe different historical events, actions of prominent people, their biographies and other tasks that may be performed by a group of authors. Creating activities can be used in history lessons to describe various historical events, biographies of famous people, and other historical facts listed by a group.

I. *Surveys*

Internet surveys replace traditional questionnaires. The main advantage of Internet surveys is that they save both paper and time. The questionnaires are answered online and do not need to be printed. It saves time as Internet survey tools often offer generalized results. Different

Google survey tools make it possible to create different types of questions to carry out public or restricted surveys for certain user groups. Survey tools may be used in different research activities when attempting to find out teachers' or parents' opinions and needs, etc.

J. *Group work systems*

Group work systems are usually created for a certain circle of users engaged in certain group work. Group work systems offer many different tools. Real-time and e-mail communication, as well as file exchange options, are usually included. It is also possible to create inner websites, different groups, etc. Only registered users are allowed to join a group work system, which may be created using Google, Elgg.org, Pbworks. com or other tools. Group work systems are applicable in such tasks as project work, where group work is required for communication and organization of group activities.

K. *Educational films*

Mass culture tools have a considerable influence (including educational) on human life. Films play an important part in this influence. Visualization is a very important principle of designing educational technologies. It is the main reason for creating educational films, which are created following educational goals. Educational films allow teachers to present training material clearly, visually and use schematic visualization and animation. Film creators (usually subject teachers) choose a certain film type depending on the didactic goals. Educational films are classified according to their purpose and didactic goals:

– *Short educational films* are made to present the most general knowledge about a teaching subject. They are usually used at the beginning of teaching a subject, with the intention of introducing the content, structure and main topics. Their length is usually 10 to 15 minutes.
– *Thematic films* are made to present certain topics of a teaching subject to a student. They are created so that a teacher can "hold" and comment on the more complicated aspects and illustrate the

education material. The scenario is usually based on the layout of a certain topic for students, employing technological possibilities. The duration of thematic films is usually 10 to 15 minutes. Teachers usually present thematic films in planned sequences, discussing the essence of the material. This is the most popular type of educational film used in *vocational training*.

– *Fragment films* differ from thematic films in scope. Fragment films are recorded to demonstrate only *a fragment of a certain topic of a subject*.

– *Micro-fragment films* refer to an even smaller scope and highlight a certain refined aspect of the object under investigation. Micro-fragment films may also be used to present a task to students.

– *Circular films* are created to visualize very quick or very slow processes. The content reflects cyclical processes that are not easy to present at their regular speed. These films are taped in a special slower or quicker motion, or present a certain short process several times in a "closed loop".

– *Chrestomatic films* consist of several parts and contain episodes of a certain teaching subject's materials where the visual aspect is important. Chrestomatic films are often used in teaching literature or history and are important in teaching ethical issues. They are often employed for both classroom and non-formal learning.

– *Story films* are created according to a certain prepared scenario seeking to visually demonstrate a certain life situation that is significant for students' critical thinking. These films are widely used to educate the students and also for preventive purposes, seeking to prevent students from addictions and the undesirable consequences of unacceptable social activities.

– *Instructional films* demonstrate how to successfully perform the steps of a certain action, seeking to prevent mistakes, violation of work safety regulations or to train student's sensory and motor performance in difficult tasks. These films are most commonly used in teaching practical pedagogical technologies and are very popular among teachers of vocational education. Educational films in their technical nature may be optical, magnetic or digital. Each one of these will determine which technical means will be needed to screen these films. The most universal technical tool used to watch them is a PC; therefore, CD is the most suitable format for watching these films.

L. *Educational computer games*

These are computer games with educational features. Most of the games are for pre-schoolers or primary school students. These may be different jig-saws or modelling games for logical and strategic thinking. There are formal and semi-formal game classifiers, but the following types are usually distinguished:

– *Dynamic games* (action/trade games) have been among the first "shooting catching" type of films that require sharp reactions, apt eyes and a minimum of thinking. Currently this type of films is undergoing rapid developments that include many logical and mathematic elements requiring sharp reactions in order to make the right decision.

– *Adventure games* are very popular. A player has to take the hero through certain activities and scenes. It is possible to only slightly change the scenario. This type of game develops by answering players' needs and refusing to use verbal management (using an English language interpreter), which is also used to develop English skills.

– *Heroic gam*es (role playing games) are very similar to adventure games, but the hero obtains more experience, power and skills as the game progresses.

– *Modelling, imitation games* (simulation games) are based on the situation in which a player is taken to the place of action: jet cabin, car interior. Depending on the chosen level of realism, the player has to operate his vehicle. There is also a camera filming option (e.g., driving) in order to analyze mistakes after the game is over.

– *Sport games* model certain kinds of sports. Whereas one of them is on the level of one player, the others allow several players to participate, or even run competitions. First, the game's rules are introduced along with certain theoretical knowledge, which realistically teach strategy and tactics.

– *Strategy games* are among the most interesting computer games. They are based on goal function and optimizing many parameters. Repeatedly playing the same game several times is only theoretically possible. Each part is original and unique. These games require problem solving, strategic planning and knowledge of economics.

- *Traditional games* are computer realizations of different traditional board games: chess, cards, Monopoly, etc.
- *War games* have not been classified as a separate game category and were classified together with simple strategic games. Only recently have war games been acknowledged as having their own strategy that has been treated as art since times gone by. The games of this type depend on the era to which the player is being transported and what weapons are being used. War games are usually related to real historical events or fantasy stories.
- *Business games* allow players to study quantitative situation analysis in making concrete decisions. Comparative decision analysis, calculations and printing out the results is computer based and employs special software. Interactive training allows players to communicate with colleagues, creatively solve problems, counsel, argument, use limited resources and favorable circumstances and think critically. Reality modelling methods, especially computer business games develop competition, entrepreneurship and a free and successful personality in a free market. This form of learning allows participants to take risks, experiment and also make mistakes.

Some games are not strictly classified to one type or another but may be attributed to several types. Educational computer games bring diversity to learning and make it more attractive and interactive. However, computer games should not be overestimated; the goal of playing computer games is to learn and try something new and not just to have fun.

M. *Electronic books (e-books)*

They are a rapidly growing alternative for regular, paper versions something that often causes debate over the "death"of paper correspondence. The advantages of e-reading are evident: interactivity, ecology, possibility to enrich the text with sounds and pictures, an easier means of distribution and a lower price.

Mobile devices also allow application of more varied material presentation forms. It is possible not only to read but also listen to audio

format and watch additional video records. An explosion of mobile devices and mobile Internet has encouraged mass diffusion of mobile software. The mobile software market is growing: in Lithuania new companies specializing in the development of mobile applications for different operational systems of smartphones are springing up.

7. **Conclusion**

Education is becoming interactive because of technology enhanced learning. "Old" methods are being enhanced with digital media. The teacher's role in the teaching process is undergoing change. A teacher has to be a class manager, e-curriculum developer and user, which places more attention on teacher training. Teachers have to receive adequate training but this may also require more time. It means shifting/adapting the whole teaching methodology. Several years ago, the first mobile devices started to be applied. Tablets are being successfully used in native language, foreign languages, mathematics, art, music and science classes. The future belongs to mobile technologies, as now the usage of mobile and handheld devices (smart phones and handhelds) prevails. Every year more and more schools try to apply mobile technologies and search for the software. The major foreign language publishing houses create software training that is both free and paid for. There are different programs for integrated training of the subject, as well as for English as a foreign language, among other lessons.

Technology enhanced learning and tools are influencing learning interactivity and bringing about an intensive change in school practice. Educational models are being improved in digital formats, the teacher role is increasing in the educational process and new curriculum presentation forms are being introduced. A rapid growth of mobile devices, mobile telephones and mobile Internet is cascading mobile software. And the market for telephone programs is growing very fast and their prevalence in schools is quite evident. Mobile devices also allow the application of different forms of material presentation as books may not only be read, but it is also possible to listen to audio and watch additional video recordings.

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Scaffolding the teaching and learning of science

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1. Introduction

In learning science, the student seeks to understand the major elements of a body of pre-established, consensually agreed knowledge. In doing science, the scientist seeks to create new knowledge. However, science education can be a motivating and exciting inquiry into this body of knowledge. Hands-on and minds-on activities certainly do play an important role in this process. A number of approaches and contexts, both in formal and informal education, have been developed. ICT provides tools for engaging with the exploration of the physical world and engaging in lab activities, as well as in conceptualizing the observations and data collected in the experiments. When providing the learner with appropriate scaffolding, inquiry is crucial in order to create a balance between free exploration and guidance to avoid frustration. This paper will use the experience developed in the UniSchooLabs project to present an ICT based approach to scaffolding the teaching/learning of science.

We will argue that an inquiry model template might scaffold the teaching/learning process of science if it becomes the evolving roadmap for classroom activities, encompassing collaborative discourse and argumentation of the investigation at hand, shared by both the teacher and learners.

Laboratories are an essential part of the teaching and learning experience in many branches of science and engineering. Ideally, laboratories provide a window on science-in-the-making, showcase the

ambiguity of empirical work, develop practical skills and foster teamwork abilities. On-line laboratories are becoming a major component of the college level teaching and learning experience since they enable students to make use of the equipment 24 hours a day [1]. Virtual laboratories and simulations also play an important role in the teaching and learning of science. Their advantages are that inquiries can be started, stopped, examined, re-examined or re-started under new conditions. They allow for investigations that are impossible in reality, such as stopping a ball in mid-flight or rewinding time [2].

2. The role of the laboratory in science teaching and learning

The educational research literature on the role of the laboratory in the teaching and learning of science points out that a laboratory should involve both hands-on investigation and minds-on reflection [3].

Common-sense understanding of the natural world, including fundamental ideas such as cause and effect, conservation of number, substance, weight, volume, classification and groupings and their interrelations are "naturally" developed since these basic ideas are regularly tested against experience in everyday situations; they are clearly functional in dealing with these and so are reinforced. Scientific knowledge, however, has been developed for more specific and specialized purposes. Many of its explanations are counter-intuitive and not supported by everyday experience (at least not until you have learned to "read" that experience in very specific ways) [4]. Learning to read the experience in the ways a scientist would requires opportunities for specific hands-on activities and support for minds-on activities that foster scientific reasoning by practicing these specific ways of building ideas, testing, discussing and even arguing about them.

A good example of how to foster the link between the domain of objects and ideas is provided by this teaching vignette by von Glasersfeld [5]: "There is no infallible method of teaching conceptual thinking. But one of the most successful consists in presenting students with situations in which their habitual thinking fails."

What you see here are two tracks (see Fig. 1) on which steel balls can roll with almost no frictional loss of energy. The two tracks are not the same, but the start and finish are at the same height for both. The question

is: which of the two balls will reach the finish first, if they are released at the same time?
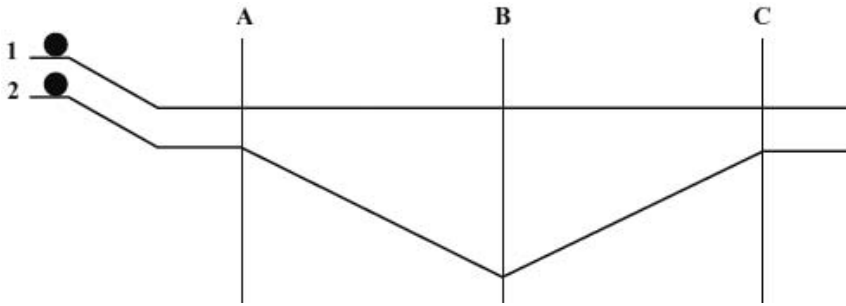

Figure 1

Experimental setting for two balls rolling on tracks

Many of the initial physics students to whom the question is put say that number 1 will arrive first, because number 2 has a longer path. Others predict that the balls will arrive simultaneously because, although number 2 gains a lead on the downhill slope, it will lose it when it has to roll uphill. Very rarely do any say that number 2 will win the race. Hence it is a considerable surprise for them when the balls are actually let go to roll, and number 2 arrives first every time[1]."

Recent research [6, 7] shows that opportunities for students to engage in collaborative discourse and argumentation offer a means of enhancing not only students' conceptual understanding but also their skills and capabilities in scientific reasoning.

3. **Can an inquiry model template scaffold the teaching and learning process?**

Rocard's report "Science Education Now: A Renewed Pedagogy for the Future of Europe" [8] calls for an inquiry approach to science education. "The science education community mostly agrees that pedagogical practices based on inquiry-based methods are more effective; the reality of

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[1] A video of the experiment is on line at http://blip.tv/file/1071517

classroom practice is that in the majority of European countries, these methods are simply not being implemented." The report borrows the definition of inquiry from Linn, Davis & Bell [9] "we define inquiry as the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments. In science inquiry projects, students communicate about scientific topics, evaluate scientific texts, conduct investigations, ask questions about science or technology policies, create designs, and critique arguments, often using technology resources."

Inquiry Based Science Education (IBSE) is a popular approach adopted in a number of European projects (e.g. COSMOS [10], Fibonacci [11], nQuire [12]) and teacher training initiatives. Although the proposed inquiry model templates vary, they are variations of a basic theme (see Table 1).

Table 1

Three inquiry model templates

COSMOS	Fibonacci	nQuire
Exhibit curiosity	Engage	Find topic
Define questions from current knowledge	Plan and design	Decide inquiry question or hypothesis
Propose preliminary explanations or hypotheses	Implement	Plan methods, equipment and actions
Plan and conduct simple investigation	Organize and analyze data	Collect evidence
Gather evidence from observation	Draw tentative conclusions	Analyze and represent evidence
Explanation based on evidence	Formulate new questions	Decide on conclusions
Consider other explanations	Draw final conclusions	Share and discuss inquiry
Communicate explanation	Communicate with other audiences	Reflect on progress

An inquiry model template provides a structure for both the authoring of an activity and its use by learners. A minimalist template for structuring a lab activity is the Predict-Observe-Explain one [13]. Students are first asked to predict what they would expect to happen in a given situation and to write this down, then to carry out some observations, and finally to explain what they have observed (which may or may not be what they predicted).

A more detailed inquiry template [11] might include:

– Plan and design – What is our question or problem? What do we want to know? How will we find out? What do we predict will happen in the experiment? Do we have a hypothesis?
– Implement the experiment – What do we observe? Are we using the right tools? How much detail do we need to record? Why did we choose these parameter values?
– Collect, organize and analyze data – How do we organize the data? What patterns do we see? What relationships might there be? What might this mean?
– Draw tentative conclusions – What claims can we make? What evidence do we have? What else do we need to know?
– Formulate new questions – Do we have a definite answer to our question? What questions do we still have? What new questions do we have? How can we find out?
– Draw final conclusions – What do we know from all our investigations? What evidence do we have to support our ideas?

However, an inquiry model should not be interpreted as a sequence of steps in a recipe. The inquiry process is iterative and its phases are interdependent [12]. Furthermore, a given inquiry might omit phases. Science inquiry, whether that of the student or scientist, is a complex process and various parts may need to be revisited, dwelt upon or even skipped at times. For example, if the results of students' investigation do not validate their original prediction, the students need to question their assumptions, return to the beginning of their investigation and develop a new experiment. If they design an investigation plan and it does not work, they need to redesign it. If they come to a tentative conclusion but it differs from that of another team, both teams may need to redo their investigations [11].

An inquiry model template might scaffold the teaching/learning process of science if it becomes map of classroom activities, encompassing collaborative discourse and argumentation of the investigation at hand, shared by both the teacher and learners.

4. **The UniSchooLabs toolkit**

UniSchooLabs is a two-year project funded under the European Commission's Lifelong Learning Programme, aimed at improving quality in science education in Europe by promoting collaboration between universities and schools in the provision of remote access to university science laboratories for primary and secondary schools through Internet-based services [14].

The UniSchooLabs tool-kit[2] supports the teacher in selecting a remote or virtual lab and developing a lab activity based on an inquiry model template. While working with the toolkit, the teacher has access to three main features: a) a catalogue of available online laboratories; b) an archive of activities created by other users; c) a tool for creating new lab activities or reusing existing ones.

A UniSchooLabs activity is composed of a number of web pages. Through these pages the teachers are able to present the tasks at hand while providing the students with supporting learning materials and assignments. Students can navigate through the pages and follow the instructions given while writing their own notes and group reports on different matters on the same page. This environment can be used by students as a shared lab notebook where they can keep track of: questions or purposes of the investigation, predictions, ideas, investigation designs, data collected, analysis of the data, emerging ideas and reflections.

As inquiry requires hands-on and minds-on, the teacher should make room for and facilitate discussion and reflections on the lab activities. An inquiry model template provides a road map for orchestrating classroom discussions based on students' intermediate results. Class discussions, based on individual and group records present in the shared lab notebook, should be held under the teacher's guidance. Class discussions might be

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[2] The toolkit is available on-line at http://unischoolabs.eun.org

organized to compare and discuss predictions, hypotheses, data and interpretations (see Fig. 2). They produce tentative conclusions, new questions, final conclusions and reports for a wider audience. Opportunities for students to engage in collaborative discourse and argumentation offer a means of enhancing students' conceptual understanding and their skills and capabilities in scientific reasoning.
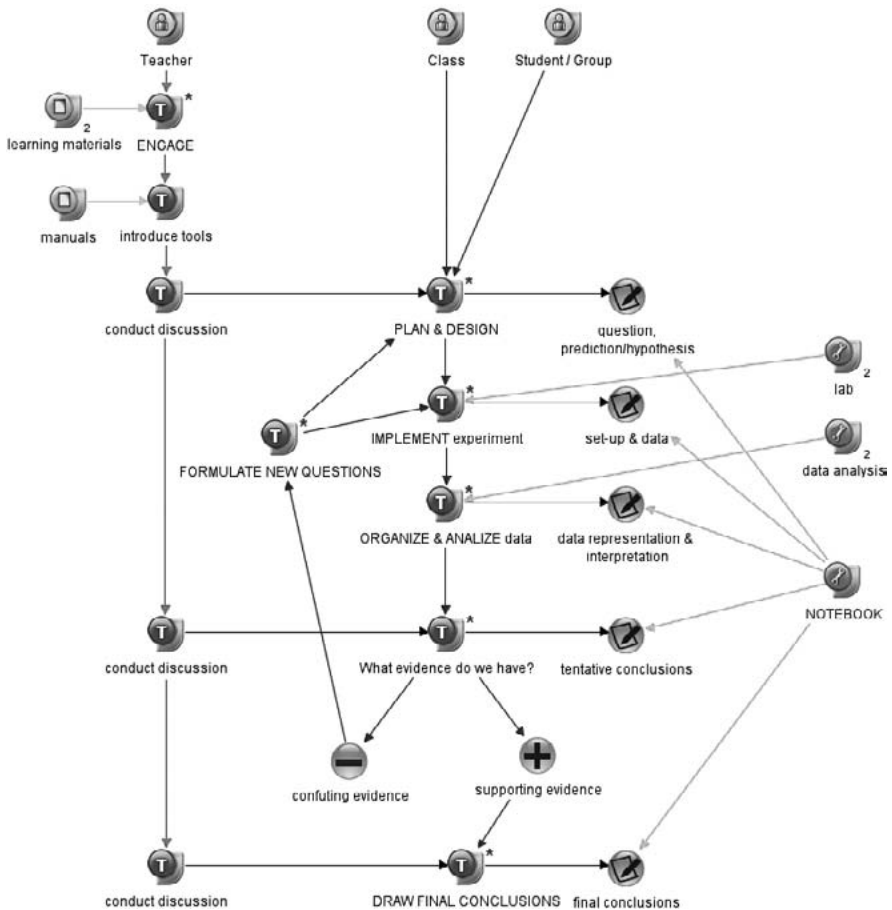

Figure 2

A concept map representing: the role of teacher and students, the resources and tools used, and their interconnections with the phases of the inquiry model template

The toolkit pilot has involved ten schools in Germany, Greece and Italy. The schoolteachers involved have used the toolkit to select a remote or virtual lab and design their own lab activities. Classroom usage did match teachers' expectations; remote labs were usually perceived as more motivating than virtual ones.

While we stressed classroom discussion and reporting, we did not find strong evidence of these activities in the notebook data. Our interpretation is that developing dedicated tools for scientific argumentation might foster this approach. A future revision of the toolkit could include support for an argumentation environment that scaffolds collaborative discussion and enables the graphical visualization of arguments [15].

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Knowledge transfer in school-enterprise cooperation of vocational education: enhancing students' self-learning ability for employability

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1. Introduction

The future of the education and employment system depends on the cooperation of schools with enterprises. It is about the involvement of employers in preparation of models and training programs, the introduction of practitioners to schools and creating incentives for companies to launch the apprenticeship space.

A common feature of education systems in countries characterized by high rates of youth employment is the great amount of compulsory practical training (internships and apprenticeships) that supplements standard theoretical education. As a result, students graduating from schools in these countries have extensive know-how, which significantly helps them to quickly find a job consistent with their expectations.

This requires the promotion of education in accordance with the needs of the labor market, with special emphasis on the promotion of vocational education. Many studies show that the present expectations of employers do not focus solely on hiring graduates with firm, strictly professional qualifications. Key to the needs of the labor market is also the development of soft skills and appropriate attitudes, such as integrity, responsibility, and discipline. The places where such competences should be shaped are mainly schools and universities.

The possibility of obtaining diplomas and certificates regardless of the form and time of education is essential for improving the quality and transparency of education, and should lead to significant changes in the approach to learning and investing in human capital. Thus the creation and implementation of the principles of validation and recognition of learning outcomes (skills acquisition), regardless of where and how the knowledge was gained, is crucial for realization of the lifelong learning idea and increasing the mobility of workers.

The support for the lifelong learning concept should be a coherent legal system and financial solutions that will encourage and stimulate employees to pursue continuous intellectual development and employers to continuously invest in human capital and labor resources.

Use of Information and Communication Technology (ICT) could be the best solution to adopt to reach the above mentioned aims, as it can provide new opportunities for education, training and employment.

Currently, E-learning is one of the main fields of application of distance learning technologies, knowledge gathering and management. Possibilities of distance training by means of Internet make it possible to develop intellectual capital and employees' potential. It enables the individualization of the educational process through the training of employees, customers or business partners in any place, at any time or for any needs.

First of all, success depends on: the readiness and openness of the work environment to share information in a comprehensive manner [1], willingness to invest in means ensuring development and a solid infrastructure, the involvement of managers in training and readiness to meet employees' expectations and needs. Benefits obtained from using learning distance systems include:

– access from one place to all resources concerning the topic
– tasks and requirements clearly defined by superiors
– effective knowledge and staff management skills
– time management
– quick and easy location of subject matter experts
– in case of difficulty, ability to find the module with the topic and remember the question

Considering the above aspects, the aim of this research is to analyze the needs in knowledge/skills required from secondary school students in order to achieve their successful transition to higher education or high-

grade vocational training or even to start a career, and also for university students as future employees in industry.

## 2. Characteristics of the enterprises

To complete this research, we have used online surveys on managers from 13 companies working in the Radom region, who were asked about the use of Internet in the workplace. All the people who took part in the survey are regular users of these online applications.

The following companies participated in the survey:

– P.P.H.U. CREATIVE MAJA RZĄP
– ROSABUD
– TECHMET
– SKANPOL
– Connecto
– Huta Cynku Miasteczko Śląskie S.A.
– Invest
– Górnośląska Spółka Gazownictwa Oddział Zakład Gazowniczy Zabrze
– MetPol
– Miejski Ośrodek Pomocy Społecznej
– POL-DOM
– Wojsko Polskie
– Spółka Oświata

The respondents from the Radom region participated in the online survey [2]. Most respondents (40%) held positions such as: specialists, electro-automatic engineers, financial advisors, warehouse managers, clerks and department managers. The next group is represented by technical directors and managers. Only 15% of respondents are product development managers. The smallest group is made up of strategy and business development directors. There were no general directors among the participants (Fig. 1).

As regards the activities of the analyzed group, they work within the companies. Most of them (81%) deal with production and service activities. The remainders specialize in technical advice, education, research and development (Fig. 2).
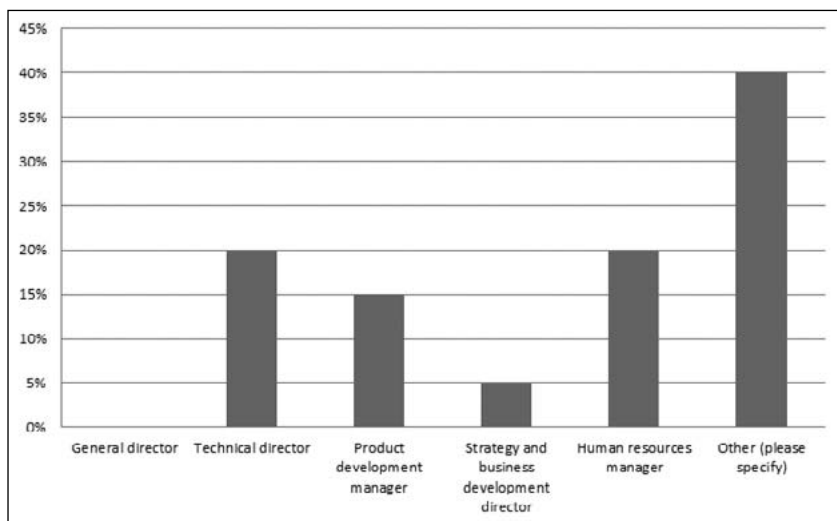
Figure 1

Position in the company
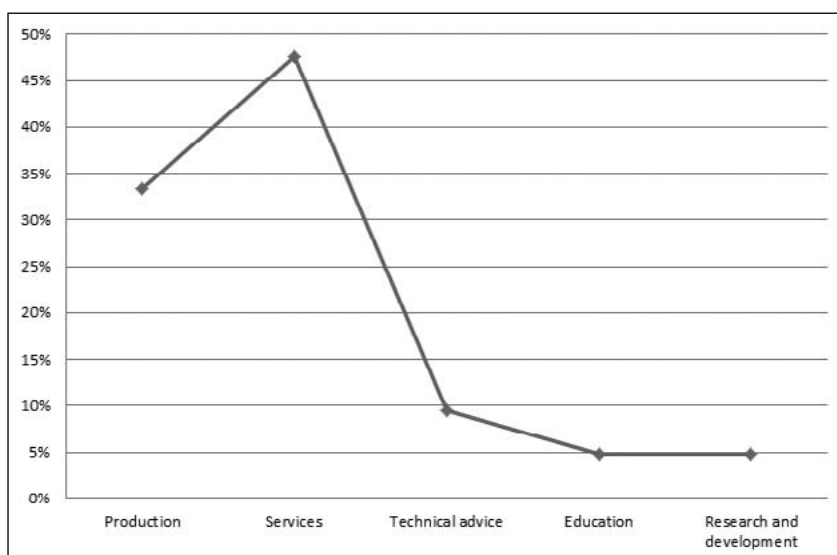
Figure 2

Main activities of the company

Fig. 3 shows the number of years the particular companies have been in the market. The majority (29%) have been working in the market from 6 to 10 years, which means they are relatively young companies. Companies with 11-20 years of experience make up 24%. The least quantity (5%) is represented by companies that have only been in business for 1 or 2 years, which is the period of time required for familiarization with a new business/product.
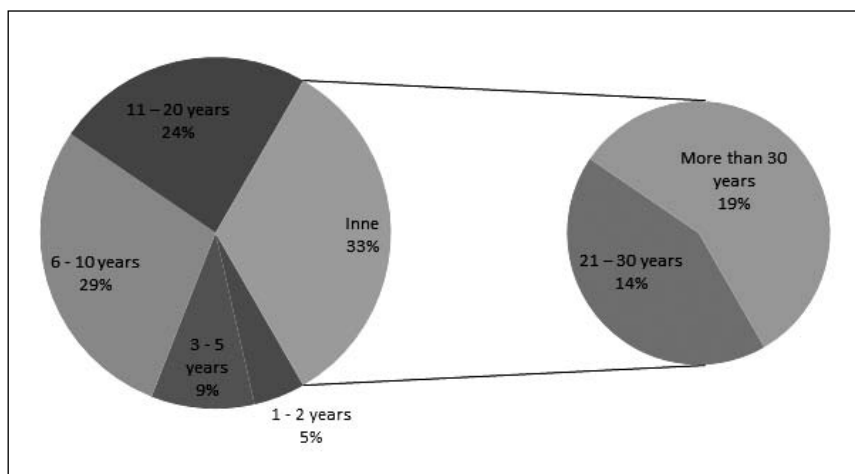
Figure 3

Years in the market

According to answers concerning the number of employees, most companies (38%) employ 21-50 workers. 29% of the researched enter-prises employ 51-200 workers; a little less, i.e. 24% of companies, have more than 200 employees. Only 5% of respondents stated that their companies employ 1-5 or 5-20 workers. Fig. 4 presents the percentage of company workers' ages and the number of companies with a selected age range of their employees.

On this basis we can define the age structure of employment. According to the respondents' answers, it can be concluded that employees younger than 25 years old and older than 50 are a minority in most companies participating in the survey (0-20% of all workers). In most of the surveyed companies between 10% and 60% of employees are 25-50

years old, and in a few cases, almost the whole employed personnel is located within this age range (Fig. 4).
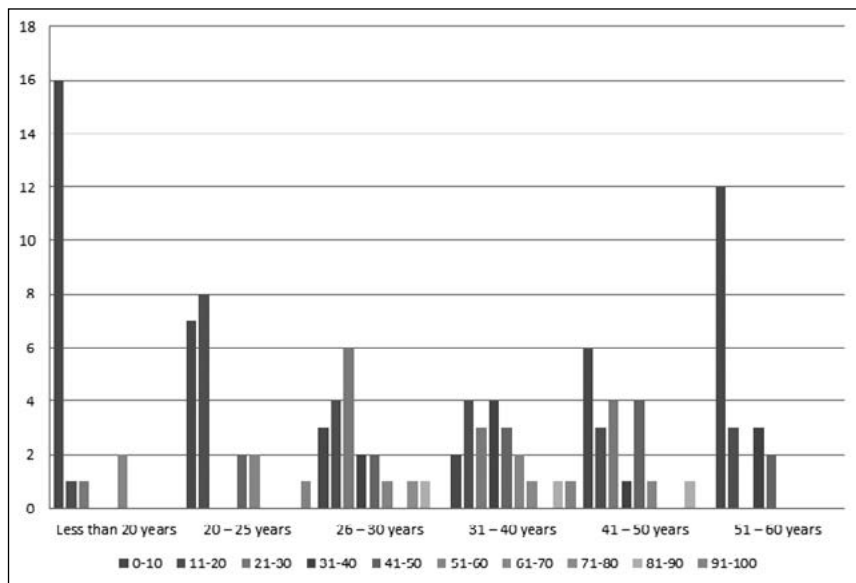
Figure 4

Percentage of company workers' age

The next question presents the educational level of employees, defined by percentage, dependent on the whole personnel and number of companies (Fig. 5).

Figure 5 shows that both the employees with primary education only and those with the academic title of doctor are a minority in most companies (0-10% of employees). The total number of employees with secondary and vocational education or a Bachelor and Master's degree is similar, and together these groups make up the majority of employees in the surveyed companies. However, individual companies have different employment structures, which usually depend on their activity profiles.
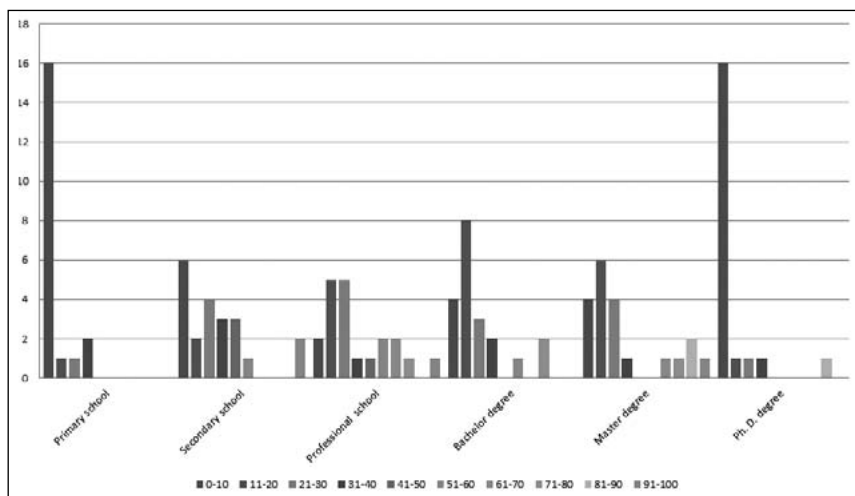
Figure 5

Estimated percentage of company's workers with specified education level

3. **Insertion of young people in workplace**

Other questions concerned companies that offer young people the possibility of vocational training and gaining experience for a position. Unfortunately, over half (62%) of the companies do not have any youth programs in their organization activity or production. The remaining companies (38%) have several such programs (Fig. 6).

It is easy to note that university students are a target audience for most of the programs, and practicums and Open Door programs are the most popular. The poorest offer from companies is aimed at secondary school students.

This is a result of the general curriculum in secondary schools. Vocational schools prepare their students for a specific profession and young people from these institutions can learn better by means of such programs as placements and internships, cooperative programs or working part-time in business, which allows them to combine work and professional experience with their school duties.

In the following questions the companies were asked to provide/ estimate the approximate number of students participating in programs.
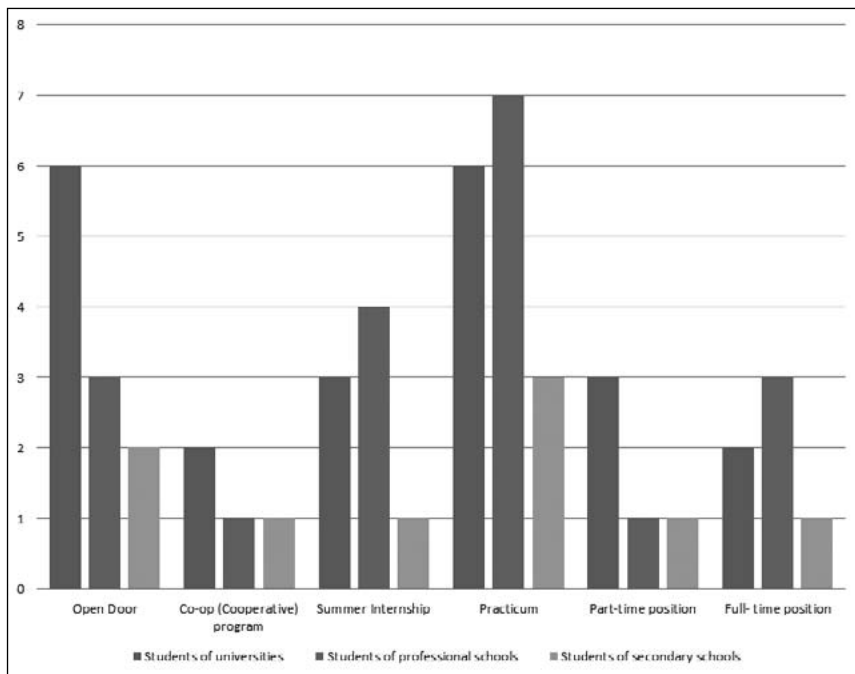
Figure 6

Yourth Program in companies

In the case of university students no company accepts more than 20 students. For the 10-20 person groups only 10% participate in such programs as part-time and full-time positions and practicum, and 20% in Open Door activities. 30% of the 5-10 person groups participate in summer internships, and 10% in practicum. Half of the companies take on 1 to 5 students in practicums, 30% for a summer internship, Open Door and part-time position.

Within the last year, 40% of companies have not taken on any students in a half- or full-time position, 30% in summer internships and Open Door, and 20% in cooperative programs and practicums (Fig. 7).

In the case of students from vocational schools, 10% of respondents invite more than 20 people to participate in cooperative programs, 20% accept 10-20 people for summer internships and Open Door programs. Only 10% of companies involve the same number of students in practicums

as in full-time positions. 20% of companies hire 5-10 students in full- and part-time positions, practicum and Open Door programs, and 10% offer them a cooperative program (Fig. 8).
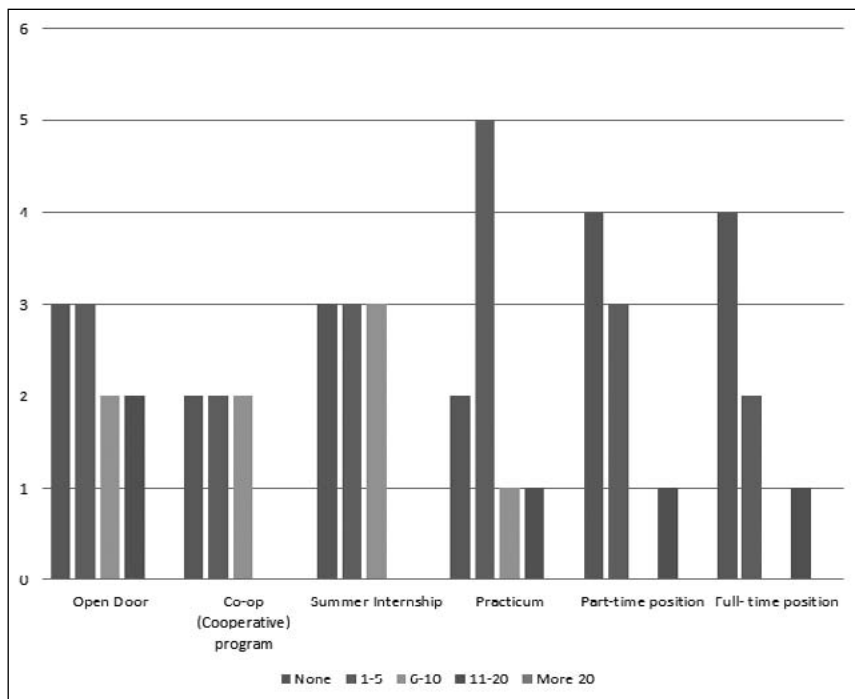
Figure 7

Approximate number of university students in each program per year

40% of enterprises declared that they accept 1-5 people in practicums, 30% in summer internships: only 20% of companies employ such a quantity of students in a full-time position or cooperative program, and only 10% invite students to take part in the Open Door program.

Up to half of the respondents stated that within a year they have not taken on any vocational school students in Open Door or Cooperative programs, and 40% of companies have not taken anybody on for a summer internship or half- and full-time positions. In 20% of enterprises there have not been any practicum participants either.
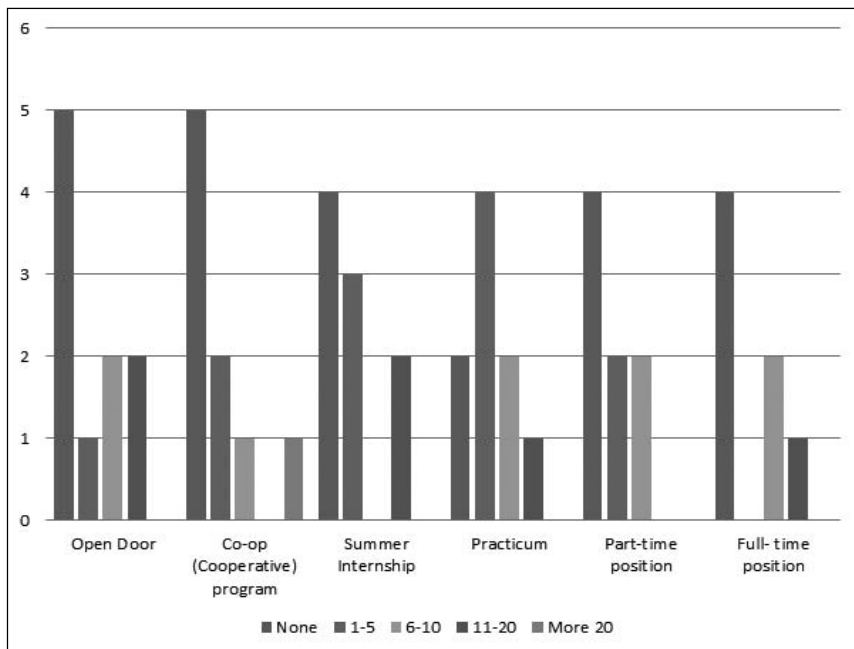
Figure 8

Approximate number of students from vocational schools
in each program per year

Secondary school students are the last youth group involved in activity and production at the selected companies. Only a small percentage of the companies (12%) engage more than 20 people in cooperative and Open Door programs. Smaller groups of 10-20 students are taken on by 38% of companies in the Open Door program, and only 12% of the companies accept both groups of 10-20 and 5-10 people in practicums and half-and full-time positions (Fig. 9).

Most companies (38%) accept secondary school students for a summer internship, but these belong to the groups of 5-10 people. Such a number is involved yearly in cooperative programs being taken on by 25% of companies. Smaller groups of 1-5 people are taken on within a year by 12% of companies on the summer internship, cooperative and Open Door programs. The same percentage of students participates in practicums at 38% of companies.
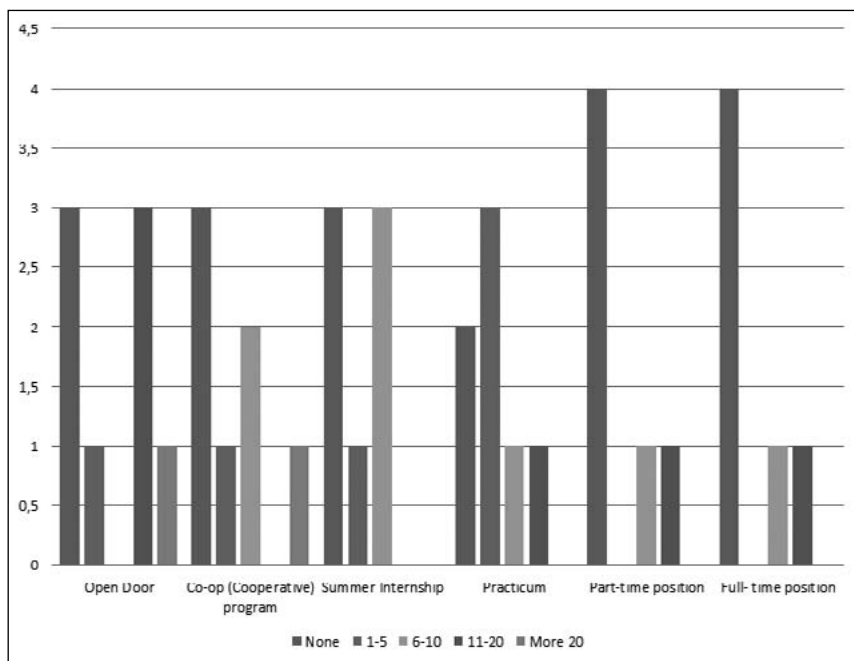
Figure 9

Approximate number of secondary school students in each program per year

Half of the respondents pointed out that, within the last year, they had not taken anybody on in half- and full-time positions. 38% declared that they had not accepted any secondary school students for summer internships, or the Open Door and Cooperative programs. At the same time, 25% of the enterprises surveyed had not had any practicum participants during that period.

4. **Work placement and Cooperative Learning**

Another question was designed to see whether companies participating in the survey had heard about the Co-op (cooperative) program before in their own cities, countries or abroad. The results show that the majority (86%) have never heard of such a program. Despite the companies' considerable lack of knowledge about Co-op program, just over a half of

the respondents (62%) declared that they would be interested in having the opportunity to set up a Co-op program in their enterprises.

This program involves cooperation between schools and universities and reputable companies specializing in various branches. The program's purpose is to achieve the best possible preparation of young people for work in the selected position by combining theoretical knowledge with practical work experience.

The companies that declared their interest in having the opportunity to create Co-op programs were asked to provide/estimate an approximate number of students that might become involved in the program.

In the case of university students, most companies (36%) said that they would involve 1-3 students, and similar results were obtained for vocational school students (29%) and secondary school students (21%). 14% of respondents stated that larger groups of 4-5 and 6-10 vocational school and university students would take part. As for secondary school students for the same quantitative group, they would be chosen by 21% of enterprises.

Only 7% of the surveyed companies would engage as many as 11-15 students from university and secondary school. As for the 15+ groups, 29% would invite university students to cooperate, but only 14% would invite vocational and secondary school students.

Concerning the student competences needed for a practical placement, we can see that over half (52%-71%) of the companies participating in the survey require the following competences from university students: multitasking, time management and good knowledge of English to use it in the professional world. Moreover, they should have the skills related to the use of software programs and hardware equipment, the ability to adapt quickly to new technologies, finding and selecting information from various sources, including searching the Internet, organization and maintenance of information, use of engineering software as well as interpersonal skills.

Competences are required to a lesser extent from vocational school students (33%-43%); here, the companies were not as consistent as in the case of university students.

The respondents indicated the following competences as being the most important: the ability to use materials –e.g. diagrams, technical instructions– properly, having basics in the "Electricity" topic and basics in computer science.

The companies indicated and estimated the competences expected from secondary school students similarly to vocational school students, (29%-33%). Again the required competences are: basics in computer science, use of software programs, finding and selecting information from various sources, including Internet search skills.

Those participating in the survey had the chance to state the knowledge and skills that will be required in their companies. Among the responses there were such additional skills as: having the appropriate certificates to perform the job, professional service that consists of combining information and passing it on to the relevant body in order to achieve a satisfactory financial transaction for both parties. It appeared that a very important criterion for employers was also the knowledge of thermal energy and the production and delivery of fuel in form of natural gas, as well as technical and practical skills (Figs. 10, 11).

The ideal candidate should also possess the characteristics of patience, perseverance and orderliness.

The enterprises participating in the survey had no objections, comments or suggestions concerning the cooperative program.
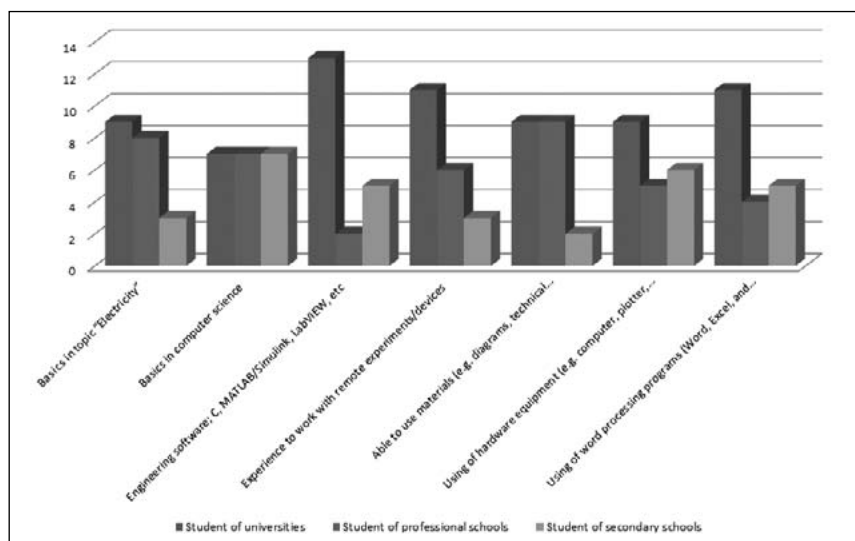

Figure 10

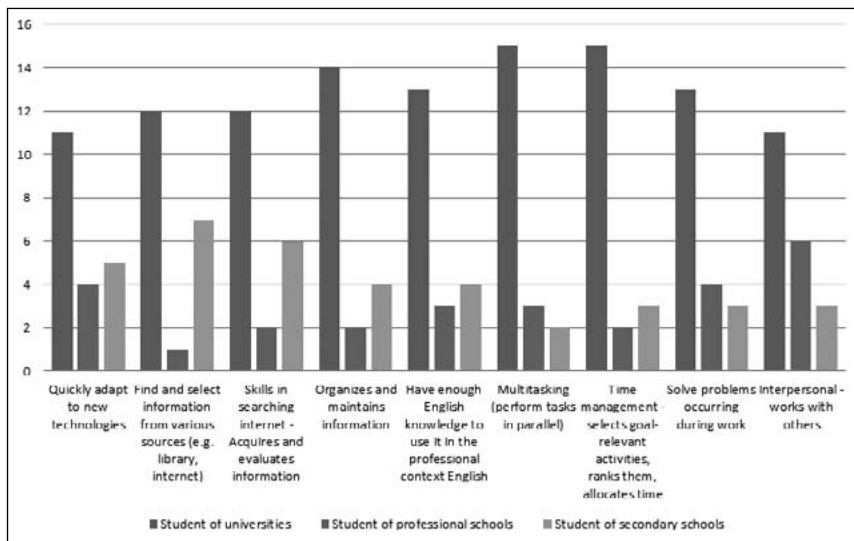Competences a student should have to actively participate in this program (a)

Figure 11

Competences a student should have to actively participate in this program (b)

5. **Conclusion**

Companies from all over Poland took part in the survey. The vast majority of them represent the production and service industry. The number of employees is from 21 to 200 people aged between 25 and 50 with different levels of education. Unfortunately, more than half of the companies do not participate in various programs that would allow young people to use their knowledge and apply it in practice, as well as being given the opportunity to start their career.

The survey shows that companies mostly and preferably accept university students in such programs as Open Door and practicum. Studies are the last stage of education in life, and therefore, future employers select people with the knowledge and skills required for a specific job rather than secondary school students, for example, whose acquired knowledge is too broad and general.

A relatively small number of people cooperating with a company in the form of practicums or internships have the chance to obtain a full-time position in this company. Additionally, these opportunities are restricted

by employers' lack of knowledge of the programs enabling the creation of new platforms for cooperation.

Despite the growing popularity of such programs, it appears that not all companies are interested in cooperating, while the companies that declared an interest in participating in the Co-op program estimated that the most effective group would be one of a maximum of three people. Again the highest requirements and expectations as to the competences refer to university students. Basing ourselves on the survey, we can conclude that the best target group for participation in this experiment is the students of secondary schools, who are the ones that need most help to enter the labor market and gain experience in the current market situation. Also, employers are primarily looking for graduates whose theoretical knowledge acquired over the years of education can be used in practice, thus becoming desired employees in the labor market.

The aims of the survey for enterprise management are**:**

– To find the best business sector for the introduction of modern distance learning methods.
– To do research among companies to find out the level of knowledge, availability and use of several types of programs enabling young people to begin their careers.
– To determine the first-choice and most popular programs whose content could be expanded to the application of E-learning, for example.
– To decide on the most effective target group.
– To understand the employers' needs in relation to establishing cooperation with young people's awareness of the labor market.
– To select the appropriate education level and acquired skills of future candidates for particular positions.
– To familiarize employers with the OLAREX program offer.
– To encourage employers to participate in research and programs aimed at the introduction of distance learning methods.
– To focus on young people who need some help to gain knowledge and professional experience.
– Definition of the needs for knowledge and skills required from a candidate for a particular position.
– To build up managers' competences for staff training.
– Initiation of cooperation with enterprises.

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Use of ICT in Bulgarian schools and museums

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1. The background of ICTs in Bulgarian schools and museums

ICTs are quite popular and often used in everyday life in Bulgaria, but not so much as educational tools in the classroom. Young Bulgarians have number of different electronic devices, but they use them mainly for personal communication, for amusement and for social activity in Internet.

ICTs as educational tools and as a tool for self-education at school are not so popular for teachers in Bulgaria either. ICTs are still not an obligatory/regular teaching method in secondary schools. They are recommended by the Ministry of education and tutors, but the process is still in its initial phase.

Most schools have their web-sites and educational platforms, but students and teachers use them for information, for extra educational materials, for feed-back control and self-evaluation of homework. In the real classroom teaching-learning process ICTs are used only occasionally, except in some specialized schools.

In the 21st century STEM teaching is the most adequate area for innovative use of ICTs in education. The project "OLAREX – Open Learning Approach with Remote Experiments" is intended to promote the use of contemporary ICTs in Bulgarian schools and museums at the same time. As museum specialists we appreciated this as innovation because, up to this moment, the ICTs in museums were used mainly for

advertising, for extra contextualization and for orientation of the visitors in the museum halls. The potential of ICTs for museum education was not sufficiently exploited. Therefore, the National Polytechnic museum became a partner of the "OLAREX" project to motivate its young public for active use of ICTs for educational purposes, so as to upgrade secondary school teachers' and museum specialists' ICT competences.

2. **The start of "OLAREX" in Bulgaria**

The European "OLAREX" project was an extremely big challenge for the National Polytechnic museum. Not being a typical educational institution, we hoped to support the popularization of ICTs in STEM teaching, also because natural sciences are thematically presented in our museum exhibition and are part of our educational activities. We wanted to enhance the teaching potential of the museum's educational and demonstrational cabinet, and to give museum specialists new ICT competences. However, the main target group for "OLAREX" was STEM secondary school teachers. Therefore, initial contact with them was rather difficult for the museum team in its role as a project coordinator for Bulgaria. As we were a different professional group (not pure pedagogues), we made an extra effort to motivate teachers to participate in a project led by a museum. We asked for some help from the educational inspectors for STEM, as well as the teachers, who often visited our museum with their students.

As a result, teachers were interested in taking part. During the starter survey they gave their opinions about the expected results of the project from their point of view. That way we ensured that the project would run as it should. We realized that if we wanted to motivate our young visitors to use ICTs for educational purposes in the museum halls and cabinets, we should start with motivating the teachers. On the other hand, the museum specialists should have more competences in using new technologies in their everyday museum work. Only after that has been achieved can the museums play the role of a contact point between school education, ICTs and the cultural, natural, scientific etc. heritage. This conclusion helped us to continue the practical activities of the project, upgrading the results with every following step taken.

3. **The teachers' proposals and expectations**

The teachers from secondary schools defined their themes of interest for the concrete use of ICTs in classroom teaching activities. They also selected the most useful aspects of the ICT competences that they need. This was very important for preparing the content of the E-learning courses. The issue of applying remote laboratories and remote experiments in classroom teaching was known by very few STEM teachers in Bulgaria. Some of them were familiar with the idea of remote laboratories, but practically no one had used them in the classroom. So their advanced opinion about the use of remote laboratories and remote experiments for educational purposes was too generalized. But they did understand the potential.

4. **The museum specialists' proposals and expectations**

The situation was the same with the museum specialists. As a first step we invited the curators from our museum, because they were closer to the STEM thematic (NPM is the only museum in Bulgaria dealing with the history of technologies, history of natural sciences and current dimensions of scientific process). The other museums in Bulgaria are focused on history, archeology, ethnography and art. Traditionally they use ICTs to advertise and raise awareness about their collections, but not for mediation or for extra educational activities for their visitors. It was therefore a real success for "OLAREX" to appeal to them, maybe because the project included a special E-learning course for museum specialists, as well.

The idea of the project was to create an active link between the classical/formal STEM educational practices in secondary schools and informal/museum education-based ICTs. The initiative was well accepted. Of course, not all the participants, both teachers and museum specialists, were deeply motivated from the very beginning of the project, but after a number of different meetings, advanced explanations and almost daily communication, they understood the significance of the project and became active participants.

5. **What were the concrete activities of the project in Bulgaria?**

As mentioned above, surveys were prepared for teachers and students from the secondary-school STEM classes. The questions in the surveys

were related to the preliminary information teachers and students have about E-learning/teaching, about remote experiments and laboratories and about the expectations and wishes for future learning/teaching activities on the basis of ICTs in the classroom and at home. The answers to these questions did not present very complete concepts or experience, but real interest on the part of both the teachers and students.

The similar survey for teaching institutions and museums presented the same wish for acquiring new information and competences for using ICTs in the learning/teaching process.

The results of the surveys defined the teachers' concrete spheres of interests, as well as those of the students and museum specialists. This information was used to prepare the E-learning courses. The Bulgarian teachers selected e-courses for using "Moodle" and remote laboratories and remote experiments in the sphere of physics.

The museum specialists from more than 10 Bulgarian museums decided to participate in the e-course on ICTs for presentational and educational activities.

The authors of the e-courses for teachers were experts from the University of Deusto in Spain and Carinthia in Austria, Vytautas Magnus University in Lithuania, The Higher School of Radom in Poland and Europa Media Non-Profit Ltd in Hungary.

The authors of the e-course for museum specialists were Ph.D. Ekaterina Tsekova and Svetozara Kararadeva, museum specialists from Bulgaria with a broad experience in museum pedagogy, museum presentation/mediation and applying ICTs in the museum environment.

The museum e-course offered a useful combination of the classical learning process with using new technologies. It helped attendees to gain more information about applying ICTs in the professional museum sphere, especially in the sphere of museum communication. Based on the Moodle teaching/learning platform, this E-learning course is useful for museum professionals to acquire better ICT competences which they need in their presentational and educational museum activities and projects.

The main idea of the e-course was to help museum specialists to work with ICTs, to understand and to use its potential for increasing professionalism and to help the audience in understanding the role of contemporary museums.

The additional aims of the e-course were:

– Using more ICTs to increase the popularity of museums

– Applying ICTs in museums to attract young people
– Giving the public greater access to ICTs at the museum to enrich the contemporary image of the museum institution
– Enhancing ICT competences of museum pedagogical staff to popularize the E-learning process
– To bring small museums closer to European museum standards

The main target group of the e-course was the group of museum professionals, such as: curators, exhibition designers, specialists in museum pedagogy, PR experts, administrative and technical staff, photographers, etc.

The advantages and the impact for the participants in the museum e-course were:

– An extra qualification and a certificate for competences/attendance;
– New ICT competences;
– Enlarging the sphere of professional activities;
– Support for the career development;
– Raising the prestige of the museum institution, as concerns staff professionalism;
– Better service for the museum public, etc.

6. **ICTs in the museum**

The course for museum specialists was designed with the idea of not just teaching but showing and giving certain examples/ideas for increasing the public's access to all museum activities by using new media and information technologies at the museums.

We wanted to show the participants that the chance to use them opens up new possibilities for knowledge and places greater importance on heritage. They supply quick action, shorten the time and distance, visualize and facilitate remote communication and allow people to participate through them in different initiatives. In other words, they give them a chance to modernize their institutions, to express an opinion about their work, and to determine their own lines of activity.

The course included some basic ICT use in the museums for research, restoration and storage work, the design of museum spaces and mostly for communication/mediation with the public. We put an emphasis on the use of ICTs for museum educational and presentational purposes and activities.

The abundance of resources and relationships made easily accessible via the Internet is increasingly challenging us to review our roles as educators. The model of the museum curator or museum educator who stands in front of an object and interprets the meaning for a passive audience is simply no longer realistic in this world of instant access. Museum professionals must respond by changing their roles to reflect the new need to guide and coach visitors in finding, interpreting and making their own connections with collections and ideas.

ICTs not only facilitate and/or accelerate long-established learning tasks, but, more critically, they permit activities that would otherwise be impossible. This includes new approaches to learning for different audiences and for different purposes. In the course we discussed how ICTs can be used for arts and cultural heritage education. We started with the E-learning environments providing curricular learning opportunities for different topics and target groups, including museum visitors.

As E-learning is widely as an educational tool used in science and technical museums to expand their educational activities and to implement/show some scientific phenomena/tasks, these museums provide their learners and visitors with remote laboratories and virtual simulations.

In addition to E-learning environments, we talked about how the wide range of on-line learning games and quizzes successfully integrates arts and cultural heritage education into a structure through which visitors can explore the information in an easier and more attractive way.

The so-called "M-learning" and mobile applications for museums was the other emphasis that we introduced in our course. During recent years, museums have started offering their visitors learning experiences that go beyond traditional exhibit labels with gallery kiosks and audio guides. More recently, they have added cell phone tours, podcasts and platform-specific applications in an effort to capitalize on the commonly-owned portable devices like iPods, MP3 players, Blackberries, cell phones that visitors already have in their pockets. The biggest challenge is that many museums do not quite know where to begin when working with a small budget and reduced staff with limited technical knowledge. This unit addressed those needs by providing a brief overview of what is being done in the mobile museum world and offered suggestions and examples, based on how to economically provide mobile users with a positive experience at the museum.

While much emphasis has been placed on mobile applications and devices that expand the experience outside the museum, there has also been considerable thought on how to use them in-gallery, especially in science museums. With a number of examples from different museums, we show the people on the course that these applications and devices provide supplementary information about an exhibit or the museum itself; they can also be used as a mobile guide through the collection or gallery space. They create extensions of the physical space, creating opportunities for people to become patrons no matter where they may be.

Tablet**s** present new opportunities to enhance in and out-of-gallery experiences in ways simply not possible with other devices. They present museums with new avenues for interpretive and educational media that take advantage of their large screens and gesture-based interfaces.

Augmented reality is a technology perfectly suited to one of the key functions of museums: interpretation. In many ways, AR can be seen as an intuitive doorway through which data can easily be attached to real world objects, settings and processes, thus facilitating a deeper meaning and understanding of what is being seen.

With regard to the use of ICTs in arts and cultural heritage presentation, we discussed some facilities that do not involve a human presenter in the communication processes between an object and a recipient.

Along with the examples of different devices providing contextual information (PDAs), in this unit we presented the Multimedia terminal that has been created in the National Polytechnic museum in Sofia. It is web2.0.-based, and is in direct on-line connection with 4 more Corners, built at 4 European museums belonging to a net (Fig. 1).

It consists of three touch screens with different functions. One of the monitors visualizes numerous galleries in pictures and texts, organized in different exhibitions. The second screen of the system ensures the feedback, which is the so-called "video guestbook" (Fig. 2).

Here, the visitors can ask questions, in order to document their comments and opinions, to make suggestions about the present content, etc. The third screen of the European corner is the "Video channel". There short films, video clips or other visual formats can be uploaded which supplement the content of the main screen. The European corner provides many possibilities for virtual extension of the exhibition area through digital presentation of previously archived exhibitions, through showing parts of future exhibitions, links to similar initiatives in other museums from the net and so on.

Figure 1

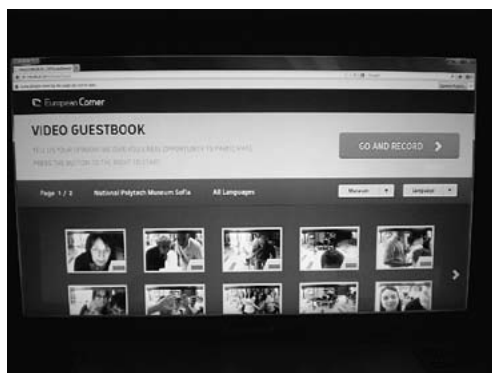European corner at National Polytechnic museum in Sofia, Bulgaria

Figure 2

The "Video guestbook" of the European Corner

Electronic publishing and museum web-sites were also included in course content. We pointed out the advantages of HTML5, which in recent years have enabled the publication of content in a variety of formats. It allows museum educators to easily create specialized versions of exhibition content for distance learning and other forums, while curators will be able to easily modify an electronic publication to suit specific audiences.

Although it is still a new application within the museum field, we included a brief description of Augmented Reality and its strong potential to provide a form of interaction with objects that otherwise would not be possible. Augmented reality is a technology perfectly suited to one of the key functions of museums: interpretation.

The invitation for participation in the course was widely accepted by our colleagues in different museums across the country. As a result, we received 32 museum workers among all the 69 registered participants. All of them successfully completed the course and received certificates for competences.

Bulgarian University students also were attracted to the idea of participating in this course. 12 of them also received certificates for their participation.

The course was also successfully completed by 3 participants from other partner countries: Lithuania and Hungary.

On completing the course, the participants gained new helpful competences, such as:

– how to identify basic ICTs and their use in museum activities;
– knowledge and application of mobile applications and devices for educational and presentational museum purposes;

All the participants had the chance to comment on their experience and express their opinions after completing the course. As authors, we were very satisfied to understand that almost all of them positively evaluate not only their participation but also the content and implementation of the course. Working in different sectors and positions in their museums, every one of them had learned new ways of using ICTs and obtained better understanding of its advantages. And some got new ideas on how to expand or to add e-tools to certain museum educational and presentational activities. For the university students, the chance to participate in the museum course was a positive learning experience adding extra knowledge to their education as a whole.

At the end of 2012, the museum invited a group of physics teachers from secondary schools in Sofia to participate in a one-day workshop whose purpose was to provide preliminary information on the forthcoming e-courses for teachers.

The seminar took place at the museum and included two basic presentations on remote labs and simulations, which were presented by

Ph.D. Ramona Oros from Carinthia University, Austria. She showed and explained to the teachers the benefits of on-line learning and especially the use of remote labs and simulations as a effective tool in teaching subjects like physics, chemistry, biology, engineering, etc. A more detailed presentation was made of the possibilities and characteristics of on-line labs, which are supported by the Universities of Carinthia and Deusto. With certain examples she described on-line experiments similar to those included in the modules for the e-course (Fig. 3).

Figure 3

Workshop with secondary school teachers at the museum. Sofia, 24.11.2012

After the presentations and subsequent discussion, the teachers, with the assistance of Ms Oros, were given the possibility to access a remote lab, to see how it works and to perform certain experiments and simulations. Satisfied by their final results in this practical training, the teachers became more confident and motivated for participation in the later e-courses.

Most of the teachers who took part in the workshop later participated in the e-courses. The preferences of the 8 registered participants were expectedly directed towards "Transforming curriculum with remote experiments: how to integrate it into the secondary school classroom".

After their training, according to the content of the course, the teachers had to use at least one of the modules in their lessons at school. We were very glad to know that one of the participants –Mrs Varadjakova, a teacher from an English language school in Sofia– offered to perform her lesson about "Black body radiation" at the museum (Fig. 4). Therefore, we had the chance to see and hear the opinion of the students on using E-learning tools in class. They told us that they not only accept teaching methods of this kind, but also think that this is a very useful way to understand the teaching material better. As young people whose everyday life is already "dependent" on different new technological devices, having and using remote labs will only bring advantages to the whole learning process (Fig. 5).

Figure 4

Secondary school students and their teacher learning with the "Black Body Radiation module. Sofia, 24.04.2012

Figure 5

Secondary school students and their teacher learning with the "Black Body Radiation" module. Sofia, 24.04.2012

In order to disseminate the results of the project, and especially the results of applying remote laboratories, experiments, teaching/learning platforms and E-learning as a whole, NPM saw the need to prepare an exhibition.

With the help of our partner from the University of Deusto, in particular, the Faculty of Engineering and "WebLab-Deusto", we designed a content which aimed to show and explain (mainly to the younger public) the basics and characteristics of remote labs and experiments. To do all this, we took "the robot" as the main character of our content.

On designing different parts of this interactive exhibition (Fig. 6), we tried to retell several stories which present the robot as a remote experiment (Fig. 7), a multifunctional device, a movie and a book hero.

The exhibition attracted the public with ROMIE, the small robot that moved in a labyrinth, controlled by the visitors through a special application. ROMIE was the main hero of the animation movie, explaining to the children what the remote lab is and how it works.

Figure 6

Part of the exhibition

Figure 7

Robot from Web-Lab Deusto

For those visitors that like reading books and watching movies involving robots, we offered an interesting quiz. A rich digital gallery

with famous robot-heroes was prepared and displayed in the European corner of the museum. Thanks to its share options, the corner provided the public from other countries with the opportunity to see this gallery too (Figs. 8, 9).
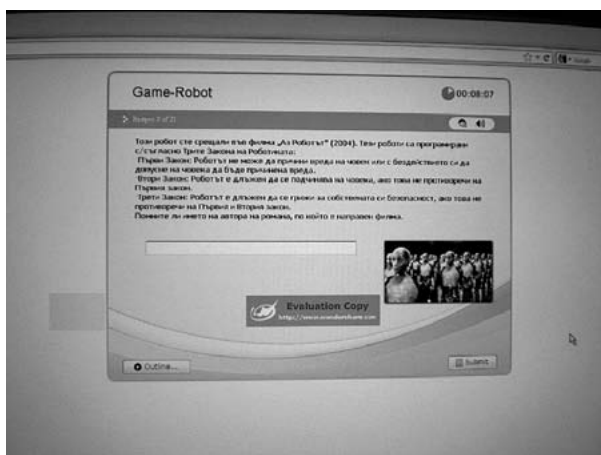
Figure 8

"Game-Robot"
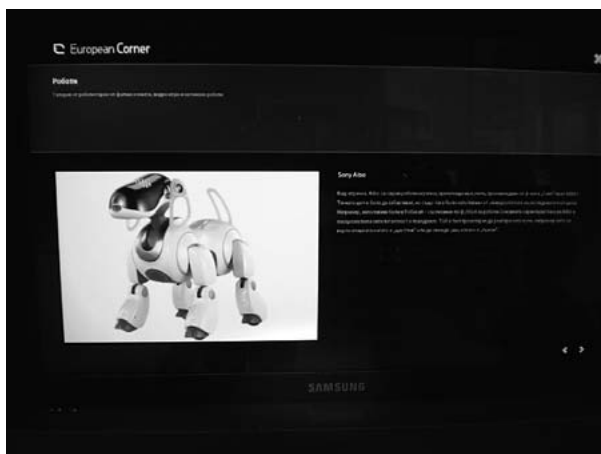
Figure 9

Digital gallery of robot-heroes in the European Corner of the museum

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Engaging STEM in secondary schools with remote experiments

RRLab: Remote Reality Laboratory to teach mechanics in schools

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1. **Introduction**

Traditional physics lessons at secondary and high schools have been based on theoretical explanations and exercises to be solved by the students and then checked by the teachers. This learning method has not evolved for many years, sometimes forcing students to believe in facts hardly demonstrable. Even if their results are correct, they are not able to check how the hypothetical systems studied follow the laws of physics.

Current technology allows people to be immersed into impossible spaces or environments thanks to virtual reality techniques. Virtual reality can simulate physical presence in places in the real or imaginary world. Augmented reality goes one step further, adding virtual components to real environments, superimposing the former on the latter.

RRLab (Remote Reality Lab) is a physics system that takes advantage of augmented and virtual reality, its main goal being to facilitate the understanding of several complex physics concepts studied at school. This way of studying these scenarios seems more attractive and is more accurate for pupils, allowing them to visualize systems that are difficult to handle manually. It is called Remote Reality because, although it is based on augmented reality, every component is real and can be remotely manipulated by the user.

The specific objective of this remote laboratory is to study the mechanics [1] of several physics systems that are simple enough to be solved by pupils at secondary and high schools although with a diversity of scenarios. In particular, we have chosen three mechanical systems: a pulley with different loads at both sides, a pendulum and a spring that holds a load. From now on, let us call each of them a "subsystem" in order to distinguish them from the whole physical system.

From a mechanical point of view, each of these subsystems is defined along the time through the position, speed and acceleration of its components. The real values of these variables are captured thanks to a webcam, while the "expected" ones are calculated by a software module that implements the physical laws and uses several parameters introduced by the user.

The physical device is controlled by the students thanks to a specifically developed web interface that allows access, activatation, visualization and modification of the components making up the physical device. The server that hosts this webpage is directly connected to the physical device, which is controlled by several electronic boards and engines. A high definition camera is constantly capturing and recognizing the accurate position of the different physical elements using a color tracking technique [2]; this is the reason why elements are painted in different vivid colours. These data will be used to calculate different magnitudes such as speed, acceleration or energies from each component.

The use of the three subsystems, pendulum, pulley and spring, is based on practical exercices with four different levels of difficulty for each one of them. While doing these exercises, the pupils are asked to calculate several parameters by using the theory they have learned and to introduce the results through a form on the web interface. When the experiments are performed, they visualize the virtual elements, whose motion has been calculated from the parameters they have just calculated,

superimposed on the real ones, whose motion is captured by the webcam in real time. Both representations, real and virtual, and the real time charts give them the possibility to check whether their results are correct or not, but they are also able to study how each parameter affects the real system.

It has to be pointed out that this laboratory is intended to be used not only by pupils, but also by teachers, as a different and innovative support for their physics lectures and, in addition, as a way for parents to introduce a little bit of fun in their children's homework.

2. **The system**

RRLab is a hardware and software system that allows students to execute real experiments on mechanics through the Internet, based on the following features (Fig. 1):

- Real time visualization thanks to high definition images captured by a webcam
- Remote physical control of all the experiments through the Internet
- Real time data acquisition and analysis
- Definition of different parameters to simulate
- Comparison of virtual simulation over real execution
- Different levels of difficulty

In this system, both parts, hardware and software, are equally important and consist of several components, each of them in charge of a different task.

A. *The hardware*

A.1 THE PHYSICAL SYSTEM

As previously explained, the system consists of three mechanical subsystems: a pulley, a pendulum and a spring (Fig. 2). All of them are allocated on the same aluminium frame, together with the rest of the components needed to handle them. The frame has a lighting system that is automatically activated when the experiments are executed, so it does not need an external light source.
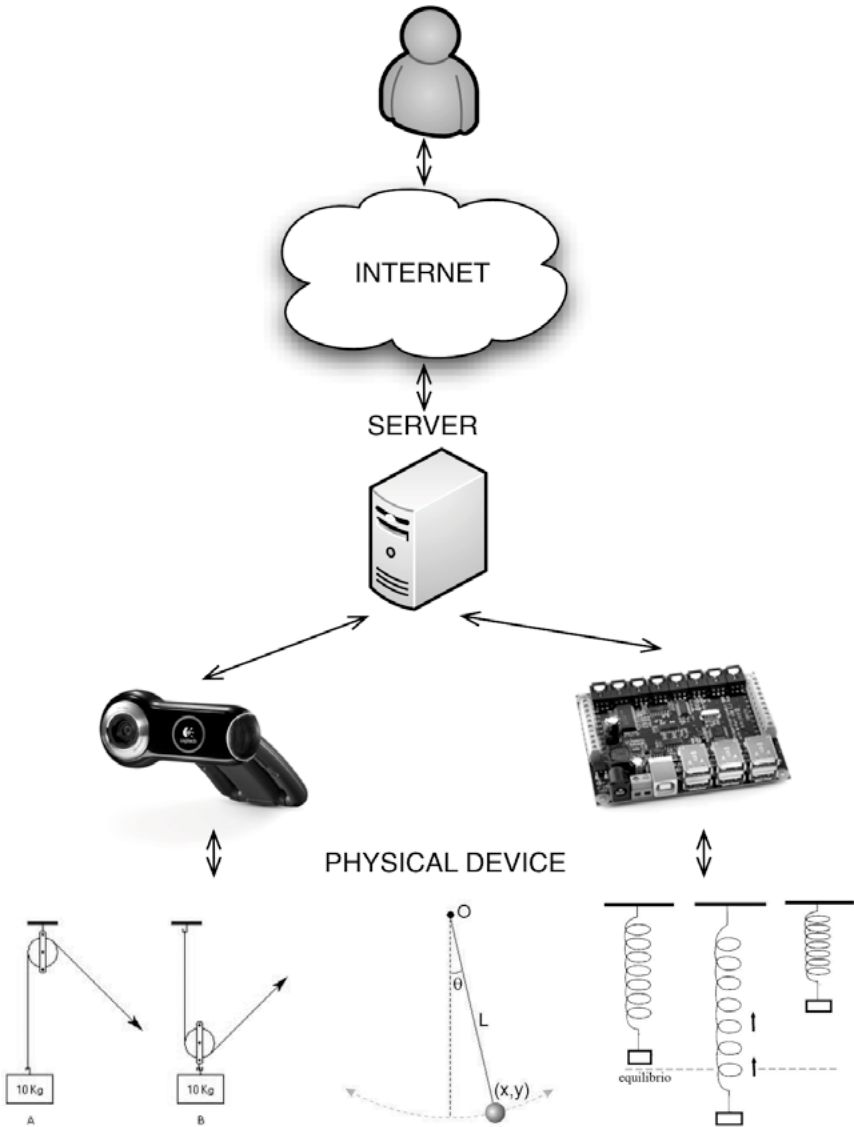
Figure 1

Architecture of RRLab

Figure 2

The physical system

Technical data of the aluminium frame:

1. Dimensions: 100 x 64 x 40 cm
2. Total weight: around 20 kg
3. Materials: aluminium profiles for the chassis, aluminium sheets for external protection and electronic components holding, skimmed PVC for extra protection, black velvet to avoid reflections and increase recognition accuracy

Technical data of the mobile parts:

1. General
   – Yellow methacrylate for markers
   – Red, white and black matt paint to distinguish tracked elements
2. Pulley:
   – Dimensions:
      Pulley radius: 4.5 cm
      Cord length: 75 cm
   – Weight:
      Red load: 400 g
      Black load: 200 g

  – Materials: steel for loads and fastening, plastic wheel for the pulley, nylon cord for holding both loads, polyurethane foam to soften the fall and avoid damage
3. Pendulum:
   – Dimensions: from 25 to 50 cm length (there are several non-identical systems)
   – Weight: from 300 to 440 g
   – Materials: steel for loads and fastening, a bearing to allow the pendulum to spin
4. Spring:
   – Dimensions: 11 cm at rest
   – Weight: from 250 to 400 g
   – Materials: steel for the spring and loads, aluminium for fastening

The steel density used for every component is 7.874 kg/dm^3.

A.2　THE CONTROL AND OBSERVATION HARDWARE

Each subsystem holds an engine in order to be remotely manipulated through the website. These engines are controlled thanks to the corresponding electronic boards (Fig. 3). The boards and engines chosen for this project were Phidgets [3] (physical representation or implementation of a GUI widget), whose producer is Phidgets Inc. These devices were used because they were easy to integrate (there are specific boards for particular engines), they are controlled by USB, they have control libraries available for a lot of programming languages and platforms, they are relatively cheap and, in short, they fulfill all the needs for this project.

The following elements have been used for each subsystem:

1. General
   – Specific board for sending commands to the engine boards
   – Specific USB HUB for controlling the elements and supply power to them
   – 450 W power supply
2. Pulley
   – Step by step engine to make the pulley spin
   – Specific board for controlling the engine
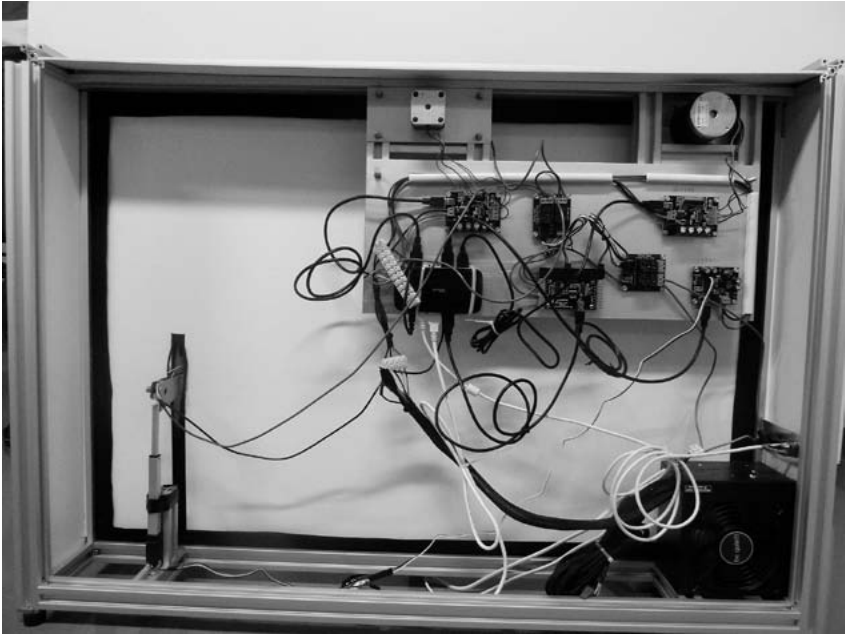
Figure 3

Control boards of the systems

3. Pendulum
    – Step by step engine to move the pendulum
    – Electromagnet for engaging/disengaging the pendulum
    – Specific board for controlling the engine
    – Relay for controlling the electromagnet
4. Spring
    – Linear actuator to move the spring
    – Electromagnet for engaging/disengaging the load
    – Specific servo board for controlling the linear actuator
    – Relay for controlling the electromagnet
5. Lighting system
    – Relay to switch on/off the lights

The positions of the elements that are tracked (loads are painted in red on each subsystem) are analyzed in real time by a high quality Logitech webcam situated in front of them (Fig. 4).

Figure 4

Logitech high resolution camera

The main technical features of the webcam and the streaming server are the following:

– Webcam distance (to the physical subsystems): 90 cm
– Webcam height: 25 cm
– Capture frame rate: 14 FPS
– Bandwidth: 30 KB/s upload: 30 KB/s download

B. *The software*

This laboratory could not live without a "brain". The intelligence of the system lies in the software that is in charge of performing several critical tasks: interpreting the images captured by the camera, transmitting the orders from the user to the control boards, calculating the expected results according to the theoretical models, allowing access to the interface to users, and, in general, controlling everything for a precise execution of the experiments.

B.1 TRACKING SYSTEM

The images of the physical system captured by the camera are sent to the server in order to be processed and to recognize the elements.

First of all, the frame dimensions are detected by the identification of several fixed markers (in yellow). Then, the server makes a change of scale between the real world (cm) and the virtual world (pixels) based on the physical configuration. After this step, the system is able to start tracking the position of the mobile elements that are studied (in red) in relation to the fixed ones. This position is used, together with the timestamp of the moment that was captured, to calculate the speed, acceleration and energies of these elements.

B.2 CONTROL SOFTWARE

As explained before, the boards are controlled by a computer thanks to their USB ports. There are libraries for controlling these elements for different programing languages and for different Operating Systems. We chose the official Python library because this programming language is multiplatform, and the web server is also developed using this language. Based on this library, we created our own set of methods to control the physical elements. The main functions used are:

1. Pulley
   – Move the pulley X degrees (from 0º to 720º)
   – Release the pulley
   – Restart the experiment
2. Pendulum
   – Move the pendulum X degrees (from -30º to 30º)
   – Release the pendulum
   – Restart the experiment
3. Spring
   – Stretch the load X cm (from 1 cm to 4.5 cm)
   – Release the load
   – Restart the experiment

Moving functions are special because they use feedback from the tracking system to increase accuracy at the moment of positioning the

elements. Restarting functions also try not to damage the physical components, avoiding the pendulum engagement if it is moving too fast, or moving the spring stepper back little by little with the electromagnet activated in order to avoid big hits. There is also a mechanism that prohibits sending several orders to the same engine simultaneously.

B.3 SIMULATION SOFTWARE

Once the tracking system has captured the position data, the simulation software starts running. This code is executed on the client side, the browser. The server sends the position of the tracked elements to the client and this is who calculates at every instant the other parameters for both the real system and the user simulation. The speed, acceleration and energies of the real system are always calculated in the same way, while the speed, acceleration and energies of the user simulation depend on the parameters that has been calculated and introduced, as well as on the theoretical models used in each exercise. In the initial difficulty levels, the virtual simulation uses the theoretical equations of motion for each system, while in the most difficult ones numerical approaches like Euler's method or Verlet's [6] method are used.

B.4 WEB SERVER
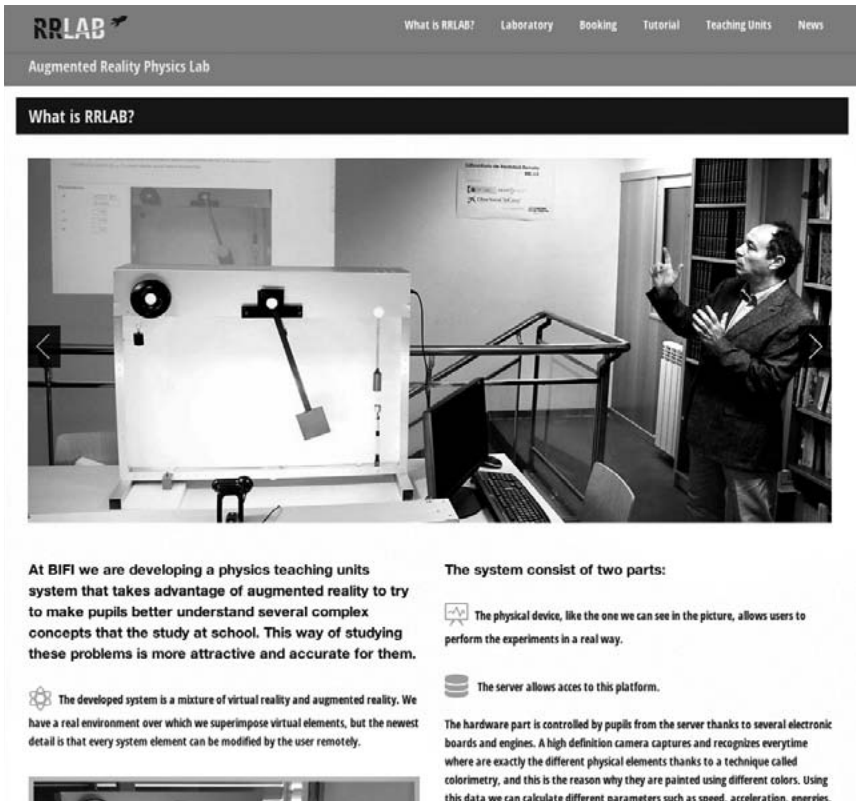
The web server allows users to perform the experiments through its interface. It is based on Pyramid [4], a Python framework that makes it easy to develop web applications from scratch. This technology is multiplatform and the development task is simpler and quicker than in other languages. Multiplatform support is an important feature because some replicas of these systems will be installed in different institutions, so the system should not be technology dependent, if there is an extension of it.

The web server manages a queue system for the use of experiments. There is a queue for each subsystem that gives the user 10 minutes to test everything he needs. Users are also able to book an experiment for up to 4 hours per week divided into 15-minute sessions. While the user that

has booked a period of time is not logged into the system, it can be used for free.

The user interface is based on a web browser that connects to the server. Users can access RRLab by visiting the following link: http://rrlab.bifi.es. The web page has been designed with the goal of offering simple access to experiments together with all the complementary information they may need.

The main page shows a video demo of the laboratory: what RRLab is, how it works and how it can be used are aspects explained in this video. In addition, the three subsystems and the booking method are shown as highlights of the main page (Fig. 5).

Figure 5

RRLab web page

In order to offer the information in a structured way, a menu is displayed at the top of the web page, with the following sections:

– *What is RRLab*, which contains a generic explanation of RRLab
– *Laboratory*, with three submenu options that allow access to the mentioned subsystems
– *Booking*, the reservation system where users can program-exclusive access
– *Teaching units*, with didactical material for learning more about the laboratory.

The most important section is the laboratory and includes four main subsections (Fig. 6):

– The first is common to all the experiments and consists of a short help section that summarizes how to operate the lab.
– The second one is the monitoring screen, on which users will see how the experiment is performing both physically and virtually. It also has a virtual ruler that makes the measurement of different elements possible.
– Close to this one, we can find the controls section. These controls make it possible to change the exercise difficulty, to enter the previously calculated parameters and to launch/restart the experiments. Depending on the difficulty level, there will be more or fewer parameters to calculate and enter.
– Finally, at the bottom, we can find the dynamic charts that show parameters of the real experiment and the simulation, such as position, speed, acceleration and energies in real time. All these variables, both real and theoretical, besides the kinetic and potential energies, can be exported to text files for their study with more sophisticated tools.
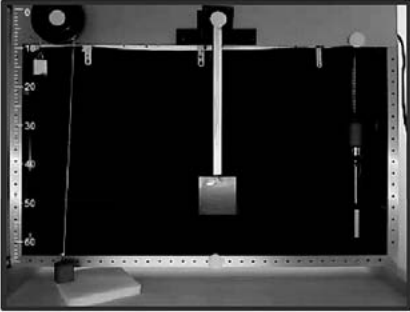
Monitoring, control and charts were developed using Flash in the client side and a Red5 [5] server in the server side. The latter provides the images captured by the webcam and the information coming from the tracking system in order to represent the simulation and draw the charts, always in real time.

Figure 6

RRLab web page: the laboratory

3. **The experiments**

As commented before, the main objective of RRLab is to have the possibility of comparing, in a remote way, the theory learnt during physics lessons with the corresponding real systems.

There is a series of experiments that the user may perform on the RRLab website. For each subsystem, there are four exercises with different levels of difficulty, in which the user has to make some previous calculations in order to introduce the corresponding parameters on the interface. On one hand, the camera tracks the position of the weights each time, and for these positions, the software calculates the real speed and acceleration of each mobile component. On the other hand, the program calculates the expected values of these variables according to the theory. This calculation is based on the parameters introduced by the user.

Basically, experiments at level 1 are merely an introduction to the problem where the user has to take some measurements of time, length or angles, and to make some geometrical calculations. Experiments at level 2 are mainly the cases where the theoretical calculation does not take into account the complete distribution of the load on some of the components, and neither the friction. At level 3 the real distribution of mass is used, but not the friction. Level 4 uses all the parameters, including friction. For this reason, at this level, numerical simulations are used to solve the problem in real time.

In general, for the real part of the experiments, they begin by positioning the element under study (the main piece or mass of each subsystem) in the place decided by the user. This position is defined by an angle or height/elongation, and is physically reached thanks to the engines. Once the user has decided to start the experiment, the masses are released from this initial position and the mechanical system is ready to be studied.

When the experiments are in fact performed, the users can visualize the images captured by the webcam, over which the images of the virtual system (computed according to the parameters introduced by the user) are superimposed. This way, users can immediately compare them, confirm whether the calculated parameters are correct or not, or even study how each of them would affect the behavior of the system.

It is worth remarking that, when the camera captures the image to identify the position of the weights (red square), it is not fully precise and has a small error. Moreover, as the system captures 20 images per second,

this error is different each time. This finally produces some minor fluctuations on the graphical representation of this position (and on the corresponding variables such as speed or energies). These oscillations are more visible when the system is stationary (in the "zero" position), mainly due to the charts' auto scaling.

Due to the fact that we are dealing with a real physical system, each subsystem can only be managed by a single user at one time, though any other user can be visualizing the experiment simultaneously. There is a reservation and queue system to execute the experiments, as was previously explained.

Let us now describe more in detail the main features of the experiments one can carry out on each subsystem.

A. *The spring*

This subsystem consists of a spring where a cylindrical iron weight is suspended. The spring hangs from a fixed point on the upper side. In order to locate the weight and unfasten it, there is an electromagnet fixed to the linear actuator axis whose displacement can be controlled.

In order to move the weight, it is necessary to indicate the number of centimetres that we wish to move it down, starting from the equilibrium position. The positive direction is downward. Once the centimetres are indicated, when pressing the *Prepare* button the electromagnet is activated by binding to the metal weight, and then the engine starts to move until it reaches the selected position. For this position, the webcam takes pictures of the weight, tracking the surface of the red square. The system has previously recognized the fastening point (centre of the yellow circle). With the anchor point and the centre of the weight recognized, the system calculates how much the spring is stretched at each moment. When the desired elongation is reached, the engine stops.

After pressing the *Start* button, the electromagnet is deactivated and it moves slightly in the opposite direction to the motion in order to prevent further collisions. The spring starts to move freely (in a strict sense, the motion is not totally free because there is a small friction with the air and also because the elasticity of the spring is not perfect).

As for the rest of the experiments, the system will draw the real motion superimposed over the virtual one. The virtual motion is obtained

from the theoretical motion equations, using the data entered by the user. At Level 4 this is done by means of a numerical simulation. In order to draw the elongation values y(t) on the screen, the system must know the relationship between pixels and centimetres. This ratio is calculated at the beginning of the experiment based on the recognition of the yellow marks. Since we know the number of pixels captured, and we know the distance between the marks, we can set this conversion factor for each axis (axes X and Y in our case).

The evolution of different variables is calculated and shown in the corresponding charts:

1. Weight position
2. Weight vertical speed
3. Weight vertical acceleration.
4. Energies: Kinetic, Potential and Mechanical (Only at levels 3 and 4)

For example, considering the speed, at levels 2 and 3 the theoretical speed is directly calculated from the theoretical formula, since we know the time and the rest of parameters, while at level 4 it is calculated through the numerical simulation. To calculate the actual position, the system recognizes the weight centre of the red surface in each frame. By subtracting the position of a frame and the previous one, and dividing by the time interval, the actual speed is calculated.

B. *The pendulum*

The pendulum is a uniform thickness iron piece, with a much larger area at the bottom part than in the rod that connects it to the spinning axis. The pendulum is suspended from a shaft attached to a bearing, with certain friction. In order to be located and released, there is a magnet attached to the spindle of a stepper motor, so that you can control the spinning angle. To place the pendulum, we need to indicate the grades we want to move it from -30° to 30°. The positive direction is counter clockwise. Once the grades are indicated, if the user presses the *Prepare* button, the electromagnet is activated, thus engaging the pendulum shaft, and the engine rotates it in the indicated direction.

The webcam captures pictures of the pendulum, tracking the red square surface. The system has previously recognized the rotation centre

of the pendulum which coincides with the centre of the yellow circle. With the rotation axis and the centre recognized, the system calculates at each moment the angle between the pendulum and the vertical axis. When the angle matches the value selected by the user, the motor stops. After pressing the *Start* button, the electromagnet is deactivated and moves slightly in the opposite direction to avoid collisions. The pendulum begins to move freely (although there is some friction with the bearing where it is hung and with the air).

Moreover, in this case, the virtual simulation is directly obtained from the theoretical motion equations or from the numerical simulation. In order to draw the values of x(t) and y(t) on the screen, the system must know the relationship between pixels and inches. This ratio is calculated in a similar way to the case of the spring.

The evolution of different variables is calculated and shown in the corresponding charts:

1. Angle
2. Angular speed
3. Angular acceleration
4. Energies: Kinetic, Potential, Mechanical

We stress that the theoretical mechanical energy obtained in Levels 2 and 3 is only constant for small oscillations, therefore for large initial angles the total energy curve is not a straight line.

C. *The pulley*

Finally, the third subsystem is a pulley where two different loads are suspended, falling with a little friction. The pulley is positioned at the top frame where the two iron masses of different sizes are hanging. The pulley shaft is inserted in a step by step motor. To be positioned, the motor that rotates (clockwise from the observer point of view) is activated. Users can physically handle the pulley by indicating the number of degrees to be rotated. The motion will start after pressing the *Start* button, when the engine will rotate the pulley at the specified angle.

The identification process of the weights and the pulley axis is similar to the previous cases (red squares and yellow circles). The motor stops once the pulley has been rotated, as indicated by the user. Knowing the

radius of the pulley, one can equally talk of degrees or centimetres. The radius of the pulley can be estimated, for instance, by using the horizontal ruler.

After positioning the pulley, the motor is stopped but active, which means that it is restrained. After pressing *Start*, the engine disengages and the bigger weight begins to fall. It is important to note that, besides air friction, there is also a certain resistance due to the engine's internal friction (the pulley shaft is directly joined to the engine).

The system detects only the red load, while the other weight position is calculated knowing the radius and position of the pulley and the cord length. Superimposed on the real motion, the system draws the pulley and two virtual weights held together by a cord, whose motion is calculated from the theory in a similar way to the cases explained above.

The evolution of different variables is calculated and shown on the corresponding charts:

1. Right weight position
2. Right weight speed
3. Right weight angular acceleration
4. Energies: Kinetic, Potential, Mechanical

Knowing the position as a function of time, the speed and the acceleration can also be calculated, and therefore the energy of the weight. From the speed and the pulley radius we can calculate the angular speed (the cord does not slide on the pulley).

4. **Case study: the ideal pendulum**

As an example of the experiments that can be performed, let us describe the level 2 exercise on the pendulum subsystem (Fig. 7).

The objective is to measure the length of the pendulum, calculate the theoretical angular frequency and initial phase, as well as the energies, and verify the data by comparing the theoretical to the actual motion.

Let us assume that the load of the segment that connects the shaft to the bottom part of the pendulum is zero and also consider that the pendulum has its mass concentrated at the centre of the square. We shall not take into account either the shaft or the air friction, and shall also assume that we are dealing with small oscillations.

The user is able to calculate the potential energy of the system depending on the angle, mass, length and gravity (when the system is at the equilibrium position, the potential energy is set to 0). To calculate the height, the ruler can also be used.
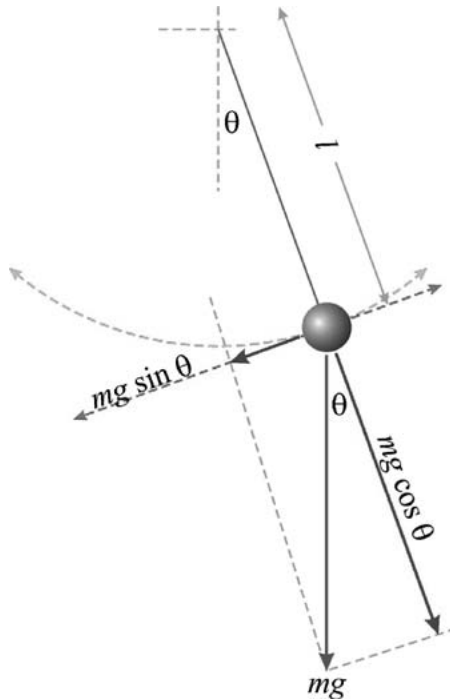

Figure 7

Components diagram in a pendulum motion

The exercise consists of the following steps:

1. Assume you have a simple pendulum. Using the ruler, measure its length x and introduce its value on the interface. Remember that all units are in the International System (SI).
2. The equations of motion for small oscillations are $\phi(t)=Asin(\omega t+\theta)$, $\omega=2\pi/T$, $T=2\pi\cdot\sqrt{l/g}$. Select the initial angle of the pendulum, A, calculate and introduce the angular frequency ω and initial phase θ (the pendulum will start from rest).

3. Calculate the kinetic energy (T), potential energy (V) and mechanical energy ($T+V$) at the initial point (i.e. according to the data entered in the previous step) and enter their values.
4. Place the pendulum in the desired position (*Prepare* button) and then start the experiment (*Launch*).
5. Discuss the differences between the theoretical motion (superimposed in red) and what actually happens.

According to these steps, the values to be introduced by the user are the following:

1. Initial phase. A positive sign means moving the pendulum to the right (counter clockwise looking from the user towards the screen). In order to obtain an intuitive idea, the displacement is shown in degrees, though all other data and parameters are given in radians.
2. Length of pendulum. Estimated from the attachment point (centre of the yellow spot on the shaft) to the centre of the red load, in the lower centre of the square (in this exercise we are assuming we have an ideal pendulum).
3. Angular velocity. Calculated according to the formulas above.
4. Initial phase, given the initial conditions just before *Start* (angle and initial speed).
5. Initial energy: kinetic, potential and total.

If the values of ω, θ and x introduced by the user are not correct, the real and virtual motion will not match. Also, if the calculations are wrong, the theoretical mechanical energy is not preserved.

On the contrary, if the user has correctly calculated the different variables, real and virtual images will match at a relatively reasonable level of accuracy. It is important to note that this approximation (ideal pendulum) will work properly only for small oscillations (not a very high initial position) and during a few periods. As time passes, the differences between reality and virtuality will increase because, in this exercise, the theoretical model does not take into account the real distribution of mass or the friction.

5. **How to access the experiments**

RRLAB is accessible from a web browser following one of the following links:

- http://rrlab.bifi.es (Installed at BIFI)
- http://rrlab3.bifi.es (Installed at BIFI)
- http://rrlab.juandelanuza.org:8080 (Installed at a private school, Juan De Lanuza in Zaragoza)

Since the laboratory has limited physical resources, a queuing system is necessary to administrate the access and utilization of the labs by users. This system is responsible for receiving the clients' requests and giving them access in the correct order, so the last user will have to wait until those that arrived beforehand have finished their interaction with the experiments. Each subsystem has its own queuing system, so that if one of them has a high occupation rate, users can try to access the other subsystems, which might be free or with a shorter waiting time.

If a user accesses an experiment and there is no waiting time, he/she will be able to interact immediately with the laboratory for an unlimited time. If there are more users waiting, the user will be able to use it for a maximum of 10 minutes. At that moment, the system will issue a warning that he/she will be requeued.

If someone needs the laboratory for a fixed period of time, there is an alternative way to access the system. This is achieved thanks to a booking system. It grants exclusive access to one laboratory for up to four hours a week divided into quarter hours. To book a period of time, a user just has to click on the corresponding menu button and follow the instructions. He/She will be asked for the subsystem, the date, and the period of time he/she would like to reserve. Once this has been configured, a name will have to be entered for the reservation and an e-mail address that will be used to send a confirmation e-mail, as well as the direct access link that will work only in the selected period. If, at the time of performing the experiments, another user is accessing the same subsystem, the user will be requeued until the reservation user has finished.

6. Conclusion and future work

RRLab was created with the goal of helping both students and teachers, to better understand the real behavior of the concepts they study in class.

With this objective in mind, and making use of virtual and augmented reality techniques, we have developed a remote laboratory to study three

mechanical systems (pulley, pendulum and spring) that allow the user to compare the theoretical calculations they learn with the real physical processes.

The lab is accessible from a web browser and can be used any time when available, or under schedule if students or teachers wish to book an exclusive date for themselves.

Many physical concepts are still far from being clearly understood with the traditional way of learning, so several kinds of experiments are being studied for future developments. Besides the possibility of continuing working with other mechanical systems, some new scenarios are being evaluated in different fields, such as astronomy, light phenomena, and even in fields not directly related to physics, like biology or chemistry. In these latter cases, further work will be necessary in order to ensure the reproducibility of the results and replacement of the materials under study.

Finally, let us remark that, although RRLab has been developed at BIFI (our research institute at the University of Zaragoza), some of the systems have been shared with Secondary Schools thanks to the agreement signed with the Education Department of the *Gobierno de Aragón* to collaborate with students in research activities, while another system is hosted by the private school, Juan De Lanuza. We would also like to acknowledge FECYT and Obra Social La Caixa for their financial support in this project.

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Using a VISIR laboratory to supplement teaching and learning processes in physics courses in a Swedish upper secondary school

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1. Introduction

In science education students' understanding of theory seems to a great extent dependent on laboratory experiments proving and/or explaining the theory taught in class. Moreover, the experiments provide students with training and experience of experimenting, as well as enabling them to develop competences that concern: the handling of instruments and components, the evaluation and determination of physical parameters of objects, the design and use of tables, calculations, planning and implementing experiments.

Hands-on laboratories are the most common forms of laboratory environments, offering students opportunities to experiment with real equipment related to education material. Another approach is using remote laboratories or simulated laboratories. The paper [1] describes how the nature of educational laboratories has changed because of factors influencing laboratories today. The authors of [2] draw conclusions from the debate about the value of hands on, remote and simulated experimentation.

A remote laboratory (RL) is a software and hardware system that enables remote students to use real equipment physically located in a

school. Today remote laboratories supplement hands-on ones in science courses at upper secondary schools. The Virtual Instrument Systems in Reality (VISIR) Open Lab Platform is an architecture enabling universities and other teaching organizations to open instructional laboratories for remote access with preserved context. Seven VISIR electronic labs where students can work and conduct experiments that can be remotely performed on a solderless breadboard without any risk of being harmed are online at seven universities globally. An active VISIR community also exists.

Katedralskolan is an upper secondary school located in Lund, in the southern part of Sweden and can be accessed via Internet at the address: [3]. The number of students at Katedralskolan is approximately 1,200 and they are distributed among the Natural Science Programme, the Social Science Programme and the International Baccalaureate. In a study carried out during the period 2009-2011 concerning development strategies and methods for implementation of remotely controlled laboratory experiments, two teachers and 94 students at Katedralskolan participated. The results obtained from this study are reported in [4]. The majority of the students in this study were satisfied with the VISIR electronic lab at BTH. The students showed great interest in the laboratory experiments, and appreciated that these were not simulations but real experiments carried out with real physical instruments and electrical circuits. Fig. 1 shows the locations and buildings of BTH and Katedralskolan. There is a distance of 200 km between BTH and Katedralskolan.

The students' satisfaction with the RL and perception of the RL resulted in a proposal for improvements in the RL's user interface. After these improvements to the VISIR electronic lab at BTH for use in upper secondary schools were implemented, it was used during the 2012-2013 academic year for electrical experiments in the courses of Physics1 [5] and Physics2 [5] at Katedralskolan.

This chapter presents the VISIR electronic lab at BTH extended for the physics courses at the upper secondary school, Katedralskolan in Lund. In this chapter we shall discuss the advantages and disadvantages of using the VISIR lab to enhance and supplement the hands-on laboratory in physics courses at Katedralskolan. Examples of laboratory work carried out in the VISIR electronic lab by students at Katedralskolan are given. The main purpose of this chapter is to serve as an introduction and inspiration to

online electrical and acoustic experiments for teachers at upper secondary schools. The continuation of this chapter is organized as follows: Section 2 describes the VISIR electronic and acoustic lab. In section 3 you can read about the Swedish education system and the teacher's tasks in the VISIR lab. Sections 4 and 5 provide examples of students' remote laboratory work. Finally, Section 6 concludes the chapter.

Figure 1

Locations and buildings of BTH and Katedralskolan

2. **Introduction to the VISIR laboratory**

A VISIR laboratory for experiments is more or less a replica of an instructional hands-on laboratory, which are common place at universities and upper secondary schools worldwide. Remote students and guest users can perform real physical experiments, using real instruments and experiment objects within limits defined using a web browser only. The VISIR concept involves adding a remote operation option to traditional

instructional laboratories to make them more accessible, regardless of whether the students are on campus or mainly off campus [6]. The BTH VISIR solution uses a unique interface enabling students to recognize and operate the equipment found in the hands-on laboratory. At present the department of Electrical Engineering, BTH, has VISIR laboratories for electronics [7] and for signal processing, which include experiments on mechanical vibrations [8] and acoustics [9]. It is the VISIR laboratories dedicated to experiments on electronic circuits and acoustics that are currently being used in the project between Katedralskolan and BTH. BTH also offers RLs based on other principles than the VISIR platform: one remote lab for antenna theory [10] and another for security [11]. All RLs at BTH can be accessed via the Internet at [12].

A. *VISIR electronic lab*

A.1 HARDWARE

VISIR is a client-server architecture where measurements are carried out using a server. Virtual instrument front panels are displayed on the client computer screen [13]. A significant difference for a remote student compared with a student in a hands-on laboratory is how to wire circuits and connect instruments. A remote student must use a suitable telemanipulator instead of a solderless breadboard to perform such actions [7]. VISIR specifies a relay switching matrix and a virtual breadboard combination [7]. The remote student wires the circuit and connects instruments on the virtual breadboard displayed on the computer screen. The physical circuit and the instrument connections are created in the switching matrix by controlling relays to set up appropriate electrical connections.

Only Internet access and a web browser with a Flash player are required to access the remote experimental resources [13]. The client software is automatically downloaded from a web server.

The switching matrix is a USB-controlled circuit wiring robot, where the student's requested circuit can be realized and measured. It is built like a stack of cards (PCBs), with a shared bus that passes through them all; the switching matrix is shown in Fig. 2. Components are connected through relays on what are called component cards, instruments on instrument cards, and by controlling the matrix to close relevant relays,

the circuit can be constructed and the instruments connected. New cards may be added to the stack, when, for example, more flexibility or new component types are needed.

Available components are:

– resistors from 50 Ω to 220 000 Ω
– two potentiometers, 10 000 Ω and 100 000 Ω
– capacitors from 6.8 nF to 10 μF
– one coil, 82 mH
– diodes
– operational amplifiers

Available instruments are:

– digital multimeter (DMM)
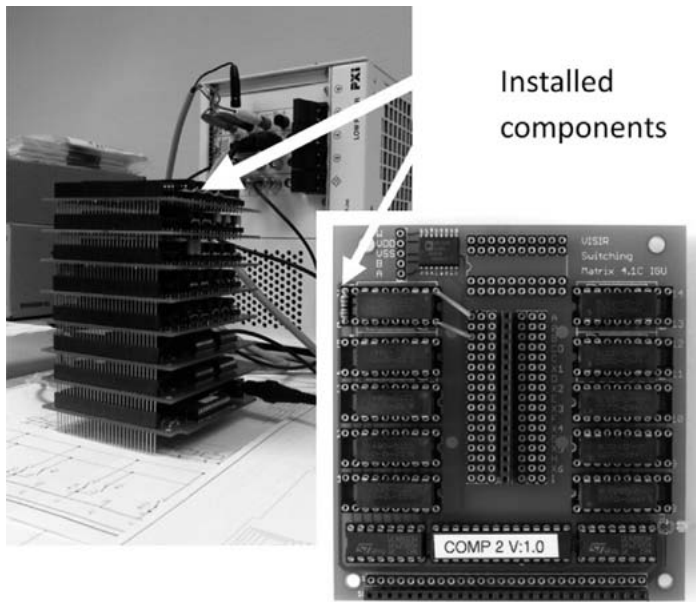– oscilloscope
– DC power supply
– function generator

Figure 2

The switching matrix

A.2 SOFTWARE

The client software is written using Adobe Flash, which is now being replaced successively by HTML5. It is responsible for displaying and handling the breadboard as well as the instrument front panels, so the student can set up their experiment and view the measured response. Each front panel is based on a real-life instrument and should look identical and behave identically as far as possible, just like the real-life instrument. Fig. 3 illustrates what is displayed on the client's computer screen when the DC Power Supply is activated: an interactive image where it is possible to change the DC Voltage level, for example. Users are then able to interact with these instrument front panels, which include animated controls and displays, in the same way as they would when physically operating the instruments in the hands-on laboratory. Basically, the mouse pointer is used to click on buttons or rotate knobs similar to the usage of fingers in the hands-on laboratory to press buttons or turn knobs. The graphical user interface (GUI) presents the instruments with a sense of realism and functionality that matches the physical instruments. Front panels are interchangeable, so if another model of an instrument is needed, it is possible to select one.

Figure 3

DC Power Supply

When a measurement is carried out, all settings of the instruments in the client computer are encoded in a measurement request and sent to the server. The server responsible for carrying out measurement is called a measurement server. It is software written in C++ and has the responsibility of validating the settings and the circuit sent by the client. The server also needs to figure out if the circuit wired on the virtual breadboard can be safely implemented by the switching matrix. When everything is verified and safe, the measurement is carried out and the results are sent back to the client. The client can then display the results on the instrument's front panels.

A.3 VISIR ELECTRONIC LAB ACCOUNTS

The user interface is the frontal web page of the VISIR electronic lab that handles the whole administration, access and authentication process. It provides many features similar to those provided by a learning management system (LMS) in order to facilitate the implementation of the VISIR electronic lab in the physics courses. The capabilities and limitation of these features are associated with the account types. The properties and the privileges of each account type are:

Administrator account (the lab provider) can

1. create contents in the user interface
2. upload files
3. create and delete courses and add teacher responsible for the course
4. modify or remove user accounts
5. switch to "teacher view"

Teacher account (created by the administrator) can

1. add or remove experiments
2. add, remove and modify student accounts
3. provide a teacher with a scheduled reservation for a group of students
4. switch to "student view"

Student account (created by the teacher) can

1. select instruments
2. select experiments with prepared components
3. make a scheduled student reservation

A.4 ENHANCEMENT OF THE VISIR ELECTRONIC LAB AT BTH.

The results from a survey that involved students from Katedralskolan concerning satisfaction with the VISIR lab at BTH and the perception of it [4] resulted in a proposal for improvements in its user interface. These improvements were implemented and now only the instruments that are used in the experiment are shown in the user interface. The user interface before and after improvement is illustrated in Fig. 4, at the top of which can be seen the old user interface with all instrument connectors, to the left and right of the breadboard, and instrument select buttons at the bottom of the breadboard. At the bottom of Fig. 4 the new user interface instruments and components prepared for an experiment on Ohm's Law are only available. Another improvement is shown at the bottom of Fig. 4: on the right there are two DMMs, which are used in experiments concerning Ohm's Law.

In the enhanced version of the VISIR electronic lab you can choose to use Flash or HTML5. HTML5 is working on handhold devices, for example, iPad and smartphones. Another advantage with not using Flash is that the providers of RL do not need to buy an expensive development environment. It is possible to use the language of the web browsers to create new front panels, which simplifies the creation. The new tools also allow you to use the front panels in new ways, like having several front panels on the same web page, see Fig. 5. The use of handheld devices with a touch screen also makes it possible to investigate the interaction with your fingers.

B. *VISIR acoustic lab*

The VISIR acoustic lab is a novel and unique laboratory setup developed by BTH on the foundations of VISIR with the requisite changes demanded by the active noise control (ANC) field [9]. The laboratory is designed to support experiments in the fields of both Acoustics and Digital Signal Processing. The laboratory can supplement traditional experiments ranging from advanced level to basic acoustic experiments suitable for upper secondary school students. In order to understand the laboratory setup and appreciate the changes made to the basic VISIR architecture, it is important to briefly review some ANC concepts.
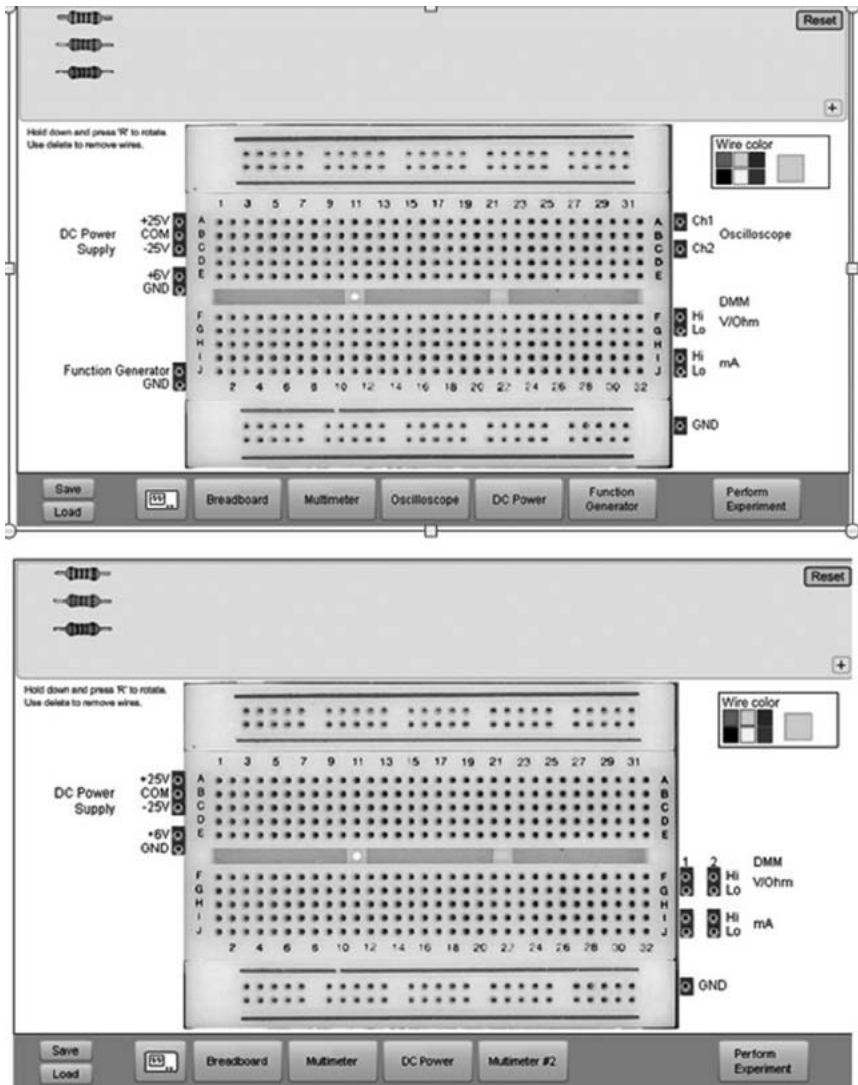
Figure 4

Top: user interface with all instrument connections to the left and right of the breadboard and the instrument selection buttons at the bottom of it. Bottom: user interface with instruments and components prepared for Ohm's Law experiment only
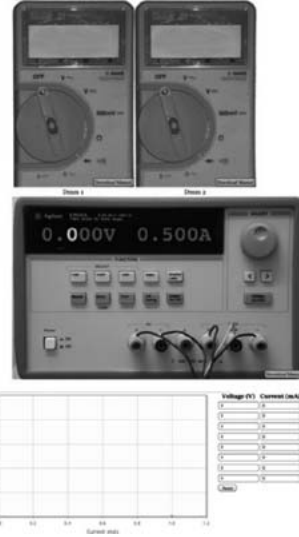
Figure 5

VISIR electronic lab Web site based on HTML5

B.1 ACTIVE NOISE CONTROL

Active noise control is a method used to control or reduce unwanted noise (sound), known as primary noise, by an anti-noise known as secondary or control noise. The control or reduction is achieved by a superposition of the primary and secondary noise resulting in a residual noise. Fig. 6 shows a simple ANC concept through the principle of superposition. The amplitude of the residual noise is dependent upon the amplitude and phase similarity of the secondary and primary noise. To achieve 100% attenuation (zero residual noise), the secondary noise must be 180 degrees out of phase and equal in amplitude with respect to the primary noise. The same concept is applicable to vibration control. Active control of sound or vibration is preferred in applications where the passive methods are unpractical or unfeasible for implementation. For example, in heating ventilation and air conditioning (HVAC) systems, low frequency noise is controlled actively as passive methods such as mufflers and absorbers become large, bulky and unfeasible at low frequencies [14], [15].
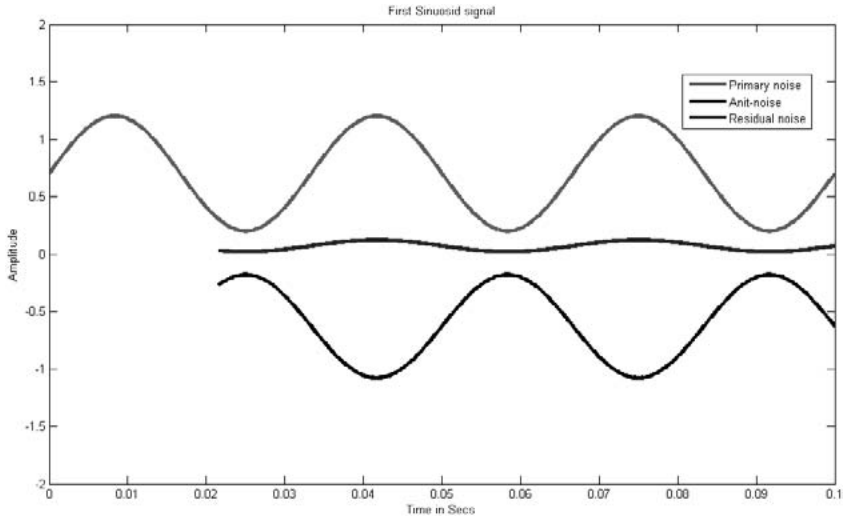
Figure 6

Illustration of the ANC concept using superposition

The idea of ANC is simple but in practical application the primary noise and the surrounding environment are usually non-stationary, therefore, the controller which generates the secondary noise must keep track of these variations in real time and hence, the ANC must be adaptive. One such class of adaptive controllers are the feed forward adaptive controllers. These controllers are comprised of a Finite Impulse Response (FIR) or Infinite Impulse Response (IIR) digital filter and an adaptive algorithm, for example, the Least Mean Square (LMS) algorithm, which steers the coefficients of the filter to minimize a cost function, such as the instantaneous residual noise power [15]. The term feed forward means that the controller is supplied by some prior information on the primary noise, known as reference signal. Fig. 7 shows the feed forward adaptive control applied to noise in HVAC ducts shown as plant P. The cost function is usually defined by the squared instantaneous residual error, e(n), sensed by a microphone, known as error microphone, and the reference signal (primary noise), x(n), is sensed by another microphone, the reference microphone. The controller output, y(n), is given to a loud speaker to generate the secondary or control noise and d(n) is the desired signal, the primary noise at the point where the superposition of the

noises take place. The physical equipment –microphone, loud speaker, etc.– introduces, between the electrical signals y(n) and e(n), the so-called Forward path, F, in the system. The effect of this path is included in ANC by filtering the reference signal by an estimate of the Forward path, F'. The forward path is estimated before applying ANC, like an FIR filter designed using adaptive system identification techniques.
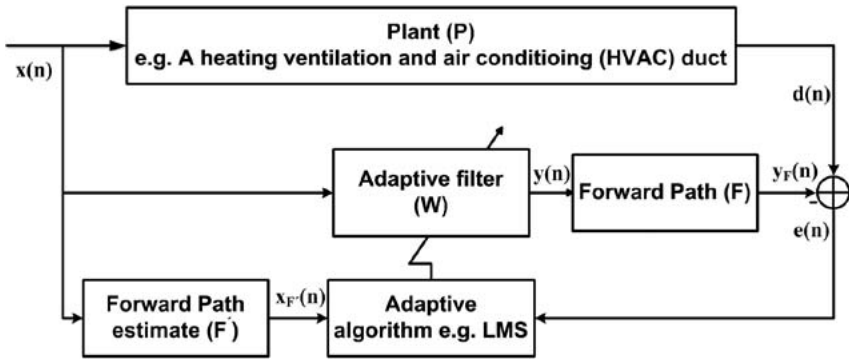

Figure 7

A simple feed forward active noise control system for a heating ventilation and air conditioning duct

B.2 THE VISIR ACOUSTIC LAB SETUP

The VISIR acoustic lab is developed for a single-channel feed forward control system and is shown in Fig. 7. The equipment required for a normal acoustic and active noise control lab is described first and then the equipment needed for remote control will be presented. The overall VISIR acoustic lab is shown in Fig. 8. The equipment required for the remote controls is shown in light grey while the rest is in dark grey.

Laboratory equipment: Plant P is a 4.05m long circular duct normally used in HVAC systems, with a 315mm diameter. There are four reference microphones and one error microphone (VM-6052-5382) inside the duct to sense (measure) reference and error signals. It may be noted that, being a single channel controller, only one reference microphone is enough. The use of four reference microphones provides flexibility in positioning the microphones for the control of the acoustic field in the duct. For
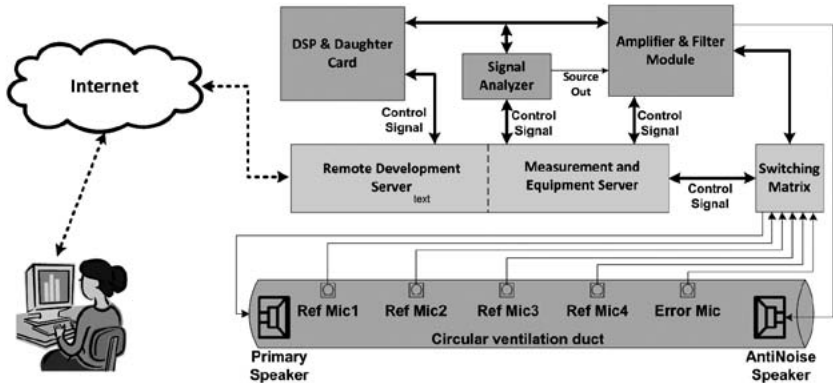
Figure 8

Block diagram of the remote VISIR acoustic lab, showing the interconnection of the equipment

instance, any one of the four microphones may be used as a reference microphone to control noise at an Eigen frequency of the duct. The primary and secondary noises are generated by two loud speakers (Fostex-6301B3) placed at each end of the ventilation duct. A four-channel dynamic Signal Analyzer (HP36570A) is used both as signal source for the primary noise speaker and for analysis of the control, as well as for other microphone signals.

The adaptive controller is implemented on a digital signal processing (DSP) board (TMS320C6713DSK) by Texas Instruments. To increase the number of input and output channels, a mini data acquisition board (S. Module 16-100) by SEMATIC is connected to the DSP board via a mini-bus interface. The data acquisition board provides four differential analog inputs and four analog outputs with 16 bit resolution. Although the S. Module 16-100 has internal anti-aliasing and reconstruction filters, a separate filter/amplifier module (USBPGF-S1/L) by Alligator Technologies is used to enhance the signal conditioning demanded by ANC applications.

Equipment for remote control through the Internet: The laboratory is based on client server architecture, similar to other remote laboratories based on the VISIR open source platform. The server can be divided into two servers based on the tasks they perform [6].

Measurement and Equipment server: The Measurement and Equipment server, developed using C++, is responsible for connecting the

equipment and making measurements in the lab remotely. The Signal Analyzer is connected to the server through the General Purpose Interface Bus (GPIB). The microphones and loud speakers are connected to the server via the switching matrix, which itself is connected to the server through the USB interface. The new device i.e. the filter/amplifier module, supplied with an Active X control, is integrated with the server by initializing a separate thread.

Web server: The web server hosts the GUI or remote client as web pages, through which the student accesses the remote lab.

The remote client: Similar to other web-based remote control systems, students access the VISIR acoustic lab via a remote client or graphical user interface (GUI). There are two main tasks in the remote VISIR acoustic lab: configuring the equipment, i.e. microphones, loud speakers, Signal Analyzer and filter/amplifier module, and implementing the adaptive controller on the DSP board. For each task there is a separate sub-client or web-page called Measurement and Configuration Client and Web-Based Development Environment respectively. The former, developed using Hyper Text Markup Language (HTML) and JavaScript, is shown in Fig. 9. The Adobe Flash front end for the Signal Analyzer is embedded in the HTML web-page. When the VISIR acoustic lab is accessed via the Internet, this client is presented to the student first. The later sub-client is initiated from the first client and is basically an Integrated Development Environment (IDE), as shown in Fig. 10. The IDE provide interaction with the Code Composer Studio (CCS) by Texas Instruments, installed on the server, through LabVIEW's Test Integration toolkit and Web Publishing tool. Only basic functionalities such as project creation, file save, editing, run time variable update, compilation and downloading the code to DSP are available. To run this client, the user is required to install the freely available LabVIEW Runtime Engine by National Instruments for their browsers.

3. Teacher's tasks in the VISIR lab

A. *An overview of the Swedish education system*

The Swedish education system comprises a number of types of schooling and education, designed for individuals of different ages and
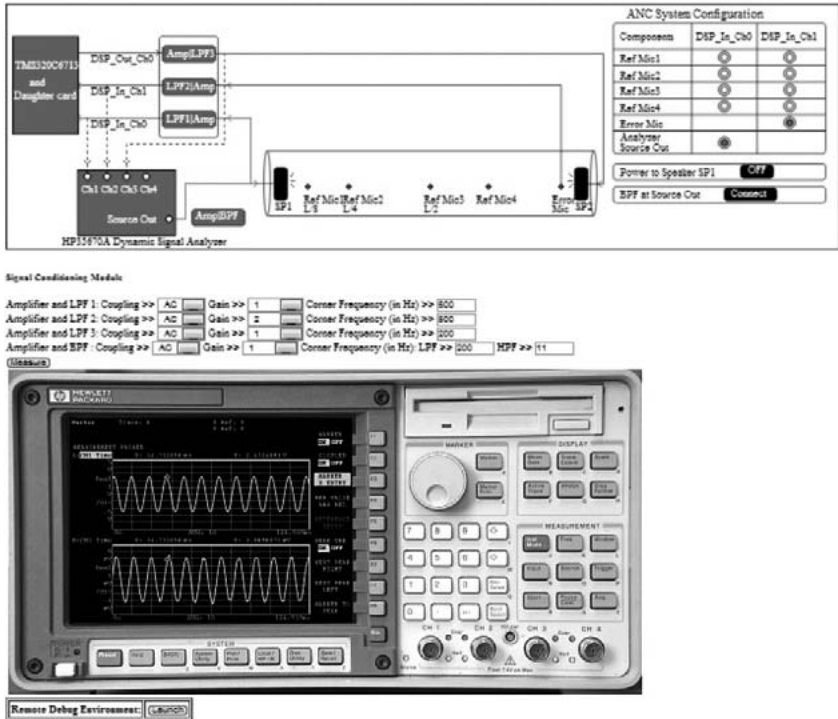
Measurement and Configuration Client

Figure 9

A snap shot of the Measurement and Configuration Client used during a basic acoustic experiment

with differing needs and abilities [16]. All youths in Sweden who have completed compulsory school are entitled to a three-year upper secondary school education. Upper secondary education provides a good foundation for vocational activities and further studies, as well as for personal development and active participation in society. Upper secondary school consists of three different types of program:

1) 18 national programs each lasting three years. They are divided into upper secondary foundation subjects, subjects common to a program, orientations, program specializations and a diploma project; 2) Five introductory programs for pupils who are not eligible for a national program; and 3) Education that deviates from the national program
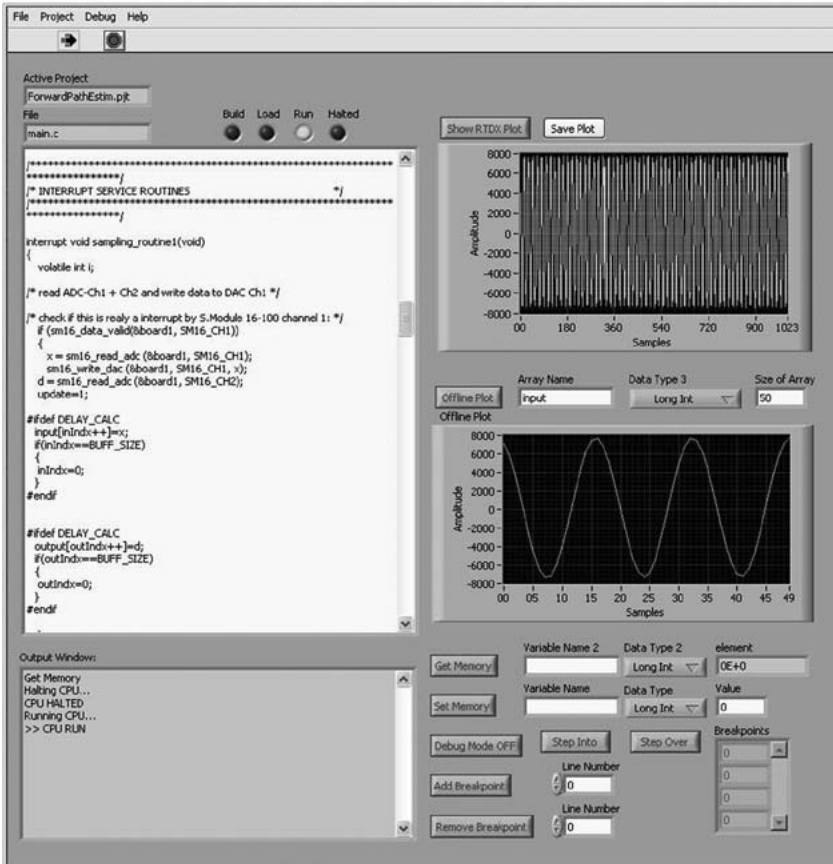
Web-Based Development Environment

Figure 10

A snap shot of the Web-Based Development Environment used during an ANC
controller implementation

structures; special variants, program based on national recruitment and
nationally approved sports programs (NIU).

Upper secondary school has a six-level grading scale from A to F
with five pass grades and a non-pass grade. Enhanced clarity in the
grading scale and knowledge requirements should lead to clear information
and a fair and balanced assessment of students' work. Grades are awarded

based on the goals and knowledge requirements set out in the syllabuses. A teacher awarding a grade should not compare a student's performance with others in the class, but assess how well each student has achieved the goals of the course. Grades cannot be appealed against. The teacher awarding the grade should also be able to inform the student of the reasons for the grade assessment.

B. *The courses Physics1 and Physics2*

The national Natural Science Program is intended for students who wish to work in natural sciences. The program provides the foundations for further studies in natural sciences, mathematics, technology and social sciences in higher education.

Physics is one of the scientific subjects in the Natural Science Program and it covers everything from the interaction of the smallest particles of matter to the origins and structure of the universe. The core contents of Physics 1 are: 1) Mechanics, Kinematics and Dynamics, 2) Electricity, 3) Thermodynamics and 4) Nuclear Structure. The core contents of Physics 2 are: 1) Mechanics, Kinematics and Dynamics, 2) Electricity and Magnetism, 3) Optics and Waves and 4) Atomic Structure.

Why does the natural science program include experimental work? On the basis of systematic observations and experiments, physics strives to discover basic principles that can be expressed mathematically in models and theories. In the aims of the subject it is written: "the teaching in the subject of physics should give students the opportunities to develop the ability to design, carry out, interpret and report experiments and observations, and also the ability to handle materials and modern engineering tools". This course aim, experimental work, is also required by universities and possibly in future employment.[5]

In Physics 1, the students have three hours per week of class spread over one and a half years, a total of 150 hours, and in Physics 2, the students have three hours per week spread over one year, 100 hours in total. A single teacher usually gives all the lessons in a course. The number of students is approximately twenty. The teacher decides when to have laboratory work, problem solving or theoretical classes. Students are assessed by two evaluation components: their lab work performance and theoretical examinations during the course.

C. *The learning management system of Katedralskolan*

New technologies, in particular the Internet, provide teachers with many interesting tools that can be used to improve the teaching learning process. E-learning platforms, also known as a learning management systems (LMS), are a software system designed to support teaching and learning. An LMS is especially useful when teaching Science in general and Physics in particular because it allows implementation of objects of many kinds, such as links to remote laboratories which can be used for laboratory work and animations which can be used to dynamically show many physical situations and concepts that are often difficult for the students to apprehend.

The LMS, Itslearning, has been in use at Katedralskolan since 2009 and provides tools for assessment, communication, uploading of content, return of students' work, administration of student groups, questionnaires, tracking tools, chats and forums over Internet. Itslearning enables teachers to follow the evolution of the learning process and to know the performance of each student in specific tasks. Every student at Katedralskolan has unlimited access to Itslearning resources because they have computers at their disposal at school.

D. *The teacher's tasks in Itslearning and VISIR electronic lab*

There are preparations to be done by the physics course teacher in the both in Itslearning and in the VISIR lab.

Itslearning:

The teacher's task in Itslearning is to design and structure the Itslearning-course with the following contents;

– a link to the VISIR lab
– an instruction manual and/or video clip for students that provides them with information on how to gain access to VISIR lab and how to use the VISIR lab for experimental work
– experiment instruction manuals, describing the experiments to be performed during the sessions
– a discussion forum
– a folder, of every type of assignment, where the students can return their results from the experiment

The teacher's tasks in VISIR electronic lab:

The course in the VISIR electronic lab is started by the administrator on request from the teacher. The administrator adds the teacher responsible for the course. As a support for teachers using the VISIR electronic lab, there is a comprehensive teacher manual available [17].

The teacher then adds his/her students to this course, see arrow C in Fig. 11. This action simply implies copying and pasting the list of e-mails of the students enrolled in the teacher's course from Itslearning into the VISIR electronic lab. The student then uses this e-mail to activate his/her account in the VISIR electronic lab. In the list of users, arrow B in Fig. 11, the teacher can see whether a student has activated his/her account.

Figure 11

Teacher view of course physic 1 in VISIR electronic lab for electrical experiments

The next step for the teacher is to create and add newly prepared experiments (arrow A in Fig. 11), i.e. a set of components and instruments, for students according to the course. Here the teacher needs to be aware of the components physically available in the matrix. A prepared experiment is a file saved in the VISIR electronic lab. By uploading the file to the system in the students' course, it becomes available to the students. The teacher must verify that all the circuits to be wired by the students in his/her session have permission to be created. The teacher may ask the laboratory staff for a list of the current virtual instructor rules i.e. the Max Lists. It is most likely that at least some of the circuits will not be supported and a number of the components may not be present in the online component store. The staff responsible for the VISIR lab can include the components and define new Max Lists. These lists should not only support the teacher experiments but also support all safe circuits possible to create using components of the online component store extended with the teacher components.

E. *The students' steps using VISIR electronic lab*

The student starts with login at the VISIR electronic lab website at: [18], chooses his/her course and then clicks on the prepared experiment, i.e. a set of components and instruments. As a support for students at Katedralskolan using the VISIR electronic lab at BTH, there is a student manual available at the address: [19]. A typical practical session in a VISIR electronic lab has four steps:

1. configure the circuit,
2. configure the instrument (DMM),
3. run the experiment, and
4. analyze the results.

4. **Electronic experiments**

In a study carried out during the period of 2009-2011, two teachers and 94 students at Katedralskolan were participating in a project in which both Katedralskolan and BTH collaborate. The students were divided into

five groups according to physics course and teacher. Very interesting experiences from remote experiments are reported in [4]. The majority of the students were satisfied with the VISIR electronic lab. The students showed great interest in the laboratory experiments, and appreciated that they were not simulations but happened in real life.

After some improvements in the VISIR electronic lab at BTH for use in upper secondary schools, it now has been used for electrical experiments in Physics 1 and Physics 2 at Katedralskolan in Lund, Sweden. So far, the VISIR electronic lab has had more than 150 registered users from Katedralskolan. The courses have been offered by the first author and another physics teacher at Katedralskolan. The tasks to be carried out by the students in the VISIR electronic lab were compulsory in the physics courses. The experiments had been prepared beforehand with theoretical lessons and real experimental work for the students. In Physics 1 the experiments deal with direct current and in Physics 2 alternating current.

A typical hands-on experiment used to start the Physics 1 course is when a student investigates the relation between voltage and current in a circuit with a nonlinear component, a light bulb. In the VISIR electronic lab component library there is no nonlinear component. It is not possible to place a light bulb in the matrix because measurement time is too short for the bulb to warm up. However, there are other components that do not follow Ohm's Law that can be placed in the VISIR electronic lab.

A. *Ohm's Law experiment*

In this experiment the student's task is to investigate the relation between voltage and current through a component in a DC circuit. The students follow the instructions and when they have set up the experiment, they press the "Measure" button to carry out the measurement. To analyze the result they use a calculator program.

The experiment instructions for the student:

Begin by building your circuit, see Fig. 12. Connect the 2.7k resistor to the power supply in series with the digital multimeter (DMM1) used as an ampere meter. Place the other digital multimeter (DMM2) in parallel to the resistor and set it to measure volts. Set the power supply

to 0.5V, measure and observe the results on the instrument displays. Vary the voltage from the power supply from 0.5 to 6V and document the voltage and current from 8 different measurements. Draw a graph of the voltage as a function of the current. Calculate the resistor based on the graph.
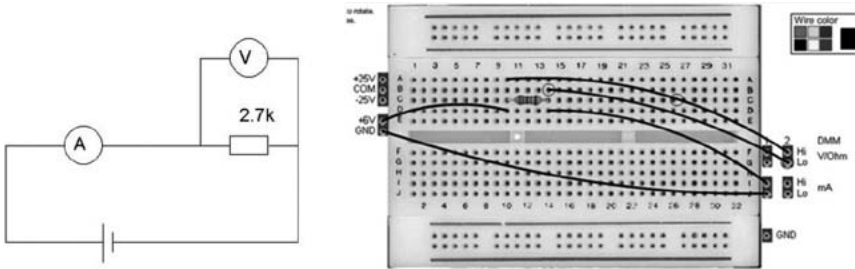

Figure 12

Left: The circuit for experiment Ohm's Law. Right: The circuit in VISIR electronic lab

B. *Electric current experiment*

Frequently, students at upper secondary level do not know that the current is the same in the circuit before and after a component. It is possible for them to check this out in this experiment.

The experiment instructions:

Electric current is measured in amperes. To measure current, you must connect the two leads of the ammeter in the circuit so that the current flows through the ammeter.

Question: Does it matter where you insert the ammeter in this circuit? Do you get the same current reading whether you insert the ammeter before, between or after the resistors?

Method: Connect the 1.0 kΩ and the 2.7 kΩ to the power supply in series with the digital multimeter (DMM1) used as an ammeter, see Fig. 13. Set the power supply to 5 V and read the value displayed on the instrument for the three different positions of the ammeter (see Fig. 13).

Conclusions. Theoretically Calculate the current with Ohm's Law and compare the result with the measured data.
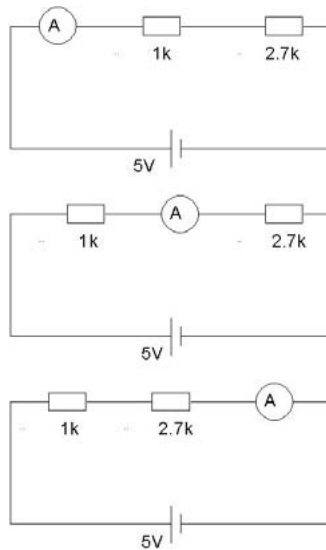
Figure 13

Circuits for experiment: measuring current in different positions

C. *Kirchhoff's current law experiment*

The principle of conservation of electric charge implies that, at any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node. With this circuit, top of Fig. 14, the students can investigate whether this is true. In Fig. 14 you can see the result of the circuit configured by two individual students measuring the current going through the 1000 Ω resistor.

D. *Kirchhoff's voltage law experiment*

The principle of conservation of energy implies that the directed sum of the electrical potential differences (voltage) around any closed network is zero. The sum of the voltage sources in any closed loop is equivalent to the sum of the potential case in that loop. Voltage case is easy to measure. With the circuit, at the top of Fig. 14, the students can measure voltage case over resistors and work out if Kirchhoff's voltage law is true.
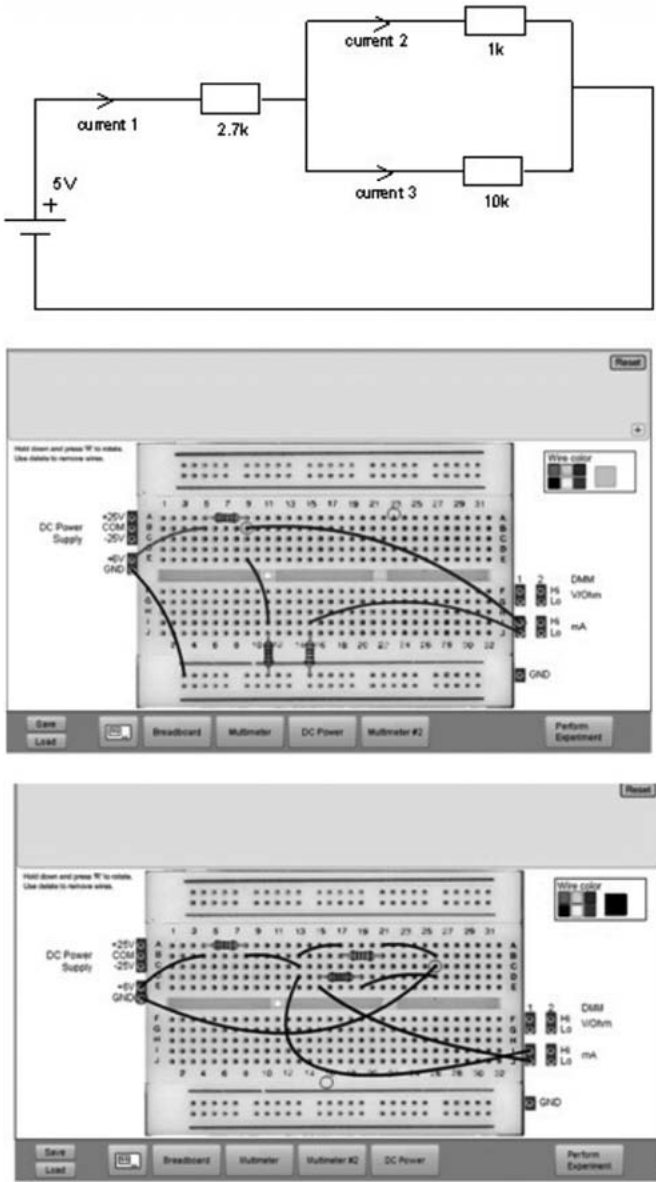
Figure 14

Top: Circuits for experiment measuring current flowing into and out of a node.
Middle and bottom: Student circuit configurations

E. *Alternating current experiments*

Alternating current (AC) is ubiquitous not only in the supply of power, but in electronics and signal processing too. The students can perform laboratory work in the VISIR electronic lab with alternating current and answer some of these questions:

1. If impedance is voltage over current, why is it different from resistor? Let the students investigate impedance at different frequencies for capacitors and coils.
2. What is the RMS value? The students can use a DMM and the oscilloscope to measure the ratio between the peak value of voltage and the RMS value of voltage over a resistor.
3. How can the voltage over a resistor and a capacitor in series be added? The addition is complicated because the two are not in phase. Let the students investigate relative phases between various voltages for the components, assessed on the remote oscilloscope.

Available components are: 1 kΩ, 2.7 kΩ, 10 kΩ resistors, 82 mH coil and 56 nF capacitor.

F. *Experimental examination*

Experimental examinations using the VISIR electronic lab have advantages over hands-on laboratories. Firstly, you can have 20 students experimenting at the same time. The time consumed in preparing hands-on laboratories does not exist for the VISIR electronic lab if you have used the lab beforehand with the students. Moreover, you do not have to examine the students' circuits at the same time if you require the students to print the screens of their experiment setup with the instruments and their circuits constructed on the breadboard. The students can easily upload a file with the results and print screens to the LMS. Afterwards, when marking the examination papers, you can discover what kind of problems the students have, for example, 1) incorrect setting of measurement range on the instruments, 2) they have connected the ammeter as a voltmeter or vice versa, or 3) incorrect circuit. To prevent eventual cheating, individual examination might be used.

5. **Acoustic experiments**

Apart from the active noise control experiments, which are more suitable for university education, several acoustic experiments are also possible on the HVAC duct, primary speaker, microphones and the Signal Analyzer setup. The equipment setup for acoustic measurements is shown in Fig. 15. For acoustic experiments, only the Measurement and Configuration Client shown in Fig. 9 is required. Only one of the four reference microphones can be selected on the Measurement and Configuration Client for single channel measurements using ch1 of the Signal Analyzer. The error microphone, together with the Analyzer Signal Out signal at ch2 and ch1 respectively, can be used for two channel measurements. This setup has the advantage that the Signal Analyzer generated the signal which is to be the input to the primary speaker, and the measured signal of the error microphone can be analyzed simultaneously for comparison etc.

Figure 15
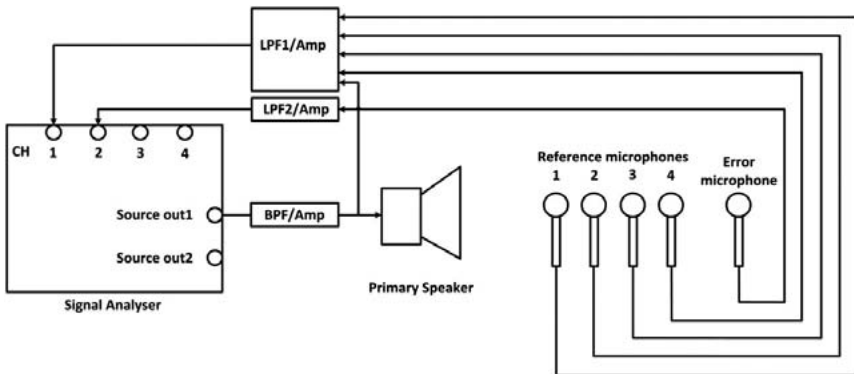
The acoustic setup of the VISIR acoustic lab. The connection
of the microphones to the Signal Analyzer via the Filter/Amplifier modules
are also shown

The Signal Analyzer is powerful measurement equipment and can be used in a variety of acoustic measurements. A teacher may define interesting and informative experiments according to the needs of his/her students. Below are a few examples.

A. *Basic conceptual measurements*

The Signal Analyzer can be used to generate fixed sine wave, chirp, random and pink (filtered random) sound or noise with a desired amplitude. The signals can be filtered or amplified using the Filter/Amplifier module as desired. The microphones can be used to measure the sound pressure in the duct. It must be noted that being a prototype, in the online version of the Signal Analyzer not all the functionalities are enabled. This means that certain acoustic measurements, such as octave analysis and hence sound pressure level (SPL) or dBSPL measurements, are not possible. The following are a few experiments suitable for upper secondary school students related to the basic concepts they may have already become acquainted with in the classroom.

B. *Study of acoustic signal properties*

The students can visualize a particular sound, e.g. a sine, random and Chirp waveforms, using the laboratory setup. The frequency and amplitude variation of these signals can be seen on their computer screens and they can listen to them via the computer loudspeaker, which may prove to be very exciting and informative for the students.

C. *Peak, RMS, Power and dB measurements*

Upper secondary schools students can verify the basic concepts associated with sine, cosine sound (signals). They can generate a sinusoidal signal form the Signal Analyzer, measure the signal using a microphone and display the same sound on the Signal Analyzer. They can verify the relationship between the peak, RMS and mean square (average) values of the signal by simply selecting the display parameters. The students may easily plot and hence see the same signal in dB scale and thus improve their understanding of the dB units for power and voltage signals, a concept usually considered difficult by students. The experiment showing a dB measurement is shown in Fig. 16.
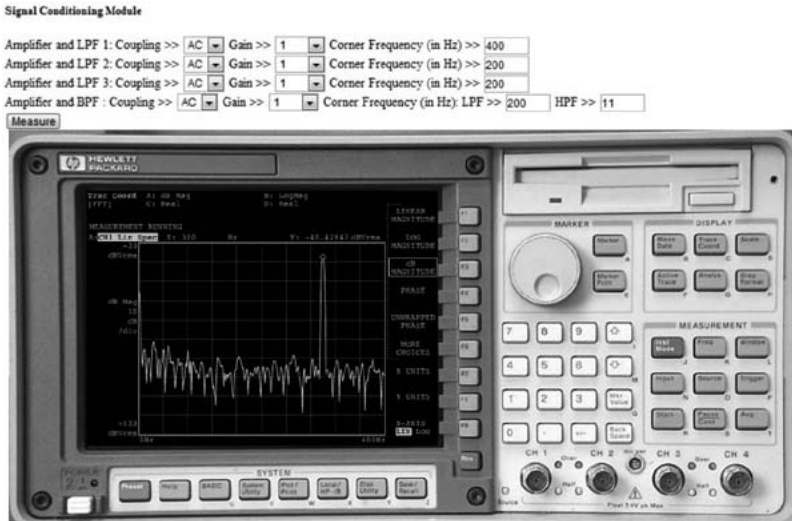
Figure 16

Use of the Measurement and Configuration Client during measurement of sinusoidal sound signal in dB

D. *Wavelength and frequency relationship*

Similarly, by changing the frequency of a waveform from the analyzer, a student can verify the inverse relationship between the wavelength and frequency using the speed of light formula.

$$c = f \cdot \lambda \qquad (1)$$

Where c is the speed of light, f is the frequency and λ is the wavelength of the waveform. The understanding of this concept, widely used in many subjects, may prove very beneficial for the students. Such a measurement performed in the VISIR acoustic lab is shown in Fig. 17.

E. *Sound pressure measurements*

Once a student is able to measure the electrical signal using the Signal Analyzer, the teacher may provide the students with a sensitivity value for the microphones, in order to measure the sound signals as pressure signals.
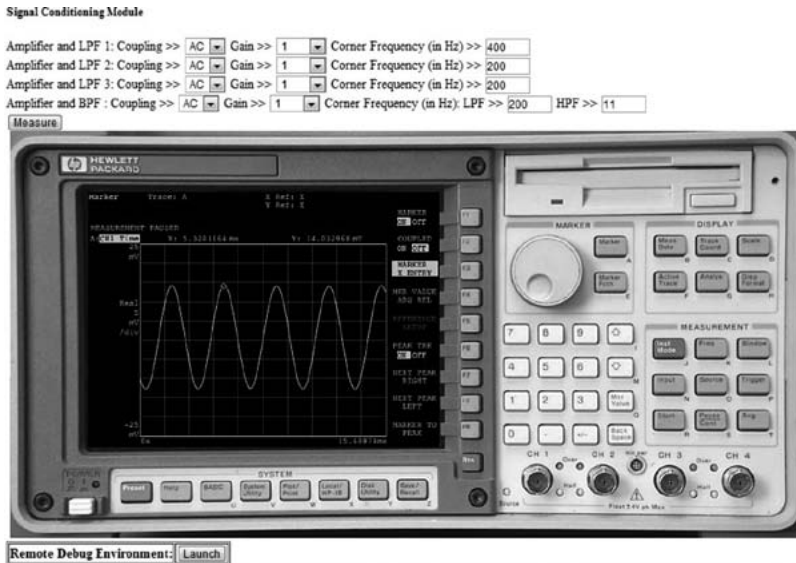
Figure 17

Illustration of a sinusoid sound signal in remote Lab experiment, to understand the wavelength and frequency relationship

The sensitivity, such as mV/Pa, is stored in the Signal Analyzer. The students can read the signal directly in pressure units, i.e. Pascal using the Signal Analyzer display tools, and verify his/her analytical calculations.

F. *Plane wave propagation*

Although this cannot be treated as an experiment, the teacher may help the students to understand the plane wave propagation for sound signals. The pressure variations sensed by the microphone can be used to explain the plane wave propagation at a particular microphone position.

G. *Propagation time or determining the speed of sound*

The students can compare a sound signal generated from the Signal Analyzer with the sound signal measured by the error microphone at the same time by using two display screens of the Signal Analyzer using two

channels. The time difference between successive peaks may be utilized to find the propagation time from the speaker to the microphone location and hence the speed of sound can be measured as the duct length is fixed. The same concept may be applied to find the delay between signals of the error and a reference microphone. The experiment using two channel measurements is shown in Fig. 18.
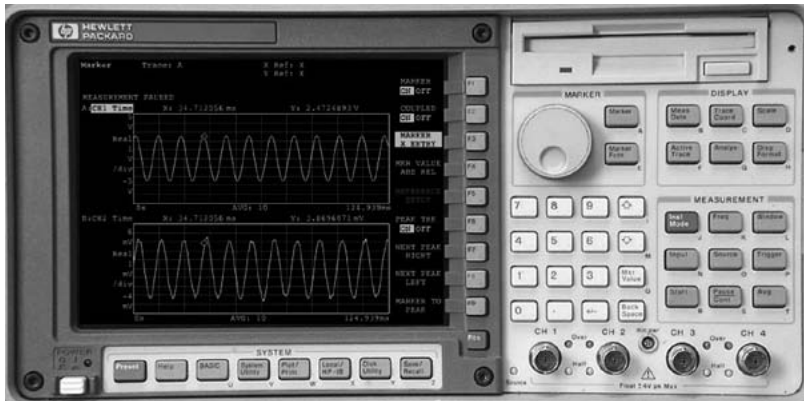
Figure 18

Illustration of determining the speed of sound in an acoustic experiment
performed remotely

H. *Advanced level*

By advanced level it is meant here that experiments are suitable for university students but may be utilized by upper secondary school students, if necessary. As mentioned previously, some of the important acoustic measurements, e.g. SPL or dBSPL, are not possible in the online version of the Signal Analyzer, but they can be added in the future and hence the range of advanced level acoustic experiments can be expanded.

H.1 EIGEN FREQUENCIES OF THE DUCT AND MODE SHAPES

Students find it difficult to understand or visualize the Eigen values and mode shapes associated with acoustic systems. The concept is similar

to mechanical systems where the mass, spring and damper are usually well understood as compared to the complex wave equations in acoustics. The laboratory facility may be used to help students understand the Eigen frequencies and mode shapes for an acoustic system. Based on the dimensions, i.e. the length and diameter of the duct, the ducts have certain Eigen frequencies. The student may first estimate the resonance frequencies f_r for the duct of length L, open at both ends using the formula;

$$f_r = (nc/L)/2 \hspace{2cm} (2)$$

Where c= 320 m/s, is the speed of sound in the air and n=0, 1, 2… is an integer number. Using the formula, the Eigen frequencies of the duct used are 39.5, 79 and 117, and so on. These Eigen or resonance frequencies can be estimated by exciting the duct using a random noise from the Signal Analyzer. In the Signal Analyzer the student can select a frequency response function plot between the Signal Analyzer signal and the error microphone signal. The peaks in the FRF show the resonance frequencies of the duct in the selected frequency range. The FRF plot using the VISIR acoustic lab is shown in Fig. 19. One resonance frequency, i.e. 80 Hz, is shown by the marker tool of the Signal Analyzer, confirming the validity of the experiment. The number of resonance frequencies can be limited to the plane wave region, if desired, by limiting the frequency range of the Signal Analyzer. The number of resonance frequencies can be limited to the plane wave region if desired. The students can further validate their findings by generating a periodic signal having the same frequency as one of the duct resonance frequencies and vary its frequency slightly while keeping its amplitude constant.

The student may also investigate the mode shapes or standing waves associated with the resonance frequencies. For example, he/she can plot the standing waves in the duct using equation. The reference microphones are strategically placed in the duct so that the microphones can measure the maximum of a standing wave or a mode shape, as shown in Fig. 20. The student can verify the existence of a standing wave by selecting an 80 Hz sinusoid signal for example, and measure it with reference microphone3. Without changing any other parameters except the measurement microphone, he/she should obtain maximum amplitude on reference microphone 3, as compared to microphones 1 and 2. This means that for the first mode only reference microphone 3 is at the maximum of the standing wave of 80 Hz. This experiment assumes that

all the microphones have the same sensitivity, but in reality this may be difficult to achieve, so this experiment should be performed with care.
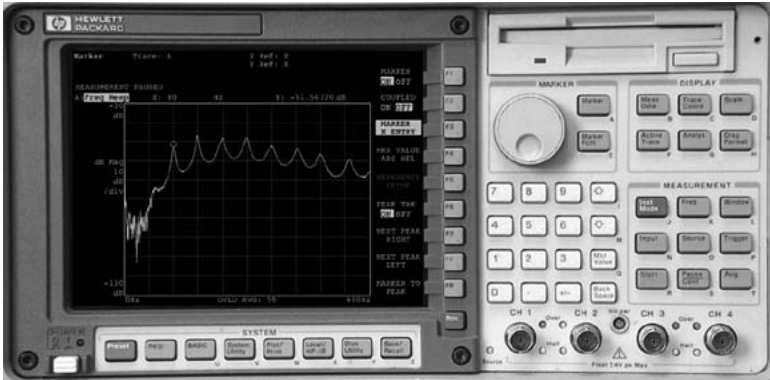

Figure 19

The measurement of the FRF for determining the Eigen frequencies of the duct. The first Eigen frequency at 80 Hz is shown by the marker
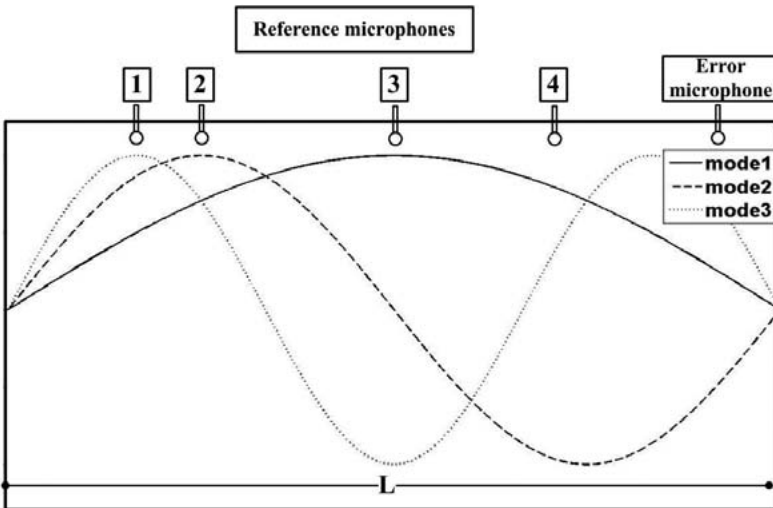

Figure 20

Illustration of the acoustic modes inside the duct and the positioning of the reference microphones inside the duct

H.2 POWER SPECTRUM AND POWER SPECTRAL DENSITY (PSD)

These experiments are similar to the basic acoustic pressure measurements. The desired signal, e.g. a single sinusoid or a random signal, may be generated by the Signal Analyzer. The desired spectrum of the measured signal can be displayed in the Signal Analyzer using appropriate display parameters including averaging, windowing and overlapping etc. As an example, the student can measure the PSD of a random signal, as shown in Fig. 21.

Figure 21

Screen shot of the signal analyzer when PSD of a random sound is plotted using the VISIR acoustic lab

6. **Conclusion**

The implications of this project are that the VISIR laboratories are easy to implement for use by both teachers and students and it is possible to integrate with the learning management system of the school. The way of carrying out experimental work provides the students with more time for experimental work as compared to what is offered by the school in the hands-on lab. The workbench for electrical experiments can be used by many students performing different experiments simultaneously. It is convenient to use the remote laboratory when you, as a teacher, do a

demonstration for the students. The more an experimental a setup used by a teacher is, the more new possibilities for experiments will emerge.

Future work in 1), the VISIR electronic lab, is to increase freedom of placing components in a circuit –this will provide more potential to assemble circuits–, and in 2), the VISIR acoustic lab, is to place a moving microphone in the duct and improve its web interface.

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Virtual System in Reality (VISIR) in school environments

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1. **Introduction**

VISIR in school environments aims to reveal the experience relating to remote control labs in education. More precisely, it shows how necessary it is to conduct and observe electricity experiments in physics at school. Including VISIR is a valuable experience, bearing in mind that in the Austrian school curriculum several weeks are allocated to the chapter on electricity, including everything from components to circuits. It makes a difference whether a teacher is merely demonstrating an experiment, or students or a group of students are receiving a task to conduct the experiments on their own. Under these circumstances, comparing VISIR with "traditional" students' experiments, hands-on labs based on specified learning material provide valuable insights. The assets and drawbacks occurring in practical and daily work with VISIR will be shown, as well as the pros and cons concerning educational adaptability. The conclusion focuses on the most important insights after working with VISIR, and the feedback received from the students.

2. **Experiments in physics education**

Physics is the one science that deals with the study of all experimental and measurable processes in nature, as well as their mathematical description. [8]

The teaching of physics should therefore also be an introduction to scientific work. In addition to the experiment, this also includes the posting of theories and their verification. It is important for the results of the experiments to be interpreted. Ideally, students should be able to transfer the results to other areas, especially to areas affecting the students themselves. Thus, the physics classes could be more lively and motivating. The experiment is therefore an important part of teaching. It should be noted here that the experiments must be reproducible. The requirement for reproducibility is probably one of the most difficult requirements. This is especially apparent in student experiments, when very simple experiments are conducted in several groups. Not all groups will provide the same results; variance can always be found. Nevertheless, a trend leading to the direction in which the results will be found can still be recognized. If the experiments are repeated, the mean will be seen more clearly. At this point one can already point out that physics is closely related to mathematics. Mean values of measurement results –later a more extensive statistical analysis will be provided– should be formed within the possibilities of the age group, and results which deviate strongly should be discussed.

With the help of experiments, it is also possible to bring the students closer to research group methods. Nowadays, such groups mostly work on projects which must be completed in a certain time. In such project units, hypotheses can be established, experimentally verified and discussed. In particular the discussion of results is one of the most important points. Critical discussion should never be lacking.

Multiple objectives, which should be reached, can be brought closer to the students through conducting experiments in physics instruction. The students learn how to obtain the data needed, and they also learn how to interpret these data, that is, they learn to recognize and understand the importance of the data. Through skillful questions from the teacher, it is possible that the students learn to apply physical laws and principles not only in familiar situations, but also in situations new to them. Another advantage of experiments is that they can be used in every phase of the lesson. They are suitable for the beginning, as well as at any point of the

lesson. For the students, it is particularly important to be in direct contact with the physical facts, which is possible when performing experiments themselves. Student experiments also stimulate further questions.

At school, we can distinguish between two fundamentally different types of experiment. On the one hand, there are experiments that are conducted to gain information, and on the other hand, there are experiments that illustrate physical relationships. As mentioned earlier, physical experiments can be used in each phase of the lesson. Experiments are suitable for giving an introduction to a topic: these are surprise, show, cognition, construction, verification, application and retry experiments.

Furthermore, we must distinguish between teacher and student experiments. When the teacher conducts the experiment, the students are forced into the role of passive spectators, which can be prevented if the students participate in the pre-considerations and planning of the experiment. Thus, the students become actively involved, which motivates them even further. Teacher experiments are often more complex in structure. There is a certain danger that experiments are no longer comprehensible for the students. This risk needs to be reduced and can be achieved by carrying out easier preliminary tests, or by creating a reference to the lives of students.

Far more important than the teacher experiment is the one carried out by the student. Here, the students become the actors. They are in charge and are immediately confronted with the physical facts. The students can influence and watch the action and they also have the opportunity to actively and productively participate in class. The self-activity of the students raises their motivation and promotes their interest. Student experiments are, however, rarely used in the classroom because this involves great technical effort and, above all, a great amount of time is needed. Nevertheless, the proportion of student experiments should be kept as high as possible.

Pair-groups are particularly well suited for student experiments. Experiments in groups of two, however, are almost never feasible in school life in a regular class. Very often the experiments are therefore carried out in groups of four or even six. There should be a task schedule for the group, so that each student is clearly involved in the work. The seating arrangements must be changed too, so that communication among the group does not suffer. When students carry out the experiments, one has the option for all students to perform the same experiment. Hence, one can compare results and the differences that are sure to occur can be discussed. On the other hand, one can also use the experiments to verify

the same facts in different ways, or even completely different experiments can be carried out. These different experiments can then be presented to the class (Figs. 1, 2). Student experiments definitely take a lot of time, but in general they raise student interest. [14]
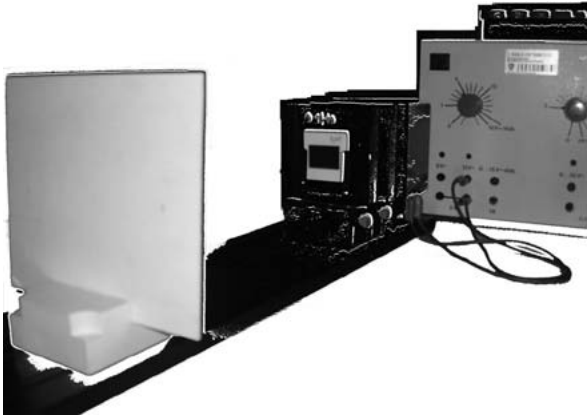

Figure 1

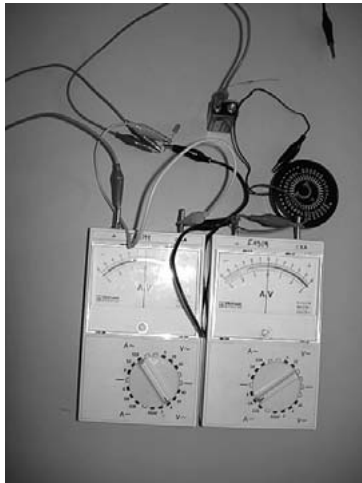Arrangement of a student experiment in optics

Figure 2

Arrangement of a student experiment in electricity

3. **The Austrian curriculum for physics – with focus on electricity**

The Austrian curriculum is divided into a general part and a technical one. The technical part differentiates between age groups: in physics these are the 11-14 year-olds and those of 15-18 years of age, which corresponds to grades 5-8 and 9-12 at high schools, or grade 9-13 at vocational schools. The most important general points concerning physics instruction are summarized here.

The subject of physics should contribute to all areas of education and not be limited to the representation of physical content. The students should have the technical language taught to them in an age-adequate way, but also recognize the physical aspects of their environment. The thinking and working methods of physics should be taught, too. This can be particularly successfully implemented through experiments. Physics education at lower and higher secondary level aims at providing physical knowledge in wider contexts. This is done through concise observation as well as autonomous and action-oriented occupation with the problems of physics. The teacher should reinforce self-activity and encourage the students to accept responsibilities. The planning, implementation and evaluation of experiments has to be given special consideration. Older students should also get to know modern methods of information gathering, data collection and processing in their lessons. Of course, there are a lot more skills mentioned in the curriculum than the students should acquire at school, but for OLAREX these are probably the most important ones.

The topic of electricity is often mentioned in the syllabus. In the 7th grade students should, on the basis of their everyday experience, already have been made familiar with the basic electrical processes in everyday technology and in natural processes. In the end, students should understand various power sources such as energy converters and simple circuits.

By the end of grade 10 students should be able to apply the fundamentals of the theory of electricity and should also have learned how to work with electrical measuring instruments. The importance of material science, in particular of miniaturization, should be brought closer to the students. Here, working with original components might prove particularly productive. [4, 11, 12]

The topic of electricity is particularly well suited for student experiments. If one pays attention to accuracy when assembling the

experimental arrangement and lets the students close the circuit only after a brief check, losses of material will be within limits, and on the other hand, students will generally obtain good test results. There are many different options and enough material for experiments.

Our school is very well equipped with student test material. Material for 8 working groups is available. The experiments are set up quickly with the help of the plug-in boards, but the students do not have the original components directly in front of them.

Another option is to buy the necessary electrical components, such as battery, resistor, lamp, LED, etc. in shops specializing in electronic equipment. Students can work with original components, but the complexity of circuits soon reaches its limits, due to many cable connections that are ultimately confusing.

On the Internet there are many simulations on electrical circuits. Of course, simulations have the advantage that students can work alone and completely independently. Work tasks can thus be carried out at home. However, the school should have the necessary infrastructure –up to 30 PC workstations per room in Austria– so that every single student can actually be given a task.

Three types of many possible simulations serve as examples here.

The page http://phet.colorado.edu/en/simulations/category/physics/ electricity-magnets-and-circuits offers different opportunities to investigate aspects of the theory of electricity. Students can quickly and easily assemble circuits, test them and process data quickly (Fig. 3).

The link http://virtphys.uni-bayreuth.de/elek/ on the University of Bayreuth's website offers programs with less variable circuit structures than in the simulation described in Fig. 4. But you can, for example, easily examine series and parallel circuits here. The measurement results can be logged immediately and the students can therefore easily recognize relationships.

The possibility of using VISIR as simulation is also interesting. Here, the students also work on a simulation, but in the background a real experiment is running. Only the range of items limits the possibilities for students to build experiments. Students learn about instruments that are generally not available in these numbers to schools. As a result, they have the chance to improve their knowledge of the world of work for scientists.
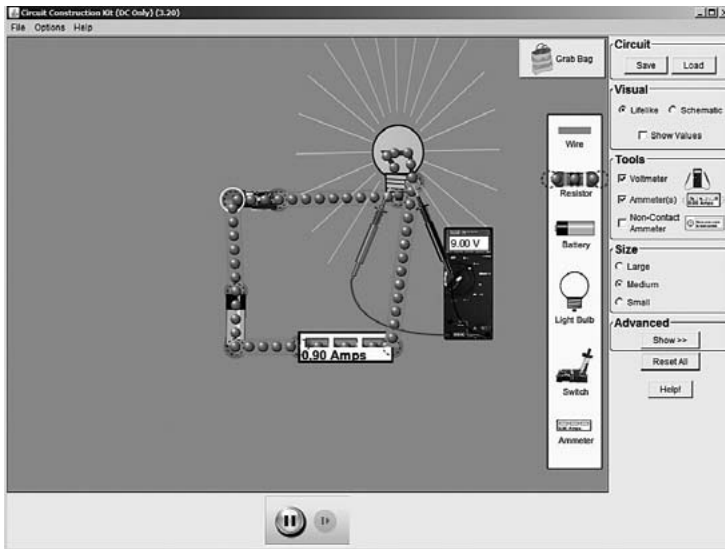
Figure 3

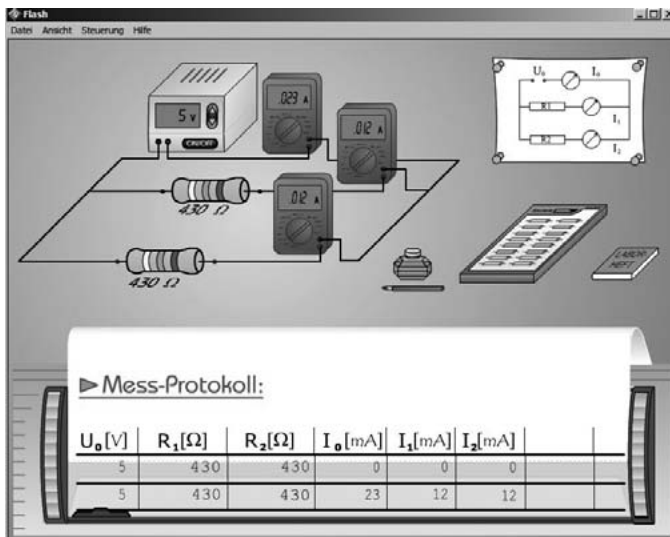Simulation – Simple DC Circuit (Phet – Interactive Simulations) [6]

Figure 4

Flash Movie of the University of Bayreuth for a simple parallel circuit [7]

4. **VISIR – Four important answers**

A. *What is VISIR?*

VISIR means Virtual System in Reality and was developed by the Signal Processing Department (ASB) at the Blekinge Institute of Technology (BTH) in Sweden. The main goal of the platform was to offer an online workbench where users, in their particular case students, can perform electronics experiments. Therefore, students could wire a desired circuit and use different laboratory equipment to test that circuit.

The experiments performed with VISIR are highly interactive and allow a real time control of the equipment. One of the most interesting aspects of the platform is that it features an expandable relay switching matrix where lab instructors can attach several components as well as whole circuits depending on the experiments to be performed. With the help of a virtual breadboard implemented as a VISIR client module, students can assemble several different circuits with different component sets available and pre-configured by the laboratory administrator/instructor. The tasks of the lab instructors are to add components to the library, update the components list, which specifies where the components are connected at the relay switching matrix, and update the maxlists. The possible connections are specified in the components list. [7,8]

As is obvious, this platform provides an extraordinarily flexible environment in which students can construct and test different circuits. The modularity of the VISIR hardware allows a certain degree of flexibility concerning the resources (circuit components and lab equipment) students have at their disposal to construct and test circuits. Beyond this, the VISIR platform is remarkable in the interactivity it presents students with.

Moreover, one of the most important aspects of the platform is that electronic circuits can be built and tested by students with a degree of freedom normally associated with a traditional, hands-on electronics laboratory, without having to worry about burning components and hurting themselves. This is the reason why this platform was introduced for students at secondary school level.

B. *How does VISIR work?*

The original VISIR online workbench offers the following Flash client modules:

– Breadboard for wiring circuits.
– Function generator, HP 33120A.
– Oscilloscope, Agilent 54622A.
– Triple Output DC Power Supply, E3631A.
– Digital Multi-meter, Fluke 23.

Fig. 5a shows a workbench in a traditional electronics laboratory and in Fig. 5b the interface for this equipment is shown. Most instruments in such a laboratory have a remote control option but the solderless breadboard does not.

In order to open a workbench for remote access, a circuit wiring manipulator is required. A relay switching matrix can serve as such a device where the relays are arranged in a three-dimensional pattern together with instrument connectors and component sockets.

The small components in the lower left corner of Fig. 5 belong to the component set delivered by the instructor. They are installed in the component sockets of the matrix. Virtual front panels depicting the front panels of the desktop instruments and a virtual breadboard displayed on the computer screen can give remote students the impression that they are working in the real laboratory. A workbench opened in this way can, for example, be a node in a grid laboratory where the virtual breadboard and relay switching matrix combination is a wiring service [8], (Fig. 6).

The virtual breadboard, where users are really working, is shown in Fig. 7. A set of virtual components provided for a certain lab session is displayed in a component box adjacent to the breadboard. The lab client routine transforms the virtual circuits that an experimenter wires on the breadboard using the mouse into a net list similar to PSPICE net lists. In the grid node, a virtual instructor compares each net list with a number of so-called checklists defining circuit loops permitted to be created and maximum voltages to be output from the sources. If the list passes the check, it is transferred to the Circuit Builder. This routine transforms the list to addresses of the relays to be engaged to form the desired circuit.
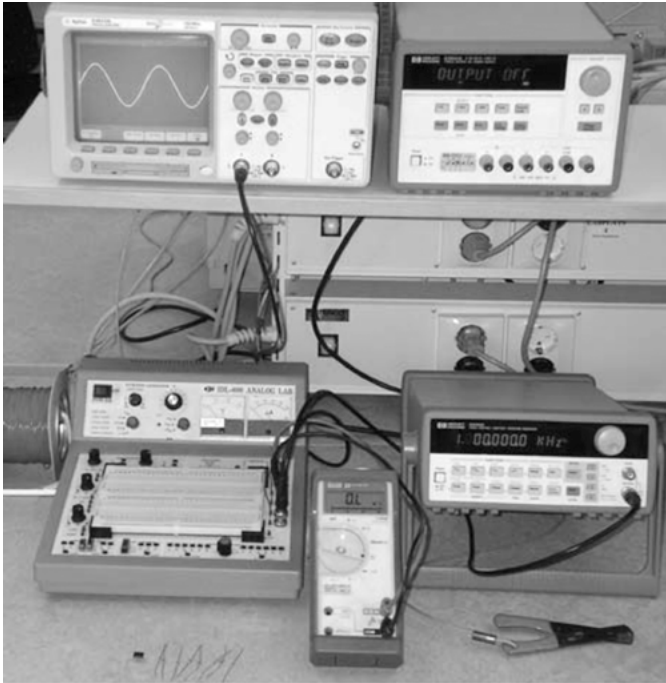
a) Traditional lab
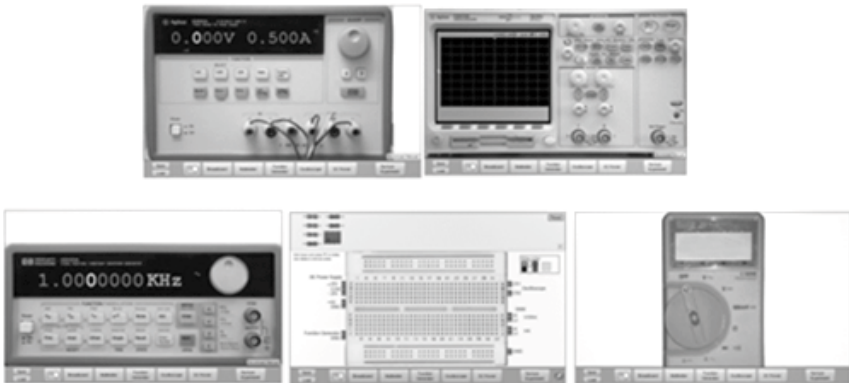
b) Remote control interface

Figure 5

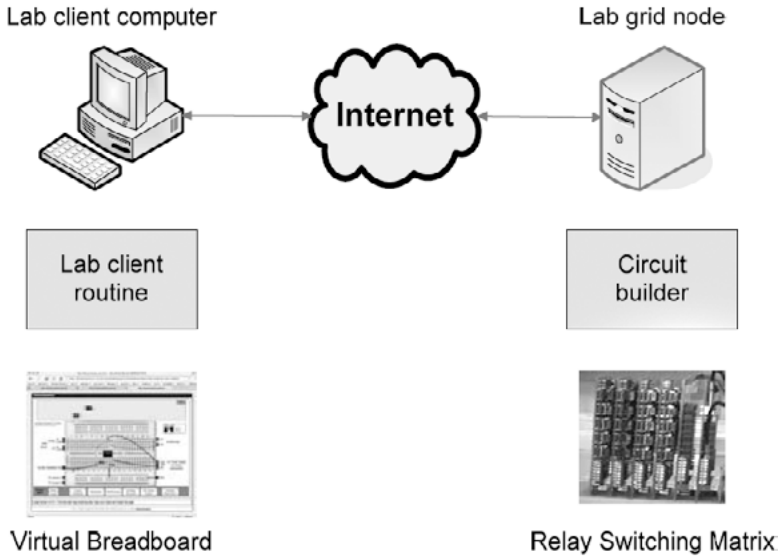Workbench in an instructional electronics laboratory

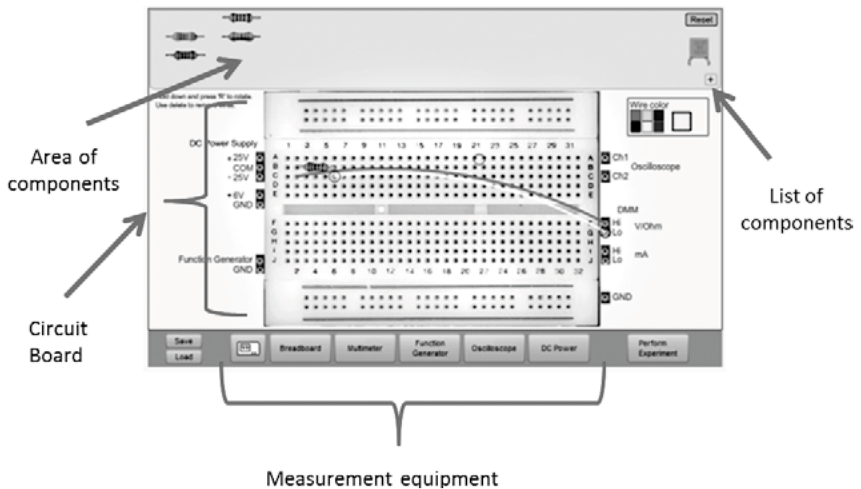**Figure 6**

Circuit wiring service

Figure 7

Virtual Breadboard

The lab staff installs components and configures the matrix that the teachers decide to use to support their lab sessions. The teachers create the rules for the virtual instructor.

C. *How complex can VISIR be?*

The complexity of an electrical circuit increases with the number of components. If a desired circuit has N nodes and the experimenter wishes to add, for example, one resistor, there are $N \cdot (N-1)/2$ branches into which it can be installed. This means 120 possibilities for 16 nodes.

So the complexity of VISIR increases proportionally with the complexity of the circuits. Adding layers to the matrix, which allows connection between components, can solve this. In our case, the number of circuits that can be wired on the breadboard, shown in Fig. 1, is limited primarily by the number of components the instructor provides and is usually too high for a matrix of practical size.

However, in secondary school lab exercises the learners are expected to wire only simple circuits. Some circuits may be destructive and need not be possible to wire. Trying to wire such circuits should cause an error message from the virtual instructor. Thus, the flexibility of the breadboard in Fig. 1 is not required. Is it enough if a matrix allows the creation of circuits in a number of instruction manuals? No, inexperienced learners should be allowed to make wiring mistakes, for example, and have the opportunity to learn how to correct them. Apart from the circuits in the instruction manuals, a matrix should allow the learner to create some similar circuits that are safe as well.

D. *How can students work with VISIR?*

So as to include the VISIR platform in the learning program, teachers have different possibilities available. These possibilities depend on two characteristics: students' ability and the degree of freedom that the teacher allows the learner. Teachers can use different scenarios for this, such as:

  – Students' age;
  – Students' knowledge in the study field;
  – Students' ability to use a computer.

Based on these criteria, teachers can choose the way the remote lab should be used:

A. Pre-designed circuit –where the teacher is doing everything and students only have to perform the experiment without making any connections. In this case, learners only have to observe the result of the measurement, their interaction with the platform being minimal (Fig. 8).
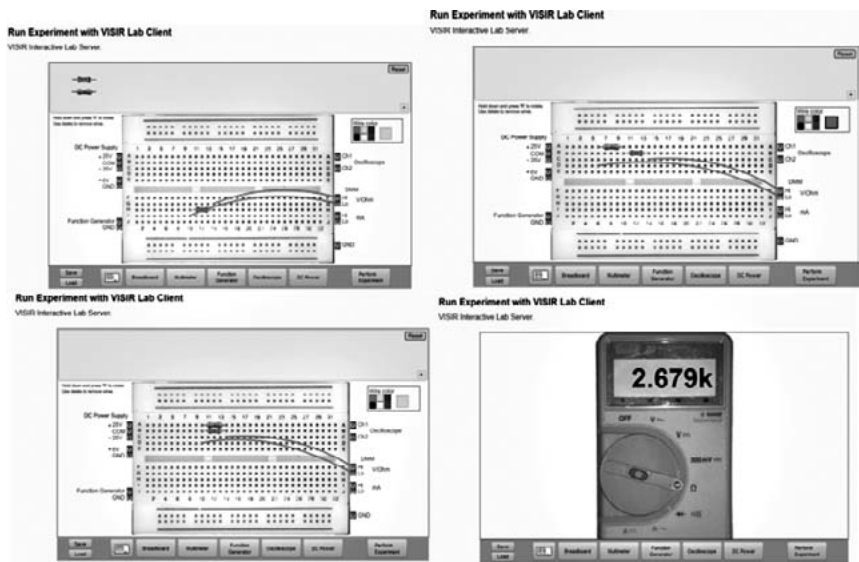

Figure 8

User interface for pre-design VISIR lab

B. Pre-defined circuit –where students design the circuit on their own; they are making the connection but they have a restricted number of components, namely the ones defined by the teacher. In this way, the interaction between learner and system is visible, and the experience is similar to one in a hands-on lab (Fig. 9).

C. Non- defined circuit –in this case students are allowed to design and choose the circuit elements on their own. Learners can independently solve any application by themselves. Therefore,

students look in the components list to choose the right component, then add the components to the board and finally make the connection with the measurement equipment (Fig. 10). The most interactive one wins.
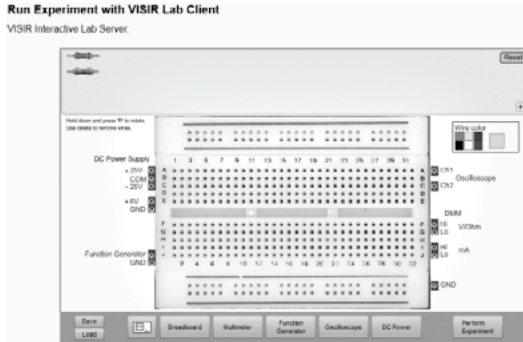

Figure 9

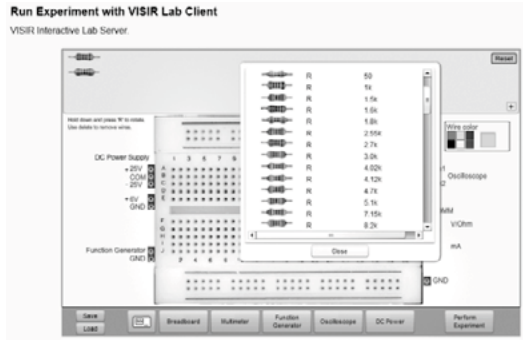User interface for pre-define VISIR lab

Figure 10

User interface for non-define VISIR lab

All these kinds of experiments can be done at school during learning hours under supervision of the teacher or at home as an alternative method to improve the knowledge level of students.

5. **VISIR in the classroom**

The topic of circuits and their wiring belongs to the general topic of the basics of electricity.

The chapter on the construction, utility and use of resistors requires a comprehensive introduction, which can ultimately lead to the following problems and issues.

– *On the garland on the Christmas tree there is a broken lamp (Fig. 11). One of the halogen bulbs on the ceiling in the living room is broken. What happens to the other bulbs in both cases, and why?*
– *How are electrical devices connected in your household?*
– *If I already know that there are series and parallel circuits, where are the series circuits, and where are parallel circuits needed? [1]*
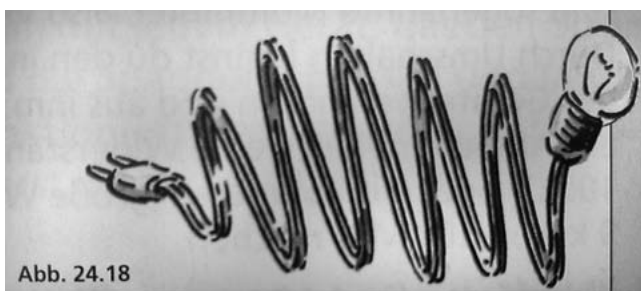

Figure 11

Light bulb

From these questions you can see that it will probably be much easier for students to study a topic if they can establish cross-connections with reality, with their own everyday lives.

Another follow-up question might be:

– *The electricity bill for the household is in kilowatt-hours. What do we mean by that? And what is the voltage in the home network?*
– *How many amperes flow through a light bulb of 100 W? And through an e-oven of 3000 W?*
– *How many liters of water could be brought to boiling level with the energy of a big flash: a) 15 b) 150 c) 1500 d or) 15 000? [1]*

Students can ask the questions above or similar ones. The teacher then could give the following hints:

– *Where is the greatest resistance in this circuit: in the cord or in the bulb? Can you explain?*

Cord or light bulb? Where is the greatest resistance? [3]

– *Why is the term "consumption of electricity" actually a bad choice?*
– *What does electrical resistance depend on? Are there analogies in your surroundings? [2]*

General physical background, which must also be learned during this training period, can be checked with the following tasks and multiple-choice questions.

– *The electrical resistance (symbol: _____) is measured in the following unit: _____*
– *Power line cables consist of*
  a) constantan b) copper c) iron d) aluminium.
– *These metals have a*
  a) large b) low resistance and allow the current to flow more easily.
– *Thin wires have a*
  a) large b) small resistance.
– *The longer the power line cable, the*
  a) greater b) smaller is the resistance. [9]

Talking about resistors and their circuits, now it is time to study Ohm's law.

– *Calculate with Ohm's law. A wire having a resistance of 50 Ω is connected to voltage 6V. What amperage does the current going through it have? [2]*
– *Build a circuit with a resistor R = 500 Ω, a voltage U = 1 V and show that a current I = 2 mA is present. Then calculate the accuracy of this current with the help of Ohm's law.*

Such an example can be explained easily, illustrated and recalculated by a teacher or student experiment.

R = 500 Ω, U = 1 V: Measurement I = 1.98 mA (Fig. 12).
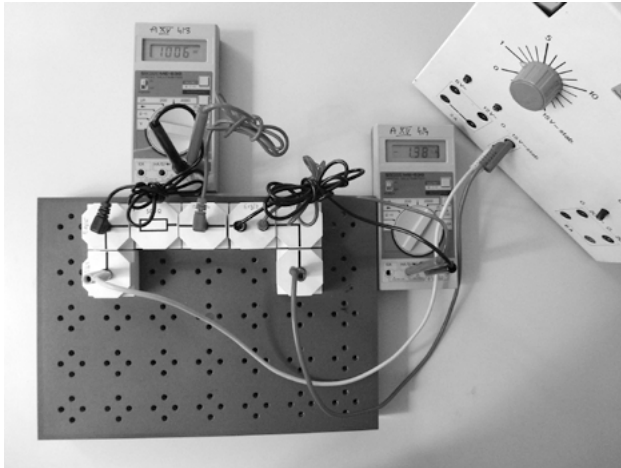
Figure 12

Hands on circuit

In VISIR: R = 1000 Ω (Fig. 13)

Figure 13

VISIR remote circuits

Let us continue in the experimental series with fixed resistors (Fig. 14). At this point it should be noted that children and young people are very interested in, and have probably already examined, the inner workings of electronic devices.

There they encounter many small coloured rolls, which are resistors with fixed resistance values. They are intended to protect components

against high currents and set exact currents in electric circuits. The coloured lines are colour codes and depict the resistance value in ohms [10].
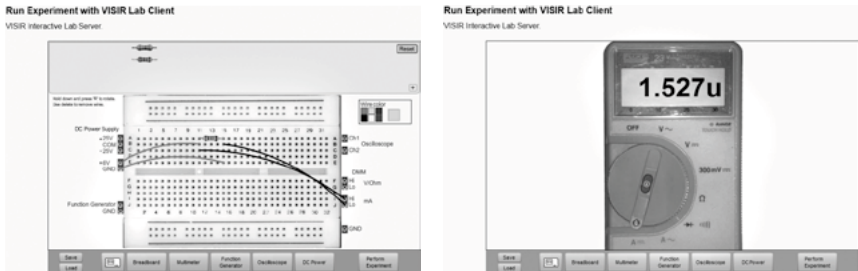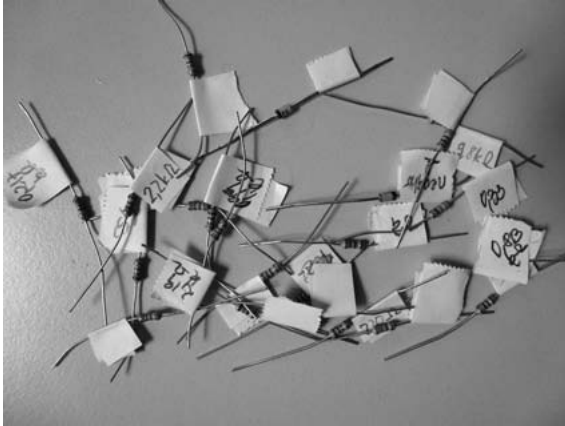

Figure 14

Resistors

Fixed Resistors

How are resistors set in the circuit?

In class there are two choices so far. The experiment is carried out by the teacher as a demonstration or the students work independently on student experiments.

There can be many reasons for the use or non-use of experiments in the classroom.

– *Is the inventory obsolete or ill-equipped?*
– *Are the experiments so complex that they cannot be implemented at school?*
– *Is there enough time for these experiments? [14]*

If these experiments can be carried out as online experiments, the questions above can immediately be answered positively.

– The experimental setup cannot be found at school, but is provided in distance learning.

- The experiment can be performed at any time and from any location. Students are assigned the task to perform the experiments at home, after having received the theory at school.
- Results may be recorded immediately.
- Protocols are written for the next lesson.
- Ambiguities can be formulated instantly and then discussed in class.
- The experiment can and must be done by each student.
- The student has the obligation to complete the task within a given time frame.

The students will obtain knowledge of the subject matter from the online experiment, student experiment, as well as from the teacher experiment. It is up to the students to decide when they perform this process, on the basis of the experiment being done at their own convenience. (Fig. 15)

Figure 15

Students working with VISIR
(Students thinking and discussing a possible circuit)

And now to the two options for the connection of resistors:

A. *Series connection of resistors*

In the series connection of resistors the same current flows through each part:

$$I_1 = I_2 = I$$

The operating voltage is distributed so that the voltage drops across each resistor:

$$U = U_1 + U_2$$

Example:

Choose an operating voltage of $U = 1V$. The resistor values are $R_1 = 1000\ \Omega$, $R_2 = 500\ \Omega$.

a) Build this circuit as an experiment.
b) Simulate this circuit as an online experiment.
c) Measure the values for U_1 and U_2.
d) Check the values for U_1 and U_2 by calculation.
e) Calculate the total resistance.
f) Measure the current and check by calculation.

Series Circuit: $R_1 = 1000\ \Omega$, $R_2 = 500\ \Omega$, $R_{ges} = 1500\ \Omega$
Measurement $I = 0.6$ mA (Fig. 16).

Figure 16

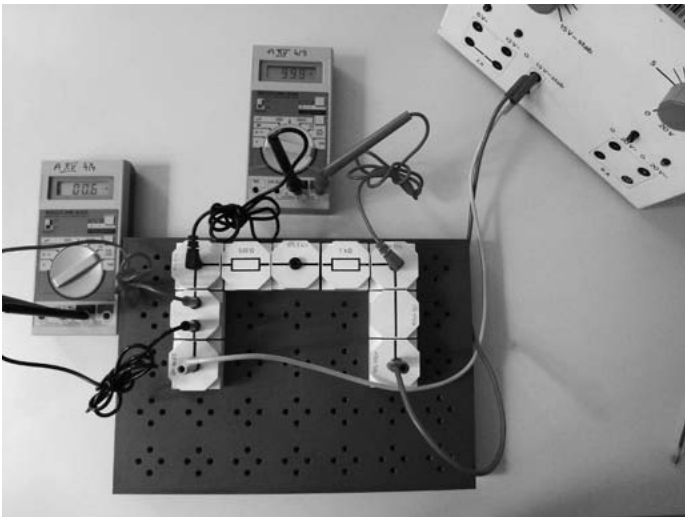Series hands-on circuit

In VISIR: $R_1 = 1000\ \Omega$, $R_2 = 700\ \Omega$ (Fig. 17)
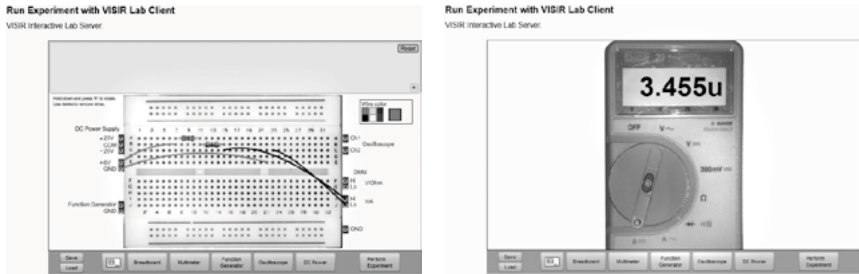
Figure 17

VISIR series circuit

Bridging of Resistance $R_1 = 1000\ \Omega$:
$U = 1V$ with measurement $I = 1.9$ mA (Fig. 18).
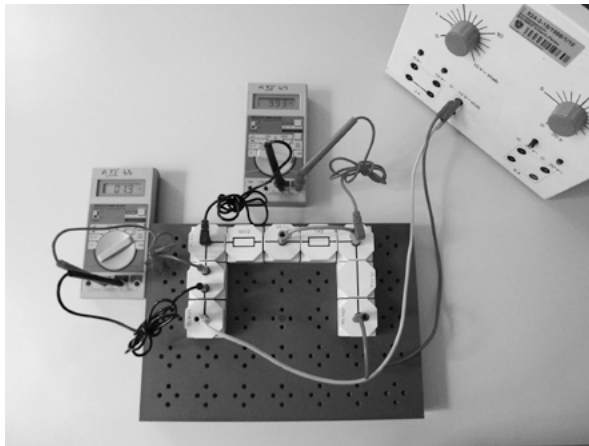
Figure 18

Bridging of R_1

B. *Parallel Connection of Resistors*

For the parallel connection of resistors, there is the same voltage across each resistor:

$$U_1 = U_2 = U$$

The current is distributed between all three parallel circuits:

$$I = I_1 + I_2$$

Figure 19

Happy students! VISIR is working! They have completed their work.

Example:

Choose an operating voltage of U = 1V.
The resistor values are R_1 = 1000 Ω, R_2 = 500 Ω. (Fig. 20)

a) Build this circuit as an experiment.
b) Simulate this circuit as an online experiment.
c) Measure the values I_1 and I_2.
d) Measure the values for U_1 and U_2.
e) Check the values for I_1 and I_2 by calculation.
f) Calculate the total resistance.
g) Measure the current and check by calculation.

Feeler on, Circuit above U = 1 V, R2 = 500 Ω, Measurement I = 2 mA (Fig. 21).
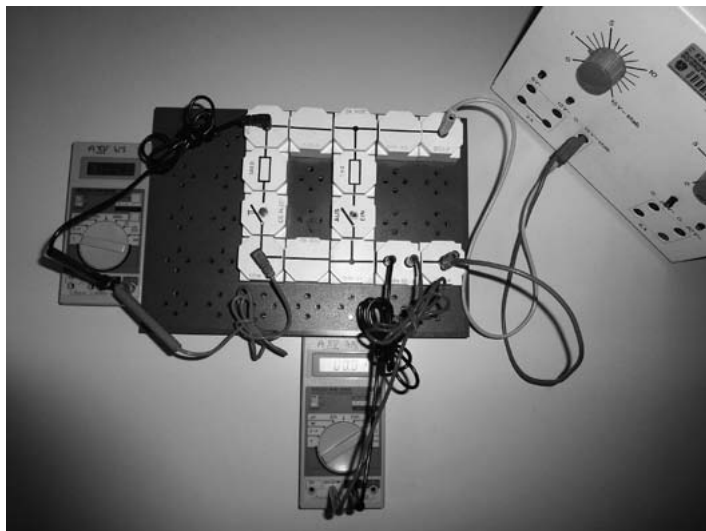
Figure 20

Built circuit Feeler off, switch off
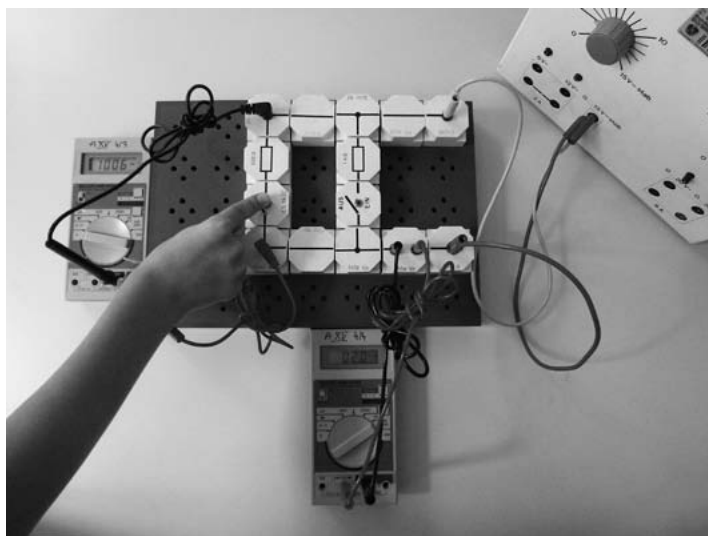
Figure 21

First resistor measurement

Feeler off, Circuit above U = 1 V, R1 = 1000 Ω, Measurement I = 0.9 mA. (Fig. 22)
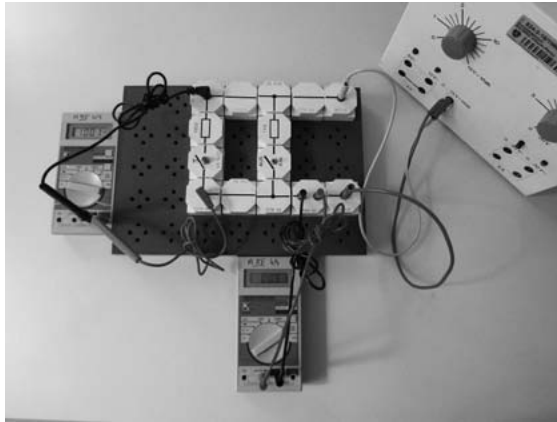
Figure 22

Circuit measurement one resistor

Feeler on, Circuit above U = 1 V, R1 = 1000 Ω, R2 = 500 Ω, Measurement I = 2.9 mA. (Fig. 23)
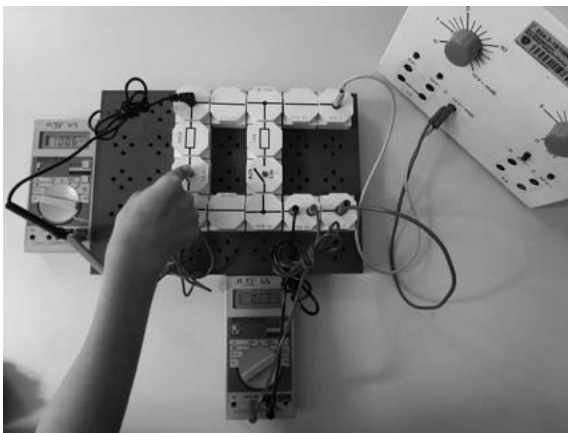
Figure 23

Circuit measurement, next resistor

In VISIR U = 6 V, R1 = 1000 Ω, R2 = 10 000 Ω (Fig. 24)
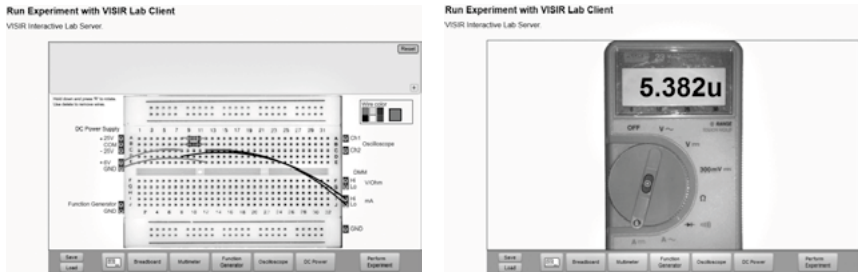
Figure 24

VISIR parallel circuit measurements

Problems that needed to be solved at the beginning of the work:

An error unfortunately occurred during class and thus strongly limited the work of the students. (Fig. 25)
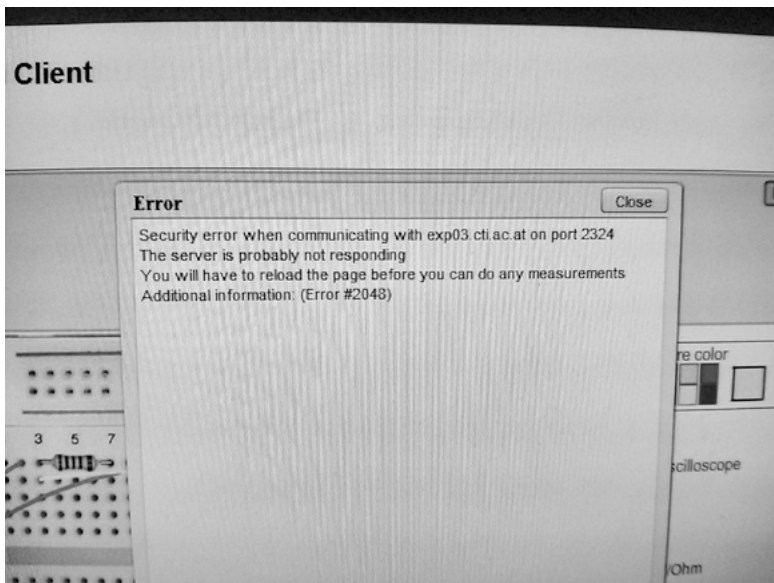
Figure 25

Connection errors on VISIR

In addition, there were problems with the starting time and the server time, which did not match. This caused confusion and self-doubt among the students.

The reservations you have made for this experiment:
15.05.2013 15:12:00 <---> 15.05.2013 15:32:00   Mi, 15. Mai, 15:15

Times shown are GMT: 2
It is 0 days and 0 hours and 6 minutes and 50 seconds earlier than the reservation
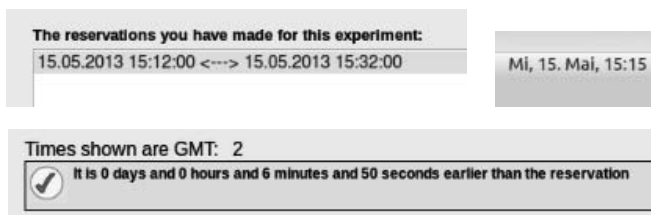
Figure 26

Synchronization delay of systems

Both problems could be solved after a while.

6. **Conclusion**

The use of VISIR in direct teaching during regular lessons is difficult because only one student or one group of students can "build" an experiment and perform a measurement, but also because students need time to think, discuss and obtain a reference, and because the reserved time or small packets of time cannot be predicted or observed.

Working with VISIR is suitable for independent work in the afternoon. If the students receive an assignment, such as homework in physics, they can do the task by themselves in their free time, at their own convenience.

From the students' perspective it can be concluded that they liked working with VISIR. Due to the aspects mentioned above, it should be noted that they preferred to work as a team rather than alone. One group of students said that they were used to asking the teacher questions immediately whenever a problem occurred and getting helpful answers. However, this was not possible when working at home on a remote experiment.

It was rated as positive that in the application of VISIR there is the possibility to redo experiments at home. Measurements and control calculations made to check them can be performed independently. For interested students VISIR is suitable for the construction of further circuits and getting to know other circuit elements.

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INTe-L: wide open door for education by remote and virtual experiments exemplified on electricity, magnetism and electromagnetism

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1. Introduction

A great deal of attention has been devoted worldwide to remote experimentation and especially remote e-laboratories, and these are undergoing a strong current of evolution [1, 2].

Technology enables labs to include different kinds of experiments, as we can distinguish among remote, hands-on and simulated laboratories [3]. Remote laboratory experiments are further distinguished by batched experiments, interactive experiments and sensor experiments [4].

Simultaneously, a great debate is still going on addressing the critical issue of whether remotely operated or simulation-based labs are as effective as the traditional hands-on lab format [5]. Meanwhile, online education has been strongly enhanced after the Bologna Declaration, which has contributed to a shift in the learning focus from the institution to the student [6], with an emphasis on "learning by doing" using laboratories [7]. In this scenario laboratory activities are considered essential in order to increase the effectiveness of teaching and learning in

scientific disciplines. On the other hand, laboratory management can be resource-intensive and expensive, since it requires qualified staff, continuous equipment maintenance and evolution, so that the number of laboratories is often limited. Also having a significant influence are the economic and logistic factors. For these reasons, the adoption of alternative access modes like remote laboratories is desirable for schools and universities [3].

Remote labs can, in fact, expand the capability of a conventional laboratory by increasing the number of times and places in which a student can perform experiments [8], while also increasing the availability of the laboratory to several students. Moreover, they have the potential to provide affordable experimental data by sharing expensive laboratory equipment within a larger pool of users. The U.S. Accreditation Board for Engineering and Technology, now known as ABET, has taken on the task of assessing whether remote laboratories can truly accomplish the goals of educational laboratories and whether they –the remote laboratories– are adequate substitutions for traditional hands-on experience. For this purpose, a list of learning objectives was created describing the goals of the engineering laboratory [9]. Plug and play remote laboratories are used by students and researchers, according to a schedule supervised by the lab manager [10]. A remote collaborative laboratory is a place where any authorized remote user can schedule a lab session, even in collaboration with other users. Different user types (researchers, university students, external users, etc.) must observe different management policies and scheduling rules, according to equipment features and lab manager requirements. Integration into an LMS system like MOODLE [11] and Personal Learning Environments like Graasp [12] is expected. In a blended remote laboratory, local and remote users can collaborate to use the lab equipment (e.g. a local tutor can coach a remote group of students on a new lab technique). The integration of remote labs into the university organization, so that they can become a tool to deliver laboratory services through the Web, is under way [13].

These above mentioned requirements set a list of technical and organizational challenges that should be specifically addressed. How can we create and deliver easy plug and play HW and SW solutions for mediating the complexities of usage and creation, especially of remote labs, and create and deliver all the mature and excellent solutions to the wide population of people interested and would-be users of these

techniques? The plug and play system for remote experiments at schools, on both the hardware (HW) and software (SW) side, with corresponding middleware, has been never understood as a complex problem till now.

Furthermore, the third point of the EU ICT-2011.8.1 project assignment [14], (*iii*) *experiments for specific pedagogical contexts in primary and secondary schools and higher education, including at university level,* has not received the corresponding attention till now. Besides the technical problems connected with remote experimentation, it is necessary to solve the methodological problems in introducing remote experimentation in the teaching and learning process. Real remote experiments bridge the gap existing to date in all forms of E-learning and a new strategy of education based on the process, similar to the cognition of real world by the sciences, was introduced by Integrated e-Learning (INTe-L) [15].

The purpose of the present work is to help in the ensuing situation and to report on a new pedagogical environment, Integrated e-Learning (INTe-L), and its use in implementing remote experimentation in real education. By wide open door we mean an easy way to master and disseminate INTe-L, using technical means, remote experiments and simulations and their easy creation, which is the main premise of our work.

The layout of the chapter is the following. After a brief introduction and motivation, we introduce the technical means we use for INTe-L in the second part. To achieve accessibility of INTe-L and interactive education tools –remote experiments and simulations– more easily, we briefly present the new EASY REMOTE - ISES (ER-ISES) environment for creating the control SW setup for remote experiments based on physical hardware of Internet School Experimental System (ISES) [16], by means of the plug and play approach using a screen questionnaire similar to the expert systems. In order to replenish remote experimentation with accompanying simulations, depicting in a graphical or visual form the remote experimentation, we suggest for use and insert the well known system Easy Java Simulations (EJS) into the INTe-L system [17]. In the third part, we provide a short description of the existing experiments on Electricity, Magnetism and Electromagnetism, carried out by the Consortium of three partners: Trnava University in Trnava, Tomas Bata University in Zlin and Charles University in Prague (more can be read in [18]). The fourth part is devoted to the introduction of INTe-L and its application to university-included distance education, secondary and

even primary school level, project work, examinations and self-study. In the fifth part there are examples of the discussion produced among its participants obtained within the pedagogical research done on distance students [19]. In the closing part the conclusions and the outlook are given of the new pedagogical means and tools to be used in the near future with ISES remote experiments.

2. **Techniques and methods**

A. *Integrated e-Learning (INTe-L)*

The present discussion about new teaching methods in physics is no longer directed towards fundamental changes in learning processes due to new ICT, but how to introduce the new techniques into everyday teaching practice by establishing the resources of E-learning, curricula, etc. The prevailing opinion exists among teachers of physics that there is a need for a change in the physics teaching strategy. In their recent paper on the physics education transformation, C. Wieman and K. Perkins [20] ask the general question: "Is there a way to teach physics that does not produce such dismal results for the typical student?" They give the positive answer by claiming: "By using the tools of physics in their teaching, instructors can move students from mindless memorization to understanding and appreciation". Many educators solve this problem through different approaches, a number of them by increasing the role of laboratories; either real computer oriented [21], real e-laboratories across the Internet [22] or virtual laboratories and simulations [23].

We also adhere to the opinion that laboratories and simulations can deeply change education in physics, but new strategies, including these new teaching tools, are needed. For that reason, we suggest the method of INTe-L, which we present comparing the criteria coming from cognitive research. The prospective methods of teaching, including INTe-L, should comply with [24]:

1. Students should be provided with a suitable organizational structure, based on their prior thinking and experience and starting from their own research results. We should not simply be pouring facts on them and not addressing the simple questions "what", but

rather "why". On top of this, previous knowledge must be carefully checked and examined and possible misconceptions dispelled. The ultimate goal in this respect should be active thinking, active exploratory work, guided by the active role of the teacher, and conditioned by the double-sided student-teacher interaction.

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

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

How does the INTe-L address these three criteria? The first above mentioned criterion is met by INTe-L thanks to its starting point, observations, regardless of whether it is a traditional computer based laboratory, a remote real e-laboratory across the Internet or a virtual e-laboratory [25]. Real experiments strongly support the examination of the real world. On the other hand, virtual laboratories or simulations support an interactive approach, employ dynamic feedback, follow a constructivist approach, provide a creative workplace, make explicit otherwise inaccessible models or phenomena, and constrain students productively [26]. The cognitive load in INTe-L is limited by supporting the individual comprehension processes offering manifold accesses to knowledge and being individually adaptive, and offering significant advantages in the individual rates of teaching progress. Traditional teaching scenarios cannot satisfy this requirement, particularly because of cognitive capacity issues.

INTe-L environments meet these needs. The possibility of making abstract objects and concepts tangible by application to real and virtual laboratories demonstrates this qualitative change in education and addresses the diminishing of the cognitive load of students [27].

In the fulfilment of the third criterion INTe-L provides the qualities and skills the students acquire when studying physics courses for their future study and professional careers. We attempted to deal with this problem in a separate paper [15]. The good news is that courses that make rather modest changes to explicitly addressed student beliefs have avoided the usual negative shifts. Those changes include introducing the physics ideas in terms of real-world situations or devices with which the students are familiar; recasting homework and exam problems into a form in which the answer is of some obvious utility rather than an abstract number; and making reasoning, sense-making, and reflecting explicit parts of in-class activities, homework and exams [20].

The INTe-L course on Electricity, Magnetism and Electromagnetism was implemented into the Learning Management System (LMS) MOODLE (see front page in Fig. 1) and delivered within the basic course of physics to the students of Informatics. We stick to the rules to minimize the number of experiments and simulations, but try to keep them in all forms of classes, i.e. lectures, seminars and even laboratory classes and also project work and examinations.

B. *Plug and Play in experimentation*

Plug and Play in Informatics refers to an approach whereby devices work with a computer system as soon as they are connected. The user does not have to manually install drivers for the device or even tell the computer that a new device has been added. Instead, the computer automatically recognizes the device, loads new drivers for the hardware if needed, and begins to work with the newly connected device [28]. This definition of plug and play comes from PC hardware and was enforced by the fact that the process of manually configuring devices, comprising the PC and its peripheries, could be quite difficult, and there was usually no forgiveness for technical inexperience. Incorrect settings could render the whole system or just the expansion devices completely or partially inoperable.
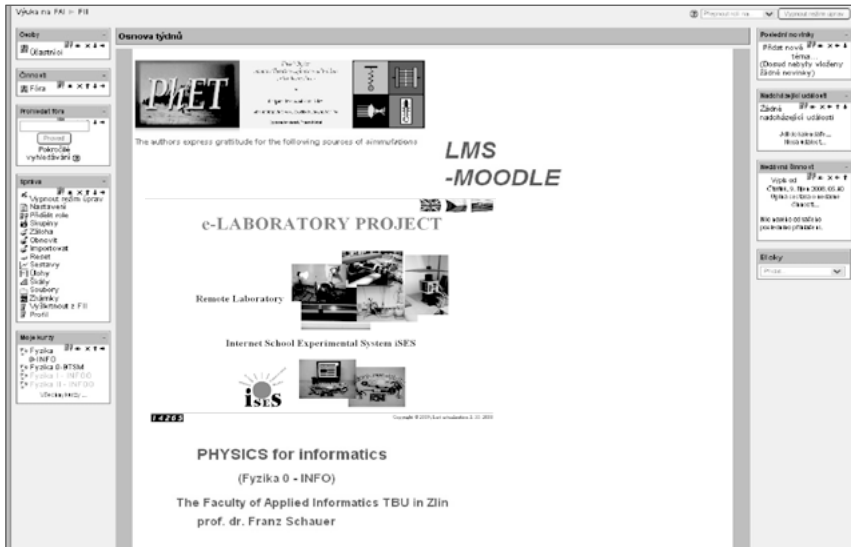
Figure 1

The front page of the LMS MOODLE for the course delivered in Integrated e-Learning (INTe-L)

C. *Internet School Experimental System (ISES)*

ISES is the physical plug and play software and hardware for building computer oriented experiments. The ISES system was described in detail elsewhere [29], [16], and here we give only a few relevant details. ISES is a complex tool for real time data acquisition, processing, displaying and control of experiments. It is an open system consisting of the ISES physical hardware and informatics hardware. The physical hardware is composed of the ISES panel and the set of modules (Fig. 2a) and easily interchangeable sensing ISES elements. Their presence and adjusted range are automatically sensed by the computer, with the automatic calibration facility. The ISES panel (Fig. 2b) enables 10 different channels (6 analog and 2 binary) and has capability to use 2 programmable outputs. The informatics hardware is composed of the interface card with A/DD/A converters and the informatics software is the controlling program (ISESWIN).

a)   b)

Figure 2

Plug and play physical HW of Internet School Experimental System: The
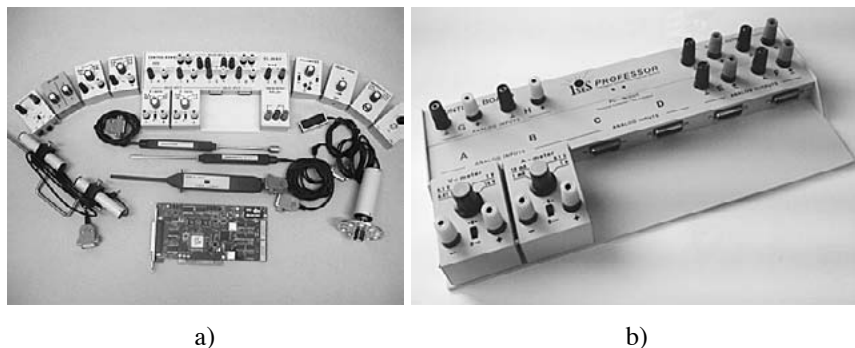ADDA card and set of ISES modules (a) and the ISES panel with two ISES
modules (b)

D. *Remote experimentation with ISES*

Once we have the hands-on experiment, it is necessary to transform it
into the remote experiment (RE) by changing the controlling software, as
depicted in Fig. 2b, using the ISES WEB CONTROL kit [30]. This is the
software that installs all the necessary components for RE as a finite-state
machine (FSM) [31]. FSM is a mathematical model of computation used
to design both computer programs and sequential logic circuits. It is
conceived as an abstract machine that can be in one of a finite number of
states. The machine is in only one state at a time. It can change from one
state to another when initiated by a triggering event or condition, which is
called a transition. A particular FSM is defined by a list of its states, and
the triggering condition for each transition. The finite-state machine built
on ISES and published in [21] creates a controlling .psc program for the
specific RE functioning.

E. *What is easy remote ISES? (ER ISES)*

The procedure of .psc file compiling was not straightforward, as it
required knowledge of a special programming language built for the
purpose. All experiments built on ISES till 2012 (about 50 in total)

have used .psc file programs when transforming the flow chart diagram of the experiment into the controlling .psc file [31]. The procedure was cumbersome and in effect was a hindrance for building remote experiments at schools, which now have a total of 450 computer laboratories with ISES.

ER ISES is a graphical development environment which generates the control .psc file for finite-state machine (FSM) [32] without any programming, as shown in Fig. 3, and the web page code for RE controlling by a client, whose welcome screen is in Fig. 4. For more details see [33].

a)

b)

Figure 3

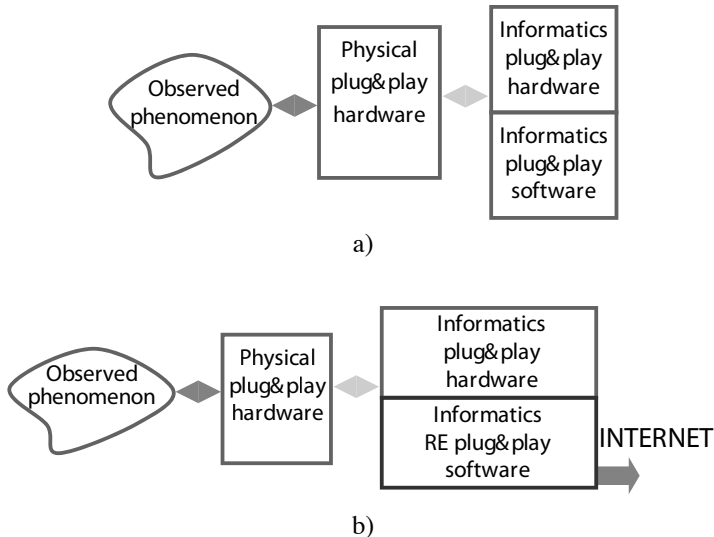Plug and play hardware and software schematic representation ISES: hands on experiment (a) and remote experiment (b)

F. *Physlets*

INTe-L uses all sorts of simulations and modelling that accompany every RE [17], [34-36]. Our ER- ISES was inspired by EJS, so a few words about this inspiring environment are necessary. EJS is a free software tool for rapid creation of applications in Java with high-level

Figure 4

Welcome panel of ER ISES graphical development environment

graphical capabilities and with an increased degree of interactivity. The applications created by EJS can be standalone Java applications or applets, and for simplicity, here we call them EJS applications or simply applications. The source files of the EJS applications are saved in a customized *XML* format. EJS is different from most other authoring tools in that EJS is not designed to make life easier for professional programmers but has been conceived for science. EJS structures the application into two main parts: the model and the view. The model can be described by means of pages of Java code and ordinary differential equations or by connecting to external applications (such as Matlab). The view provides the visualization of the application as well as the user interface elements required for user interaction. These view elements can be chosen from a set of predefined components to build a treelike structure. Model and view can be easily interconnected so that any change in the model is automatically reflected by the view, and vice versa.

3. **List of experiments with a short description**

Let us give a brief account of the Electricity, Magnetism and Electromagnetism REs we use in the present work. All REs are run on

the server-client scheme, using normal web pages, web browser and Java support; no extra hardware or software is necessary on the part of the client (student). The experiments are unique in available data transfer using the standard web page; the students can choose the range and the time interval of the wanted data for subsequent processing and evaluation.

A. *Source of DC voltage*

The Web page devoted to the experiment, "Source of DC voltage", is available for free at: http://remotelab7.truni.sk, and its technical arrangement is shown in Fig. 5 and Fig. 6. Now we will show how to use it for students.
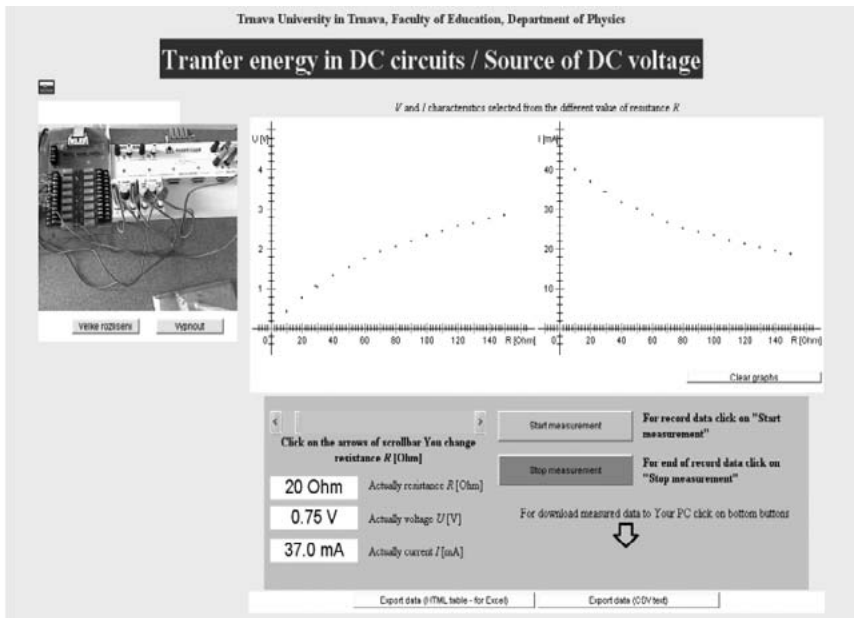
Figure 5

RE web page "Source of DC voltage"
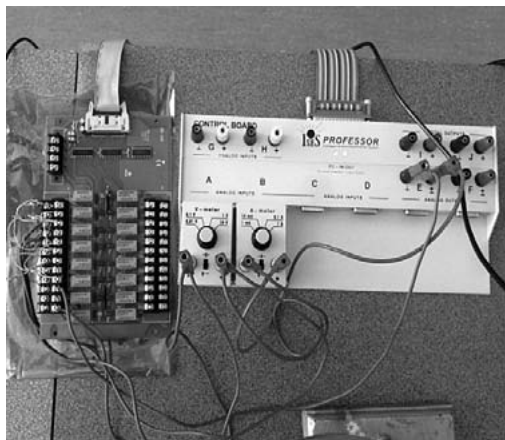
Figure 6

Technical arrangement of the experiment

A.1 Physical background

The general characteristics of a DC source are the electromotive voltage ε and internal resistance R_i. Fig. 7 shows the scheme of a simple equivalent circuit of real battery/source. If we connect the source to the load R, the current I is

$$I = \frac{\varepsilon}{R + R_i} \qquad (1)$$
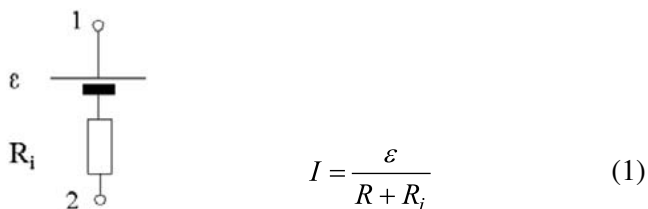
Figure 7

Equivalent circuit of the DC source

The internal resistance R_i causes the terminal voltage $U_{SV} = V_1 - V_2$ between points 1 and 2 (Fig. 7) to depend on the current

$$U_{SV} = \varepsilon - R_i I \qquad (2)$$

We can use eq. (2) to determine the electromotive voltage ε and internal resistance R_i measuring the loading characteristics $U_{SV} = f(I)$. After rearrangement eq. (1), we obtain another useful expression

$$\frac{1}{I} = \frac{R_i}{\varepsilon} + \frac{R}{\varepsilon} \tag{3}$$

Eq. (3) makes it possible to determine the electromotive voltage ε and internal resistance R_i measuring the loading characteristics $1/I = f(R)$.

A.2 ASSIGNMENT

1. Study the real source of electromotive force using loading characteristics $U_{SV} = f(I)$ and $1/I = f(R)$.
2. Explain the differences found by both methods.

A.3 EVALUATION OF MEASURED DATA

Fig. 8 shows the dependence $U_{SV} = f(I)$. From the linear fit, using eq. (2) of the data in Fig. 8, we obtain: $\varepsilon = 4.89$ V and $R_i = 114.1$ Ω.

Equation	y = a + b*x		
Adj. R-Squar	0,99987		
		Value	Standard
a	Intercept	4,9715	0,00953
b	Slope	-0,1141	3,44453
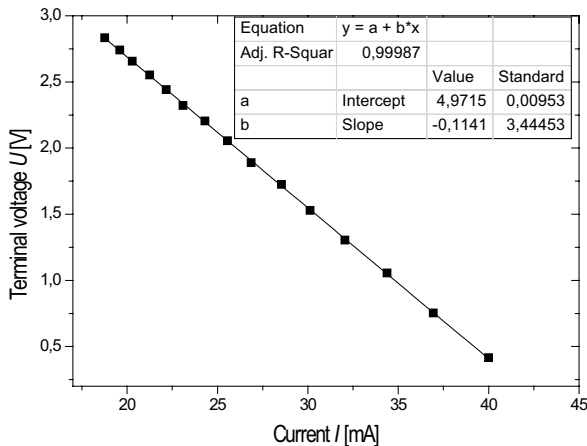
Figure 8

Dependence of the terminal voltage U_{sv} on the current I, with the linear fit

Using the loading characteristics $1/I = f(R)$ eq. (1) from the data in Fig. 9, after linear fitting we obtain:

$$\varepsilon = 4.98 \text{ V and } R_i = 114.9 \text{ } \Omega$$

The final results of the measurements by both methods are shown in Table 1:

Table 1

Final results of the measurements

	$U_{SV} = f(I)$	$1/I = f(R)$
Electromotive voltage of DC source	$\varepsilon = 4.89$ V	$\varepsilon = 4.98$ V
Internal resistance of DC source	$R_i = 114.1$ Ω	$R_i = 114.9$ Ω
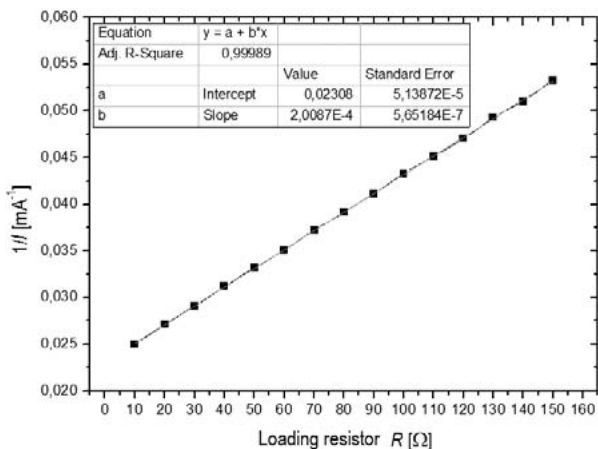
Figure 9

Dependence of the inverted value of the current $1/I$ on loading resistance R

B. *Energy transfer in DC circuits*

This experiment (http://remotelab7.truni.sk) uses the similar technical arrangement and web page as in the previous experiment, shown in Fig. 5 and Fig.6.

B.1 PHYSICAL BACKGROUND

The external resistor, which is usually referred to as the *load resistor R,* may be either an electric bulb, a heater or an electric motor. The basic purpose of the experiment is to examine energy transfer from the source of the electromotive force to the load resistor. The source of the electromotive voltage (further source, e.g. battery) delivers the energy to the load resistor with some energy loss in the battery itself, represented by its internal resistance R_i So the general characteristics of the source are electromotive voltage ε and internal resistance R_i in Fig. 10.
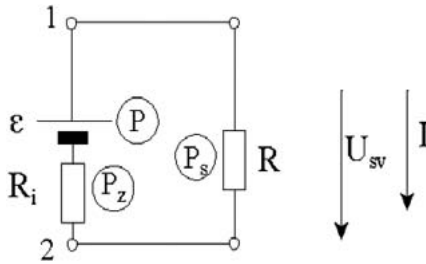
Figure 10

Closed electric circuit with the source and the load

Using eq. (1) and multiplying it by the current I, we obtain the equation for the energy transfer from the source to the load

$$\varepsilon I = U_{SV}I + R_i I^2 \text{ or } P = P_{LOAD} + P_{LOSS} \qquad (4)$$

The term $P = \varepsilon I$ is the power delivered by the source, the term $P_{LOAD} = U_{sv}I$ is the power accepted by the load and $P_{LOSS} = R_i I^2$ is the heat in the source in unit time.

By combining eq. (4) and eq. (1), we obtain

$$P_{LOAD} = \frac{\varepsilon^2}{R + R_i} - R_i \frac{\varepsilon^2}{\left(R + R_i\right)^2} \qquad (5)$$

The maximum power delivered to load R is the function of both the R and the internal resistance of the source R_i. Its maximum is found by forcing the first derivative $dP_{LOAD}/dR = 0$, which gives $R = R_i$ and the maximum value of the power delivered to the load

$$P_{LOAD} = \varepsilon^2/4R_i \qquad (6)$$

The dependence of the efficiency η of the energy transfer from the source to the load is (using eq. (5))

$$\eta = \frac{P_{LOAD}}{P} = \frac{R}{R + R_i} \qquad (7)$$

B.2 STUDENT'S ASSIGNMENT

1. Study the dependence of the electrical power from the source to the load resistance R on the current I (dependences $P_{LOAD} = f(I)$).
2. For which value of the load resistance R is this power maximal?
3. Determine the dependence of the efficiency η of the energy transfer from the source to the load on the load resistance R.

B.3 EVALUATION OF THE MEASURED DATA

Fig. 11 shows the measured dependence $P_{LOAD} = f(I)$, or

$$P_{LOAD} = \varepsilon I - R_i I^2 \qquad (8)$$

The polynomial fit of the data in Fig. 12 gives, for the polynomial $y = ax^2 + bx$, the numerical expression

$$y = -0.11434 \ x2 + 4.99563 \ x$$

From eq. (8) we then have by comparison

$$P_{LOAD} = -R_i I^2 + \varepsilon I = -0.11434 \ I^2 + 4.99563 \ I,$$
$$R_i = 114.3 \ \Omega, \quad \varepsilon = 4.99 \ V$$

The maximum power transferred to the load is

$$P_{LOADMAX} = R \cdot \left(\frac{\varepsilon}{R + R_i} \right) = 54.6 \text{ mW}$$
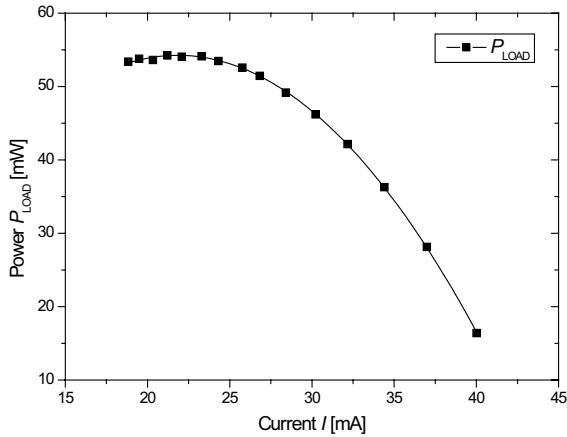
Figure 11

Dependence of the power P transferred
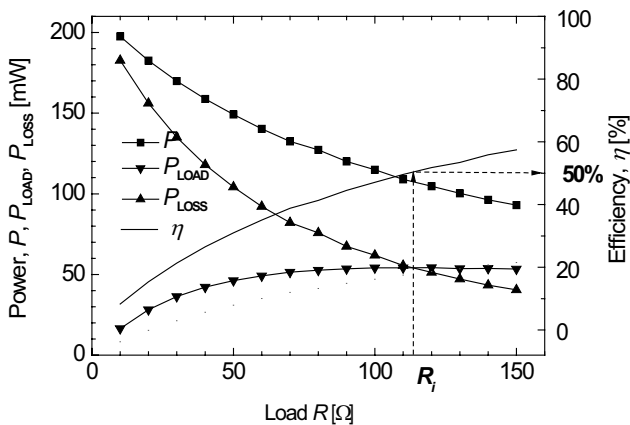
Figure 12

Dependents of $P = f(R)$, $P_{LOAD} = f(R)$, $P_{LOSS} = f(R)$,$\eta = f(R)$

The results may be summarized as in Table 2.

Table 2

Results for Energy transfer in DC circuits

Electromotive voltage ε	$\varepsilon = 4.99$ V
Internal resistance R_i	$R_i = 114.3$ Ω
Maximal power to the load P_{max}	$P_{max} = 54.6$ mW ($\eta = 50\%$)

C. *Phase in RLC circuits*

This experiment is available at: http://remotelab3.truni.sk/phase_rlc.html and the web page of the experiment is shown in Fig. 13.
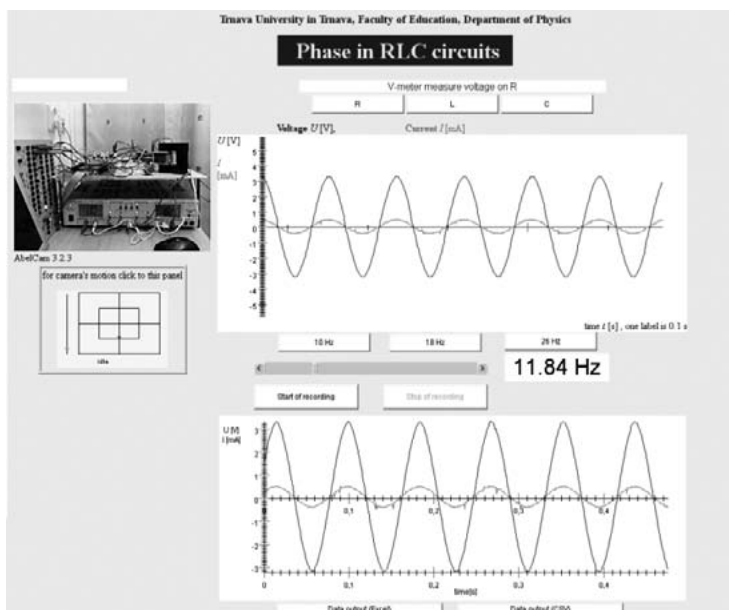
Figure 13

Web page of RE "Phase in RLC circuits"

C.1 Physical Background

The source of harmonic electromotive force ε with the resistor R, capacitor C and inductor L in Fig. 14 may be described by the differential equation for current on circuit $I = I(t)$

$$L\frac{d^2 I}{dt^2} + R\frac{dI}{dt} + \frac{1}{C}I = -\omega U_0 \sin(\omega t) \tag{9}$$
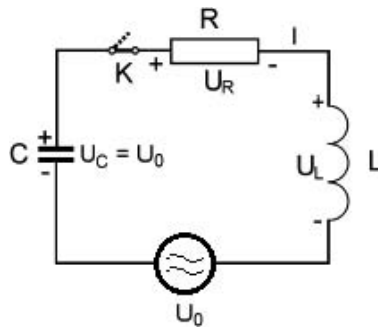
Figure 14

Scheme of RLC circuit with AC source

This equation has a solution in form

$$i = I_0 \cos(\omega t + \phi), \text{ where } I_0 = \frac{U_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \tag{10}$$

The initial phase (the phase shift of the current i against voltage u) is defined by

$$tg\phi = \frac{\frac{1}{\omega C} - \omega L}{R} \tag{11}$$

It is evident from eq. (10) that the amplitude of current I_0 and the initial phase ϕ depend both on the values of elements R, L and C, and on the angular frequency $\omega = 2\pi f$.

D. *Energy transfer in RLC circuits*

The experiment is available at: http://remotelab3.truni.sk/transfer_energy.htm.

D.1 PHYSICAL BACKGROUND

The main purpose of the e-experiment is to show the frequency dependent energy transfer in the series *RLC* circuit from the source to the load resistor defined by

$$P_{av} = \frac{1}{T}\int_0^T R\,i(t)^2 \mathrm{d}t \tag{12}$$

where $i(t)$ is instantaneous current and the term Ri^2 the instantaneous power. Eq. (12) may be simplified to the form

$$P_{av} = \frac{1}{T}\int_0^T Ri^2\,\mathrm{d}t = \frac{U_0^2 b}{\omega_{res}^2 L}\cdot\frac{1}{\dfrac{b^2}{\omega_{res}^2}+\left(\dfrac{\omega}{\omega_{res}}-\dfrac{\omega_{res}}{\omega}\right)^2} \tag{13}$$

where U_o is the amplitude of the source voltage, ω_{res} is the resonance frequency and the damping coefficient $b = R/2L$. Fig. 15 describes the frequency dependence of the energy transfer in RLC serious circuit, calculated using amplitude and phase characteristics and eq. (13). The final results of the measurements are shown in Table 3.

Table 3

Final results of the measurements *"Energy transfer in RLC circuits"*

Resonance frequency	$f_{res} = 20.6$ Hz
Amplitude of current in resonance	$I_{max} = 2.3$ mA
Maximum of average power in resonance	$P_{str} = 3.2$ mW
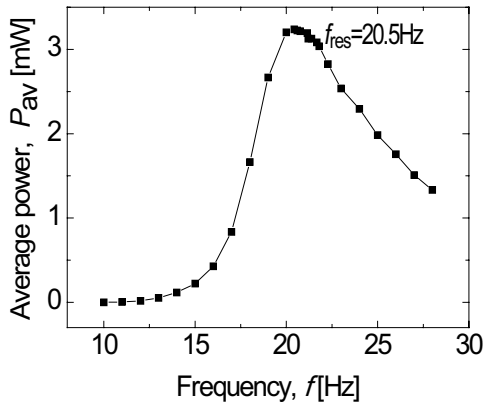
Figure 15

Frequency dependence of the transferred average power P$_{av}$ in RLC circuit

E. *Transient phenomena in RLC circuits*

The experiment is available at: http://remotelab6.truni.sk and the experiment's web page is shown in Fig. 16a.
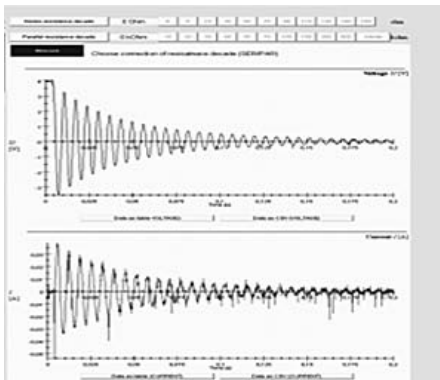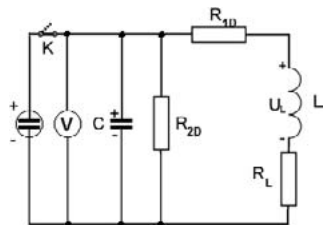
a)   b)

Figure 16

Experiment web page, a)"Transient phenomena in RLC circuits" with typical voltage u (t) and current i (t) responses, and b) Scheme of the experiment

E.1 Physical background

The RE serves for the determination of the R_L, L and C elements of the parallel RLC circuit in the time domain using artificially introduced damping by two inserted resistors R_{1D} and R_{2D} (see Fig. 16b).

The response of the RLC circuit in Fig. 16b to the applied voltage U_o step, provided $\omega_0 > b$, is

$$u(t) = U_o\, e^{-bt} \sin(\omega_o t + \phi) \tag{14}$$

where
$$\omega_0^2 = \left(\frac{1}{LC}\right) \cdot \left(1 + \frac{R_1}{R_2}\right) \tag{15}$$

and
$$2b = \frac{1}{R_2 C} + \frac{R_1}{L} \tag{16}$$

where
$$R_1 = R_{1D} + R_L,\ R_2 = R_{2D} \tag{17}$$

E.2 Student's assignment

1. Study free oscillations of the parallel RLC circuit and determine the free oscillation frequency f_o.
2. Measure the effect of series and parallel resistance on the damping coefficient b.
3. Basing yourself on the results of 2., find the parameters R_L, L and C of the circuit.

E.3 Evaluation of measured data

By changing the damping coefficient by inserting artificial damping resistors R_{1D} or R_{2D}, we obtain the dependences depicted in Fig. 17 and Fig.18.

From the graphs in Figs. 17 and 18 we can observe the dependences of the damping coefficient b with resistance R_{1D} (Fig. 17) and R_{2D} (Fig. 18). Using eq. (17) and (18), we can evaluate the dependences for unknown quantities R_L, L and C of the circuit (Table 4).
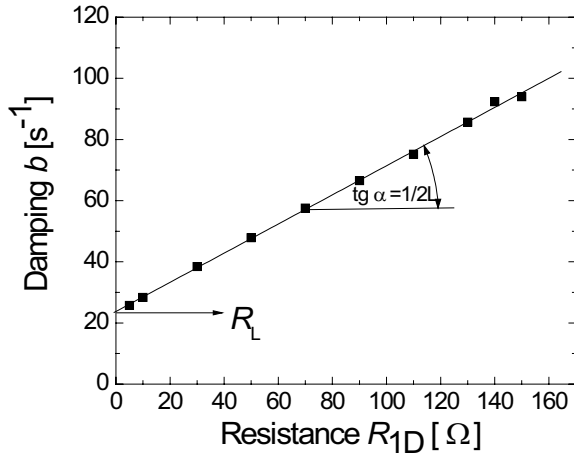
Figure 17

Dependence of the damping b on the resistance R_{1D} ($0 \div 150$ Ω),
with the linear fit
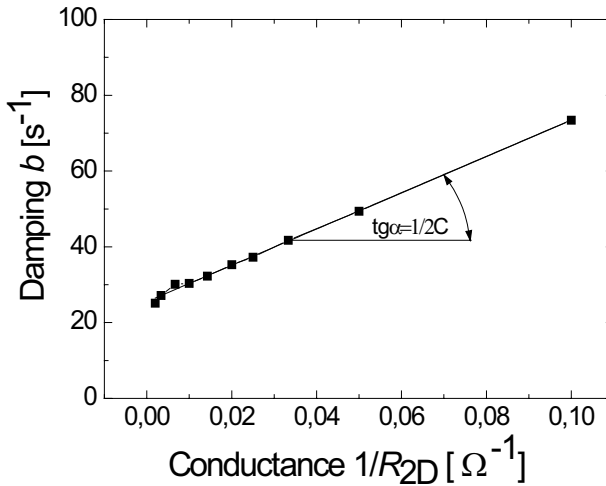
Figure 18

Dependence of the damping b on the inverted value of the resistance $1/R_{2D}$ with
R_{2D} ($10 \div 500$ kΩ) and with the linear fit

Table 4

Final evaluation -Transient phenomena in RLC circuits

Inductance of inductor L	$L = 0.476$ H
Resistance of inductor R_L	$R_L = 19.0$ Ω
Capacitance of the capacitor C	$C = 1.01$ µF

F. *Magnetic field mapping*

This is an important experiment (Fig. 19, http://kdt-27.karlov.mff. cuni.cz) for electromagnetic theory. It uses Helmholtz coils connected to the current source independently, and a 2D magnetic sensor positioned on a plane. The magnetic field distribution is presented by arrows, the direction and color of which represent the field direction and magnetic field strength value, respectively. The magnetic field distribution may be influenced by inserting materials with various magnetic properties.
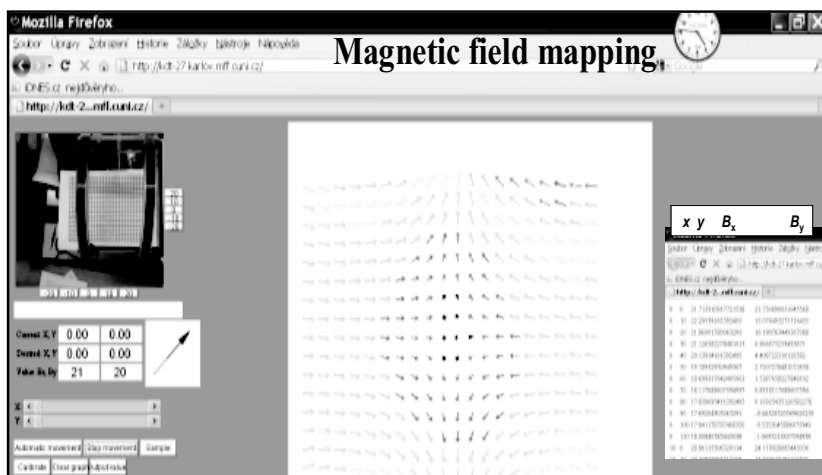
Figure 19

The web page of the "Magnetic field mapping" experiment, with a live
web camera view of the Helmholtz coils, controls (left), map of the field
distribution of the anti-parallel connected coils and the corresponding
transferred data (right)

G. *Electromagnetic induction*

The "Electromagnetic induction" experiment, available at the address http://kdt-20.karlov.mff.cuni.cz/ovladani_2_en.html, is useful for the demonstration and quantitative elucidation of electromagnetic induction phenomena. The experiment uses a rotating coil in a homogeneous magnetic field and monitors the corresponding signal (Fig. 20). The goal of the experiment is to show the phenomenon and how it complies with Faraday's law of electromagnetic induction. The only parameter is the voltage for the driving motor influencing the frequency of the coil's rotation, and data is the time representation of the electromotive voltage from the rotating coil.

The second experiment on electromagnetic induction (http://remotelab4.truni.sk) shows the electromagnetic signal produced by the fall of the permanent magnet lifted by the magnetic vessel in a tube with pickup coils, distributed evenly along the glass tube (Fig. 21). The tube may be both evacuated, with common air ambient and filled with pressurised gas or liquid. It is very suitable to study the interaction of the moving permanent magnetic dipole and the thin solenoid both in short circuit and disconnected.
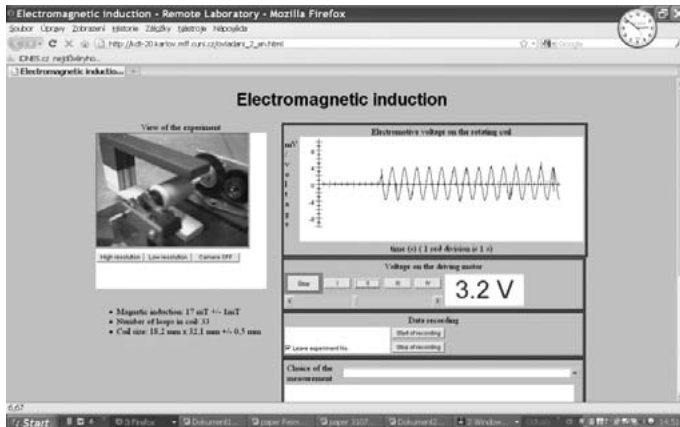
Figure 20

The RE "Electromagnetic induction" web page, live web of the camera view, frequency controls and the graph with time representation of electromotive voltage
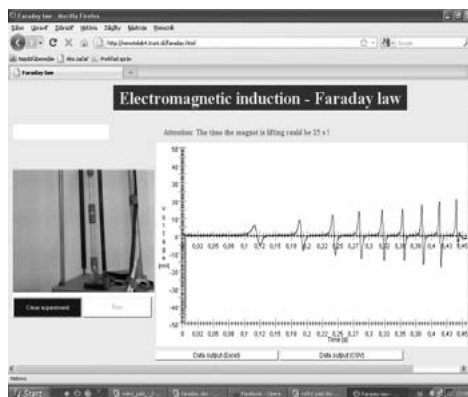
Figure 21

The web page of the RE "Free fall of the permanent magnets in different media with different representation of electromagnetic signals from pick up coils"

H. *Nonlinear electronic devices and Emission of luminescent diodes*

The remote experiment (http://remotelab8.truni.sk, Fig. 22) is equipped with a series of LED diodes. It may be used for studying static and differential resistances of devices with nonlinear *I*(*V*) characteristics and for studying the relation between the band gap energy of the semiconductor in question and energy of the emitted photon

$$h\frac{c}{\lambda} = \Delta E_g \qquad (18)$$

where ΔE_g is the band gap energy of the semiconductor in question and λ is the wavelength of the emitted photon and c an h are the velocity of light and h is the Planck's constants, respectively.

4. **INTe-L in teaching using remote and virtual experiments**

Let us demonstrate the teaching of physics using INTe-L with remote experiments, simulations and e-textbooks with the example of three teaching units from quite different parts of the physics course, namely DC circuits, Phase in AC circuits and Electromagnetic induction.
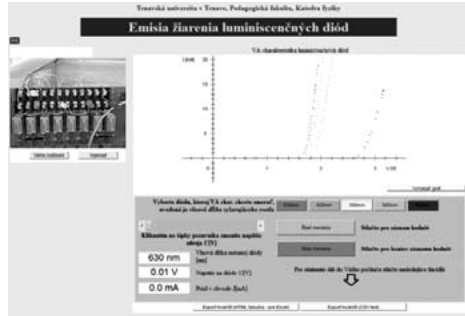
Figure 22

Web page of the RE "Nonlinear electronic devices" and "Emission
of luminescent diodes"

A. *INTe-L unit –DC circuits– secondary schools*

A.1 REMOTE EXPERIMENTS ON "SOURCE OF DC VOLTAGE" AND "ENERGY
     TRANSFER IN DC CIRCUITS"

The INTe-L teaching unit for secondary schools elucidates the
rightfulness of the phenomena of the DC circuits. The unit uses the PhET
Virtual Lab Circuit Construction Kit (Fig. 23) for building and measuring
DC circuits [37] and also the remote experiment on "Source of DC
voltage", available at http://remotelab7.truni.sk (Fig. 5).
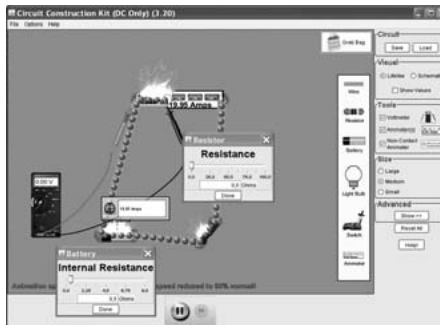
Figure 23

PhET Virtual Lab Circuit Construction Kit [37]

The INTe-L unit for secondary schools on the DC closed circuit with the electromotive source starts with some warm-up questions on right and wrong answers dealing with the electric current, its measurement and quantities encountered in DC circuits (parts 1-6). Then comes Task 7:
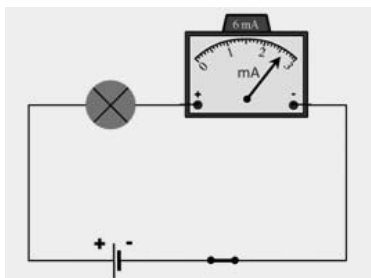
Task 7
a) *Write the list of elements the circuit is constructed from.*
b) *Determine the depicted reading of the A-meter.*
c) *What is the maximum current of the A-meter?*
d) *What is the reading of one division of the scale?*

Then comes the set of questions (8-9) dealing with the details concerning electrical conductivity of materials. *Task10: With the help of the simulation http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab and the remote experiment http://remotelab7.truni.sk, make clear the meaning of both depicted figures:*
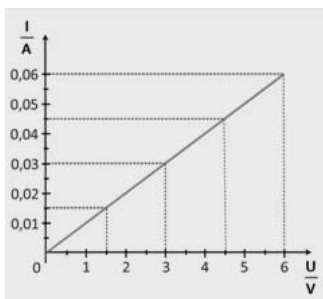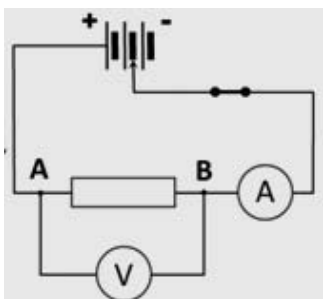
a) *In the left figure there is* ....
b) *In the right figure there is* ....

Task 11: Using simulation http://phet.colorado.edu/en/simulation/circuit-con-struction-kit-dc-virtual-lab, build the circuit from item 10 and approximately reproduce the graph in the right figure.

Task 12: Using remote experiment http://remotelab7.truni.sk, measure the dependence in the right figure and discuss the possible deviations from the results in item 11.

B. *INTe-L unit: phase in AC circuits and energy transfer in AC circuitsfor university level*

The remote experiment (http://remotelab3.truni.sk/phase_rlc.html, Fig. 23) and simulationon phase and energy transfer in AC circuits (Fig. 24) were used during the education process. The teaching unit examines the phase as an important parameter of AC signals and its importance for transfer of energy. In the first part the phase shift between instantaneous voltage and current on passive components of resistors, capacitors and inductors are shown. In the second part of the unit, the influence of the phase shift on the energy transfer in AC circuits is demonstrated.

The lecture teaching the AC signals is always started with the simulation of the behavior of R, L and C phase shift at variable frequencies using the remote experiment (see Fig. 24). The resulting instantaneous signals are transferred to the web page of the experiment and depicted (top right panel). For better understanding, the remote experiment is always supplemented by the simulation of the EJS simulation (Fig. 25) of the phase shift on the inductor prepared by a student.

The origin of the phenomenon of the phase shift in R, L and C components are discussed and exercises calculated in the seminars. The concepts of the resonance and own frequencies are discussed and the role of damping and dissipation of energy explained. The term of energy transfer is also explained.
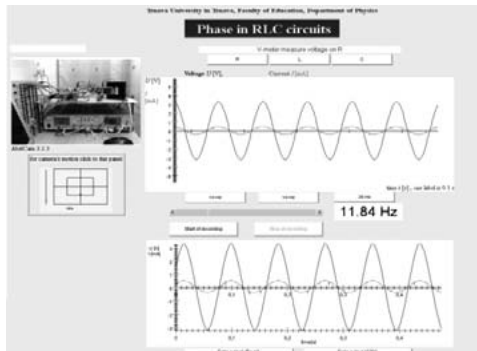
Figure 24

The RE "Phase in RLC circuits" to measure instantaneous voltage and current signals on R, L and C with variable frequency
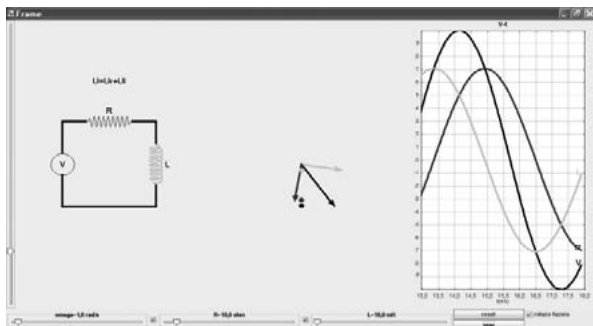
Figure 25

Simulation –"Phase shift on RL circuit"– using Easy java simulation (prepared by a TBU student in Zlin 2013)

In the laboratory exercises, the following three laboratory tasks using remote experiment are set: "Phase in RLC circuits" (see http://remotelab3.truni.sk), "Energy transfer in RLC circuits" (see http://remotelab3.truni.sk) and "Transient phenomena in RLC circuits" (http://remotelab6.truni.sk). Let us see the students' results measured on remote experiment 3, (Table 5-7, Figs. 26 a,b,c):

Assignment

1. *Measure the phase shift of the harmonic current with respect to the voltage for the resistor R, inductor L and capacitor C for several values of the frequency f.*
2. *What is the reason for the disagreement with the theory, if any?*

Table 5

Final evaluation -Phase in AC circuits-resistor

	Frequency f [Hz]	12	21	26
Resistor	Current amplitude I_o [mA]	0.49	0.68	0.66
	Phase $\Delta\phi$ [rad]	0	0	0

For the resistor is the phase shift of the current against the voltage $\Delta\phi = 0°$.

Table 6

Final evaluation -Phase in AC circuits-capacitor

	Frequency f [Hz]	12	21	26
Capacitor	Current amplitude I_o [mA]	0.49	0.65	0.67
	Phase $\Delta\phi$ [rad]	-1.57	-1.54	-1.49

For the ideal capacitor, the phase shift of the current against the voltage is $\Delta\phi$ = -90° (-1.57 rad). In our case the measured phases are near the ideal value.

Table 7

Final evaluation -Phase in AC circuits-inductor

	Frequency f [Hz]	12	21	26
Inductor	Current amplitude I_o [mA]	0.49	0.64	0.67
	Phase $\Delta\phi$ [rad]	1.47	1.53	1.51

For the ideal inductor, the phase shift of the current against the voltage is $\Delta\phi$ = 90° (1.57 rad). In our case the measured phases are near the ideal value. Fig. 26 presents graphs of voltage U and current i for the resistor, the capacitor and the inductor.

C. *INTe-L unit Faraday's law –the university level*

Remote experiments (http://kdt 20.karlov.mff.cuni.cz/ovladani_2_en.html with variable frequency (see controls for changing the frequency of rotation) http://remotelab4.truni.sk and simulation (http://phet.colorado.edu/en/simulation/faraday) on electromagnetic induction were used during the education process.

The teaching unit examines the connection of time varying magnetic and electric fields with one entity of electromagnetic field, with the focus on the time varying magnetic fields and the ensuing consequences. The central focus of this unit is Faraday's law of electromagnetic induction elucidated in lectures, seminars and laboratory exercises.

a)

b)

c)
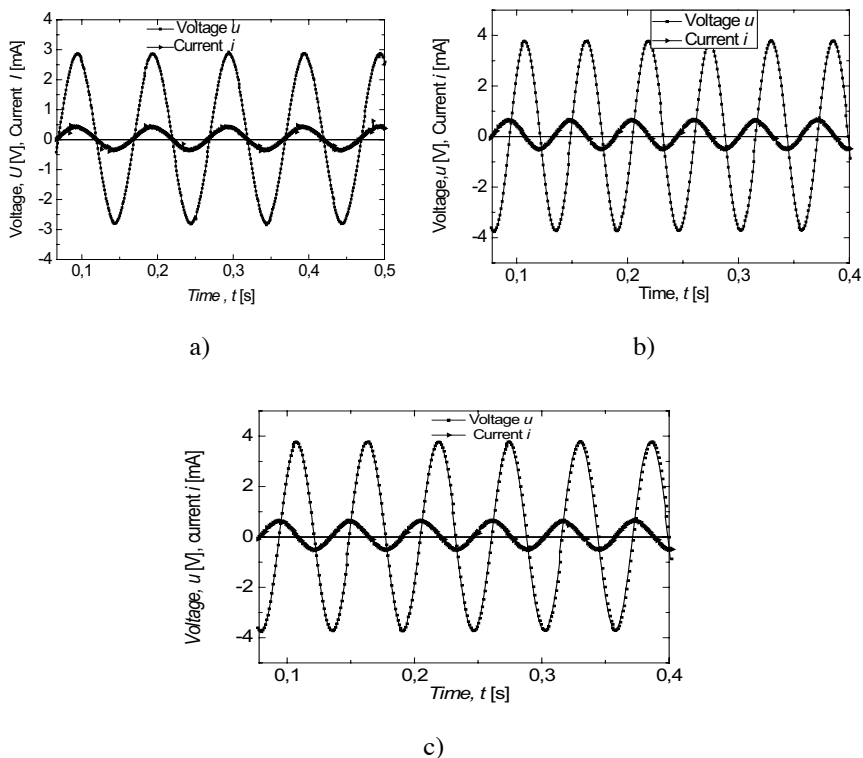
Figure 26

Voltage *U* and current *I* for: the resistor (a), the capacitor (b), the inductor (c)

The initial part of the lecture on teaching the Electromagnetic induction unit is always the introduction of the remote experiment as an observation of real world phenomenon, loaded with noise and other real world phenomena. To demonstrate Faraday's law by remote experiment (Fig. 27), we show the coil rotating in the homogeneous magnetic field (life view in the left top panel) at the constant but arbitrary driving voltage for the motor. The resulting instantaneous electromotive voltage is transferred to the web page of the experiment (right top panel). The data corresponding to the chosen time interval are transferred and stored (bottom panel). The web page is supplemented by the text, providing the necessary theory and resources. For better understanding, the remote experiment is always supplemented by the simulation (Fig. 28).
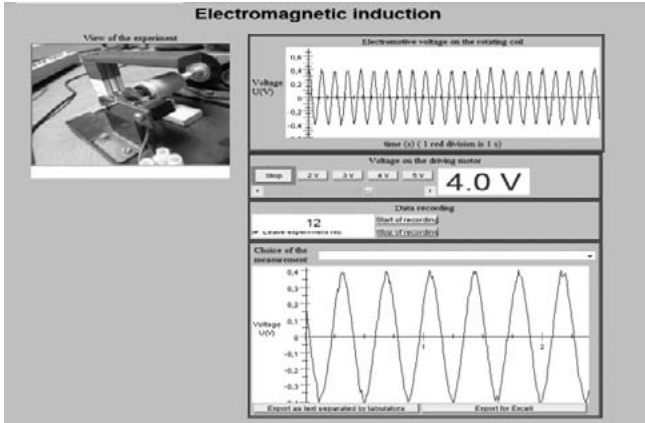
Figure 27

Web page of the Faraday's law with controls, view of the experiment
by life web camera output data and the graph of the output voltage
and view of the expeeriment by life web camera.
See the url: http://kdt-20.karlov.mff.cuni.cz/ovladani_2_en.html
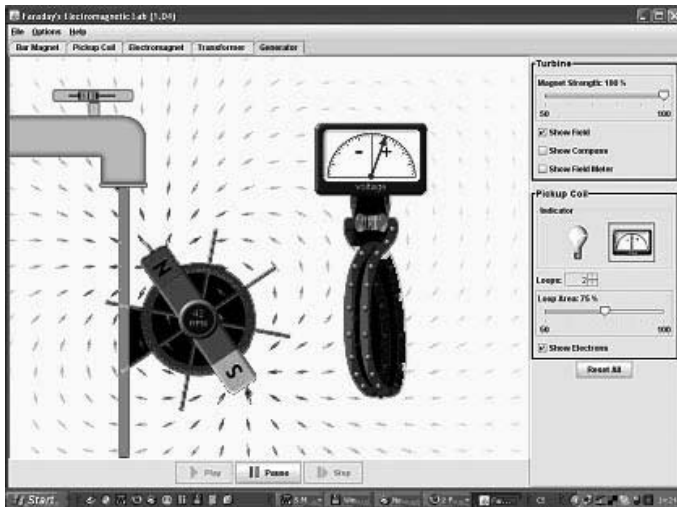
Figure 28

Faraday's law in action in the ColoradoPhET applets simulation
[http://phet.colorado.edu/en/simulation/faraday]
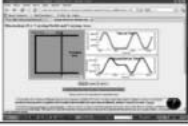
The exercises on the subject matter in question are solved in seminars. As a rule, the identical remote experiments or simulations are the starting points as a bridge to the subject matter of the lecture or even a numerical simulation for the individual exercises. In Fig. 29 is an example of the Seminar on Electromagnetic induction. In laboratory exercises, all forms of computer oriented experiments are used, i.e. hands on, remote and virtual. The assignment for the Electromagnetic induction laboratory exercise can be seen in Fig. 30. As a rule, the simulation for illuminating the basic physical laws is part of the assignment.

Seminar 7 - Electromagnetic field

Let us examine first the remote experiment to the 1. exercise see:
http://kdt-20.karlov.mff.cuni.cz/ovladani_2_en.html
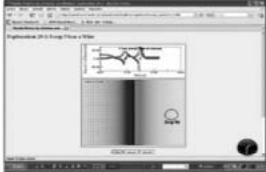
Simulation to the exercise 2. a 3.
Conductor with current in magnetic field.
See Christian, Belloni: II 29.2

1. A flat coil with $N = 50$ windings with radius $r = 0,1$m is rotating with the constant frequency $f = 30$ Hz with the axis perpendicular to the homogeneous magnetic field $B = 10^{-3}$ T . **Find both the time dependence of the magnetic flux through the coil and electromotive force generated in the coil.**

2. A horizontal metal rod of the length $L = 2$ m starts to free fall from the rest in the gravitation filed of the Earth. **Determine the electromotive voltage generated between the ends of the rod at the time $t = 3$ s**, if the orientation of the rod is N-S(W-E).

3. A metallic rod of the length $L = 1,5$m moves with the constant velocity $v = 2$ ms^{-1} parallel with the long straight wire and is oriented perpendicularly to the current carrying wire, situated $a=30$ cm from it. The current is $I = 40$ A. **Determine the electromotive voltage (value and direction) in the rod.**

Try this more demanding simulation
See Christian, Belloni: Ex 29.3

Electromotoric voltage of the solenoid
See Christian, Belloni: Ex 29.5, Pr 29.11 .

Figure 29

Example of the exercise on MOODLE for seminar on Faraday's law with RE and simulations

LABORATORY TASK 7: ELECTROMAGNETIC INDUCTION
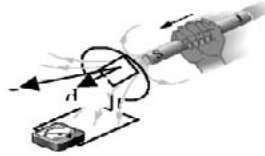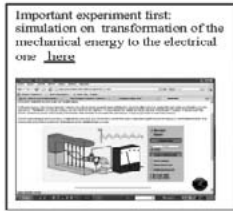
Fig. 1 Example of the induced electromotive force by
moving of the permanent magnet

1. Basic principle

The basic principle of electric and magnetic time dependent fields is their mutual dependence in the form of electromagnetic field. In the laboratory task we show, how the time dependent magnetic field forms electric field. We demonstrate this principle both on the rotating coil in the magnetic field and on the permanent magnet, moving in solenoid. In both cases the electric field is generated .

2. Assignment

1. Make acquainted with the remote experiment with rotating coil in the homogeneous magnetic field - http://kdt-20.karlov.mff.cuni.cz/index_e.html

2. Carry the measurements of the induced electromotive voltage on the angular frequency of the rotating coil and check the validity of the Faraday's law of electromagnetic induction using expression ().

3. Carry the measurements of the induced electromotive voltage by the free falling permanent magnet, and check the validity of the Faraday's law of electromagnetic induction using expression (). Determine the acceleration of gravity g.

3. Introduction

Electromagnetic induction is the phenomenon of the mutual binding of the time dependent magnetic and electric fields, when electric filed is always generated when the time dependent magnetic field occurs. Example of this sitation is in Fig. 1 where permanent magnet is moving, thus creating time dependent magnetic field and we can observe the time dependent electric filed on the connected measuring instrument.

Figure 30

Example of the laboratory task on MOODLE for laboratory exercise on
Faraday's law with hands-on and RE.

In the laboratory exercise, both remote experiments with the rotating coil and free falling permanent magnet (see experiments 7) are used with the goal of proving the validity of Faraday's law

$$\varepsilon = -\frac{d\Phi(t)}{dt} \qquad (18)$$

where $\Phi(t)$ is the instantaneous magnetic flux. One example of the students' assignment is the verification of the validity of Faraday's law using eq. (18), which after integration gives

$$\int_0^{T/2} |\varepsilon| dt = \Delta\Phi = const, \qquad (19)$$

where T and $\Delta\Phi$ are the period of the rotation and the increment of the magnetic flux at $T/2$, respectively. The other task is to determine how the angular frequency ω of the coil rotation influences the electromotive force $\varepsilon(t)$. In Fig. 31 and Fig. 32 are the students' results taken from their laboratory reports.
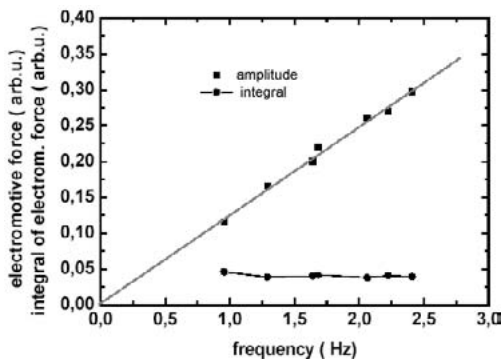
Figure 31

Dependence of the amplitude of output voltage on the frequency of the station (squares) and the integral (circles)

$$\int_0^{T/2} |\varepsilon| dt = \int_0^{T/2} NBS \cdot \omega \cdot \sin(\omega t) \cdot dt = 2 \cdot NBS = const$$
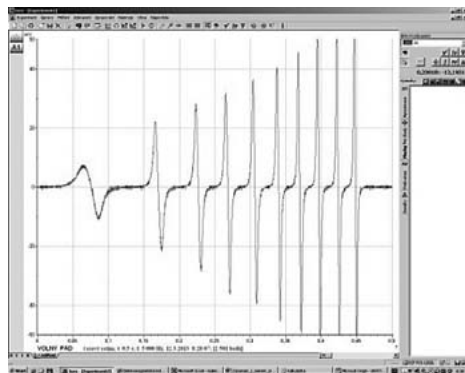
Figure 32

Time representation of the free fall of the permanent magnet by the set of 10 coils

D. *INTe-L unit Faraday's law – for the secondary school level*

Remote experiments http://kdt-20.karlov.mff.cuni.cz/ovladani_2_en.html and simulation (http://phet.colorado.edu/en/simulation/faraday on electromagnetic induction

The INTe-L teaching unit for secondary schools elucidates the phenomena related to Faraday's law. The unit uses the PhET Faraday's Electromagnetic Lab and also the remote experiments on Faraday's law of rotating coil in a magnetic field and free fall of the permanent magnet in the coil.

The INTe-L unit for secondary schools on Faraday's law starts with some warm-up questions on rigth and wrong answers dealing with the magnetic field of the permanent magnet, compass needle and Teslameter, its measurement and quantities encountered (parts 1-12). As an example, we may excerpt:

In the next figure are the permanent magnet, compass needle and Teslameter (measuring the value of the magnetic field, its *x* and *y* components and its orientation). Also in the next figure are schematically depicted magnetic induction lines of the permanent magnet.

How does the magnetic field change in the vicinity of the permanent magnet if we rotate the magnet by 180º? Sketch in the prepared frame. What will be the orientation of the compass needle?

http://phet.colorado.edu/en/simulation/magnets-and-electromagnets

1. *Sketch the magnetic field in the frame (right); follow questions 2-8 on the magnetic current in the conductor.*
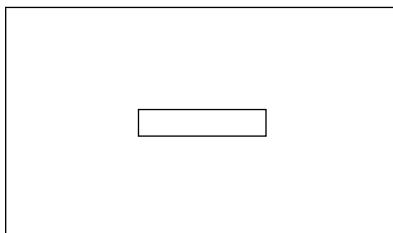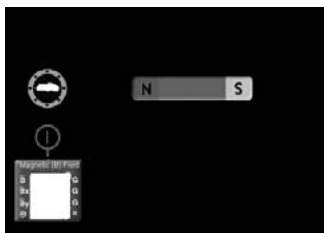
2. *Let us add to our experiment the loop made up of conducting wire, with the measuring intrument connected to its ends. Alternatively we may use the bulb. The measuring instrument shows deflections on moving the magnet. Notice the signs of the deflection. This phenomenon is called electromagnetic induction, which creates the voltage in the loop with changing magnetic field.*
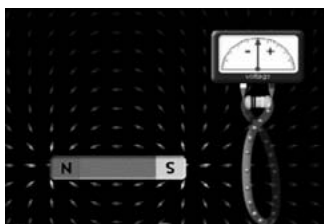
3. *Choose the correct statements:*
   a) *Along the x axis of the magnet far outside the loop and very slowly*
   b) *Along the x axis of the magnet inside the loop and very fast*
   c) *Along the y axis far outside the loop*
   d) *Along the y axis inside the loop*

Check your answers using simulation: http://phet.colorado.edu/en/ simulation/magnets-and-electromagnets
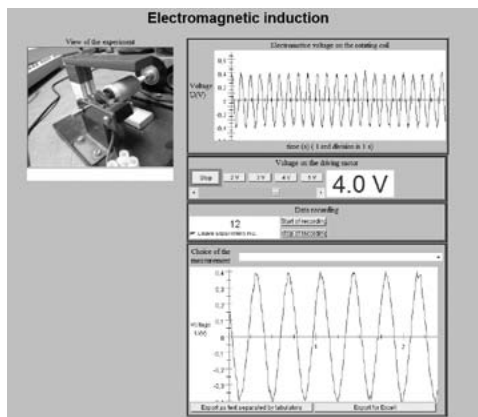
The RE Faraday's law in the rotating coil in the magnetic field http://kdt-20.karlov.mff. cuni.cz/ovladani_2_en.html, Left: life camera view; right from top to bottom: instantaneous voltage on the coil, frequency of the rotation adjustment, record of the voltage for the chosen time interval.

4. *Explain what happens when the magnet moves through the coil at different speeds and how these effect the brightness of the bulb and/or the magnitude and sign of the voltage.*

5. *Explain the difference between moving the magnet through the coil from the right side and the left side.*

6. *Explain the difference between moving the magnet through the big coil as opposed to the smaller coil.*

7. *Explain the difference between moving the magnet through the coil with different number of loops.*

8. *With the help of the remote experiment (*http://kdt-20.karlov.mff. cuni.cz/ovladani_2_en.html)*, where the coil rotates in the magnetic field, discuss the influence of the frequency of the rotation on the amplitude of the measured voltage.*

9. *Discuss the applications of Faraday's law in technology and science.*

5. Students' opinions on remote experimentation and their results

In the framework of the INTe-L building, several projects of empirical pedagogical research have been undertaken. The results and the main outcomes will be published elsewhere [38].

A. *Students opinion*

Here we publish, without any corrections, only those parts where students express their opinion on the individual experiments mentioned in this work that may be interesting for the reader. In addition, the graphical outputs are sometimes of inferior quality, but may be instructive.

A.1 ENERGY TRANSFER IN DC CIRCUITS

– I was taken aback by the bulk of information I can get from such a simple experiment. Also, the role of experimental errors and deviations is quite nicely visible as well as the variable sensitivity of the experiment to them.

– With this work, I have deepened my knowledge on this part of physics and tried to work with the measured data from a real experiment.

A.2 ENERGY TRANSFER IN RLC CIRCUITS

- This experiment helps to transfer theoretical knowledge to practical skills irrespective of the fact that it is a remote experiment. The "remoteness" sometimes causes some trouble with the assignment, as in hands-on laboratories the instructor is always present ready to explain any misconceptions. But, I want to stress the advantages outweigh the disadvantages, because the other alternative would be to have no experiments at all.
- The remote experiment I worked on is a high quality tool for understanding the subject matter in question.
- For the remote experiment execution, it was necessary to understand the physical basis of the observed phenomena in RLC circuits (resonance, changing amplitudes, phase shift, etc.) and the mastering of the mathematical background was also absolutely necessary. A very great acquisition was the use of modern ICT for experimentation and signal capturing, which are a great help and make it easier to understand the phenomena in RLC circuits.

A.3 FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

- Thanks to these remote experiments, I deepened my knowledge on this topic and, for the first time, I tried the work out with the real data from real experiments.
- Working on the experiment, I deepened my knowledge from measurements, data processing and their evaluation. I also had to express my reflection processes in written form and acquaint myself with the modern methods of teaching by ICT.

B. *Students graphical results*

Let us present some typical examples from data processing and graphical presentations taken from students' written reports. The students were given a free hand in the choice of graphical programs and data processing. The layout and quality of the examples were not corrected in any way, so the quality and layout presented here may vary accordingly.

B.1 Energy Transfer in DC Circuits

The aim of the experiment was to determine energy transfer from the chemical source of the electrochemical battery to the resistive load, more specifically, the power transferred to load R and to the internal resistance of the battery R_i and also the efficiency of the process (theoretically in Fig. 33a and experimental results in Fig. 33b), and to experimentally determine the conditions for power matching. As a by-product, the students had to determine the electromotive voltage ε and the internal resistance R_i of the electrochemical battery.

a)   b)
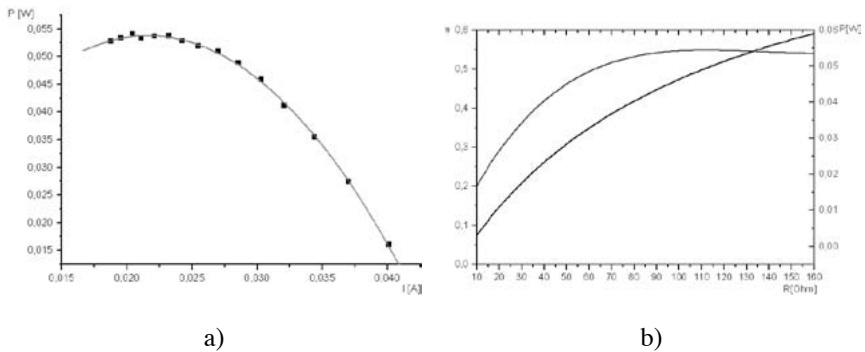
Figure 33

Examples of students' reports on the experiment, "Energy transfer in DC circuit": dependence of the power transferred to the resistive load P on the resistance of the load R (a), the same as in (a) and dependence of this efficiency η on the load resistance R (b)

Energy Transfer in RLC Circuits

The main goal and assignment was to become acquainted with the current amplitude $I_o(f)$ (Fig. 34a) and phase shift frequency $\phi(f)$ (Fig. 34b) characteristics of the RLC circuit a) theory-left; b) experiments-right and realize their meaning in applications.

Faraday's Law

The gist of the experiment is the rotating coil in the homogeneous magnetic field. The aim of the assignment was to check the validity of

Faraday's law, proved by the constant maximum increment of the magnetic flux $\Delta\Phi_{max}$, irrespective of the frequency of rotation. The student had to numerically integrate the measured electromotive force signal (Fig. 35) and to determine from the data the frequency (period) of the rotation for every driving motor voltage coil.
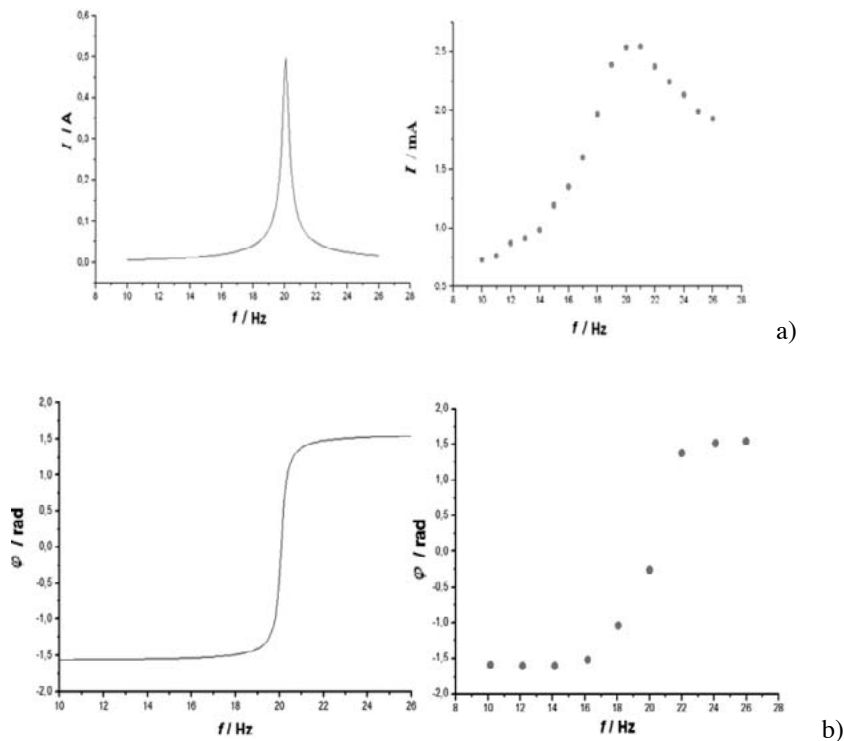
Figure 34

Examples of students' reports on the experiment, "Energy transfer in RLC circuits": Current amplitude I_o dependence on frequency f (left theoretical, right experimental dependence) (a); Phase ϕ dependence on frequency f (left theoretical, right experimental dependence) (b)
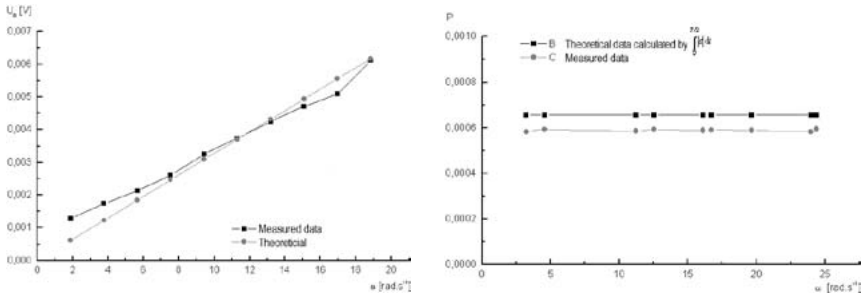
Definite integral:

$$\int_0^{\frac{2.215}{2}} 0.00929233 \sin(2.835\,t)\,dt = 0.00655543$$

Visual representation of the integral:
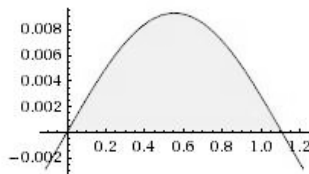
Figure 35

Examples of students' reports on the experiment, "Faraday's law of electromagnetic induction"; example of dependence of angular frequency of rotation on the voltage on driving motor (a), the electromotive voltage ε on the angular frequency ω (b), and example of experimental data evaluation (c).

$$\int_0^{t_{max}} |\varepsilon|\,dt = const.$$

6. Conclusion

Our ongoing activities in the computer-based laboratory system, employing software and hardware system ISES exploitation [21], remote e-laboratories building using ISES [38], together with the stimulating activities on transformation of physics education elsewhere [20], [27], gave rise to our incentives to devise and suggest the strategy of INTe-L education that may positively influence the teaching of physics.

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

– suitable organizational structure, based on his/her prior thinking and experience;
– it reduces the cognitive load by supporting the individual comprehension processes, offering manifold access to knowledge and being individually adaptive; and it positively addresses the students' and public beliefs about physics education and the importance of physics for society.

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

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Section 3

Inspiring Education with Remote Experiments

Creativity@School: mobile learning environments involving remote labs and E-Portfolios. A conceptual framework to foster the inquiring mind in secondary STEM education

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> "*Creativity is a game of making and testing hypotheses, taking them as far as they can be taken, then watching them crumble and wondering why*" [1].

1. **Introduction**

"The science laboratory has been considered one of the main vehicles for enhancing science learning not only as a means of demonstration but also as the heart of the science learning process. Using inquiry provides students with the opportunity to engage in the process of investigation" [2]. In addition to promoting inquiry, the science laboratory can help students to acquire higher-order cognitive skills such as critical thinking, applying, synthesizing, decision making, and creativity [3]. Fostering and encouraging creative thinking while learning may not only breathe life into what is learned but can also deepen students' understanding and creative self-efficacy [4]. To that end, laboratory learning should be based on the constructivist learning

approach in general and inquiry in particular [2]. This is because students need to come up with their own unique examples, uses and applications to develop an understanding of what they are learning: "formal education could benefit from the emphasis on personal involvement with ideas, open-style learning environments, and broad diversity among collaborating learners" [5].

Moreover, to support personal involvement and creative thinking, 'writing' can be an efficient means for reflecting, clarifying and systematizing ideas as well as ultimately for constructing understanding. Laboratory reports in particular are an integral part of science courses [6]. In this respect, innovative ICTs can provide novel opportunities to support a student's personal learning process documentation and to develop science writing competencies involving learner-generated multimedia content of laboratory experiences and field work.

Three current trends in ICT-based learning technology development are clearly recognizable at the current time to support creative STEM education: remote labs (1), personal learning environments (2), and portable devices (3):

– The experience of remote labs and tele-operated experimentation [7], [8] can be delivered to the learner by technically and didactically integrating the labs into collaborative learning systems like monolithic learning and content management systems (LCMS), or cloud-based personal learning environments (PLE).

– PLEs are "educational technology which can respond to the way people are using technology for learning and which allows them to shape their own learning spaces themselves, to form and join communities and to create, consume, remix, and share material" [4]. PLEs provide more responsibility and more independence for learners. They "imply redrawing the balance between institutional learning and learning in the wider world" [9].

– Personal or mobile devices are perhaps the most rapidly growing category of technology for informal learning environments. The increasing diffusion of portable devices such as tablet PCs, Personal Digital Assistants (PDAs) and mobile phones offer an increasingly valuable potential to support new ways of self-directed, informal and creative learning anytime and anywhere [10].

This raises three essential questions in this context:

1. How can creative cognitive processes foster and enhance science and technology education in general and how can students get the chance to conduct creative experimentation in the mode of learner-driven inquiry in particular?
2. How can students document their respective learning processes on the basis of their self-generated multimedia content and creatively write their laboratory reports and exams on the one hand, and how can teachers guide the student through these processes on the other hand?
3. How can this be fostered by the assistance of personal mobile learning environments on the basis of portable devices and remote labs?

The proposed solution in this chapter is a personal learning environment based on mobile technology that can integrate remote labs and an e-portfolio system to facilitate and nurture creative science and technology learning.

The presented contribution is based on the achievements of the recently completed *PeTEX–Platform for E-Learning and Telemetric Experimentation* project [11]. The aim of PeTEX was to design and establish a prototypical E-learning platform for mechanical engineering education, training [12], [13] and workplace learning [14]. The system development integrated remote labs and socio-technical requirements so as to open new dimensions of knowledge acquisition, particularly where experiments are the core elements of learning [15]. The proposed conceptual framework for secondary STEM education, which could also be implemented in the *OLAREX* context, enhances PeTEX to a mobile learning environment by integrating e-portfolio software. It extends didactical possibilities by adopting a creative learning approach [16]. This work is a subtask of the follow-up project *ELLI–Excellent Teaching and Learning in Engineering Education* [17], which will be funded funded by the German Ministry of Research and Education until 2016.

2. The inquiry laboratory in STEM education

Understanding learning from a constructivist viewpoint requires a focus on the creativity of learning. Learners transform new experiences

into personal knowledge by decomposing relevant bits of existing actions and understanding while constructing connections with novel concepts and new ways of resolving tasks. "According to constructivism, a lab inquiry engages students actively in processes of constructing knowledge, integrating it with existing knowledge, and applying knowledge; such processes bring about gradual knowledge revisions and conceptual changes" [18].

Research on the effects of laboratory activities outlines that involving students in authentic inquiry helps them to:

– construct their own understanding of science concepts [19]
– construct knowledge schemes and solve problems [20], [21]
– practice science as scientists [22]
– nurture positive attitudes towards science [23]
– evolve critical thinking and decision-making skills [24], and
– creatively develop their own research questions [25],[26].

"Unfortunately, science laboratory materials and exercises usually provided to teachers of science, K-16, are still centred on traditional methods of the past decades [27]. Ref. [28] compared traditional verification-type laboratory and the inquiry-based laboratories, concluding 'that in verification-type laboratory instruction, the teacher identifies the problem to be investigated, relates the investigation to previous work, conducts the demonstrations, and gives explicit guidelines that students have to follow'. [29] explained [the disadvantage] that in verification experiments learners quickly realize that they must somehow generate, copy, or paraphrase the knowledge claim that is desired by the teacher and thus laboratory report writing can easily become a rote activity". In contrast, in an inquiry laboratory the teacher asks students to formulate problems, to relate their investigation to previous work, to state the purpose of the investigation, to identify the problem, to predict possible results, to specify approaches and resolution procedures, and finally to perform the investigation [28].

A. *Remote and virtual labs: interactive tele-operated equipment*

Deploying remote and virtual laboratories provides a vast variety of opportunities to implement creative experimentation into secondary

STEM education following the path of inquiry learning. Many programs now incorporate remote (and/or virtual) labs into their instruction to extend the effectiveness of scarce resources and to share equipment with other institutions and locations [7], [8]. Students can be engaged in:

– blended and online learning scenarios at any time and from anywhere they have Internet access
– learning activities which can take longer than a typical class meeting time
– multi-part assignments which require students to use equipment for several short periods over the span of a week or longer
– socio-technically enhanced opportunities for student collaboration
– building up their own knowledge schemes using the tele-operated equipment provided by the remote labs.

Even risky experiments that may damage the equipment can be conducted in a completely virtual manner.

With the PeTEX project, the entire tele-operated experimental environment was made available by a customized Moodle system featuring an in-house developed Moodle extension. However, the key aspect in order to support the entire process for "active experimentation" is the integration of an appropriate level of interaction and feedback into the tele-operated experimental setup. One example in the context of manufacturing technology, more precisely forming technology, is the use of such a special lab concept for material characterization [30]. The complete experimental setup (Fig. 1) has been transformed to a new level of interaction by using innovative engineering designs, modern automation concepts, measurement technology and robotics, as shown in Fig. 2.

All aspects were connected by developing a clear, usable and interactive real-time feedback user interface of the running experiment. Fig. 3 shows the main screen of the developed graphical user interface for the uniaxial tensile test (for a detailed description see [7], [12] and [30]). With this remote lab set-up, students have the unique chance to tackle practical experimentation methods and are encouraged to develop their own scientific understanding and reasoning on the basis of their own individual and collective curiosity and creativity.

Figure 1

Picture of the tensile testing machine taken by the on-site camera.
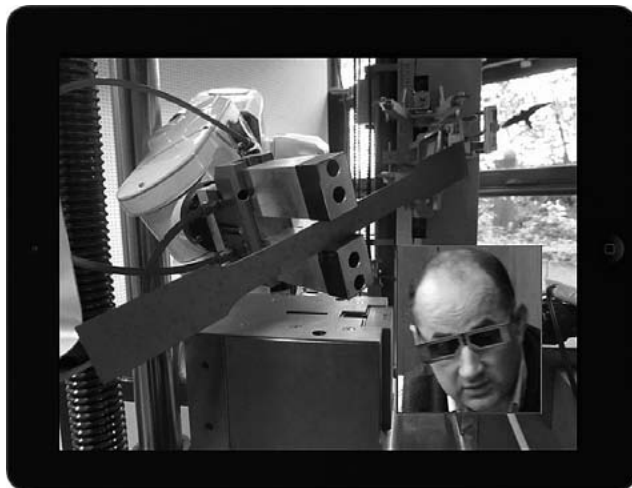
Figure 2

Local site robot positioning a specimen. The small screen is an image from the
remote site taken by a tablet PC, showing an expert in the field of online
engineering and experimentation concentrating on remotely investigating
anomalies on the surface of the specimen with special 3D goggle glasses.
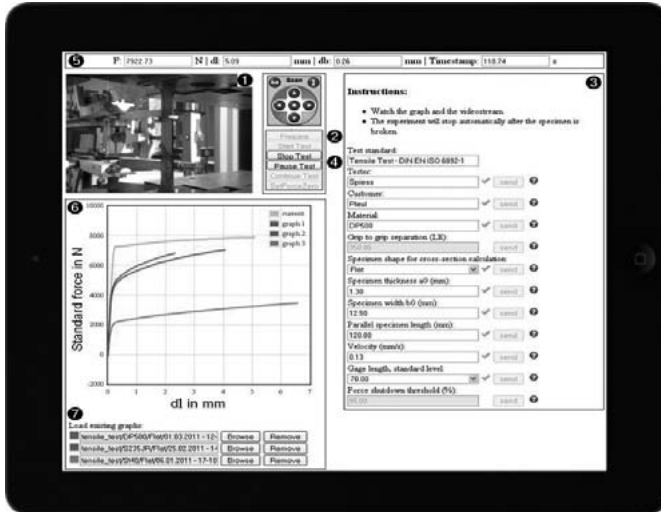
Figure 3

Interface of the tele-operated experiment. Using the live camera stream (1), users can investigate the surrounding test apparatus, e.g. sensors or clamping devices. The experiment is prepared (2) by using the integrated 6-axis robot to select and check an appropriate specimen. Relevant test parameters (3) can be freely set to configure the experiment. After the initialization of the test (4), the robot positions the specimen in the fully automatic clamping device. During the test, a high level of interaction is provided for the user by manipulating the camera view or pausing and continuing the test, causing specific material responses. This phenomenon is plotted in the real time diagram (6) and can also be inferred from the real time test data in the header bar (5). By using the data base (7) and the graph, comparisons with prior test data can be made (6). Once the experiment is over, learners are provided with data packages including all the results for further analysis and investigation.

3. Mobile personal learning environments and E-portfolios

Gay in [6] states that an approach driven by a personal and mobile learning environment "…does not only provide personal spaces, which belong to and are controlled by the user, but also requires a social context by offering means to connect with other personal spaces for effective knowledge sharing and collaborative knowledge creation".

As the name might suggest, E-portfolios, as one application of personal learning environments, are based on the broad conception of portfolios. The conventional portfolio enables learners to collect, pool and organize different kinds of documents within a folder in order to reflect their respective learning processes, as well as to edit and to present them. E-portfolios support the same processes but are based on ICT, are accessible online and provide a collection of different varieties of digital data and multimedia as well as content like texts, tables, photos, videos and audio. E-Portfolio-based PLE software, e.g., Mahara, can conveniently be combined with an LCMS based on Moodle. The integrating application Mahoodle combines the properties and functions of the teacher-led LCMS Moodle and the learner-led e-portfolio Mahara with a PLE which can be deployed as "a facility for an individual [or a group of individuals] to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences" [31].

In addition, portable devices whose unique achievements include accessibility, immediacy and users' mobility open up an extensive variety of novel occasions for creative inquiry learning across locations and time. Since students are always on the move and changing in and out of interaction with technology, periods of open time can be utilized for learning and working with e-portfolio software and the related laboratory equipment. This can be initiated virtually anywhere [32], [33].

4. **Creativity and teaching**

[34] states that someone is being creative if they come up with something new and genuine like a novel explanation: "The claim we want to make is that the creativity embodied in coming up with a new explanation is at once the essence of what it means to think, and the heart of what we mean by understanding".

Based on a teacher survey, [35] delivered a definition of creativity in the context of education, as follows:

– When a student comes up with an idea that is new to the student, then the idea is creative.
– Good creative ideas are better than bad creative ideas, but both are creative.

– Thinking "outside of the box" is adequate even if it comes from "out of the field".

– At some point, creative ideas should be appropriate to the task at hand or some redefinition of that task.

From the perspective of problem solving, which is essential in science and technology contexts, creativity can be interpreted as interplay between divergent and convergent thinking: while divergent thinking emphasizes on ideation, the uncensored and undistorted production of several responses to a specific task, convergent thinking aims at selecting and evaluating the viable ideas as solutions, the process of arriving at one or more right answers to solve the problem [36].

According to [35], teachers find value in most student ideas and often find great value in things that do not work. A 'good' bad idea is often rich in interpretive and ultimately instructional potential. A bad idea is one step further along the creative path than no idea, and good ideas will follow the bad ones. The moments when students' ideas "… go astray are often the most informative about how students are thinking about the problem or content under consideration. They are windows to the thinking processes of the students" [35]. Moreover, the application of mobile devices can boost creative thinking processes because new ideas mainly come spontaneously. Having the mobile device handy allows the user to at least make a note of an idea or even record it, as well as storing observed artefacts and activities and working on them at a later time [37].

A. *Learning objectives to foster creativity in secondary STEM education*

A model of six facets for fostering creativity in the context of education for analyzing, defining and stimulating new learning objectives and learning activities is given. The model is delivered by [38-41]. These six facets are:

1. Developing self-reflective learning skills: Learners break out of their receptive habits and start to question any information given by the teacher. An internal dialogue takes place and knowledge becomes "constructed" rather than "adopted".

2. Developing independent learning skills: Teachers stop determining the way students learn. Instead, students start to search for relevant

literature on their own, for example, to make their own decisions about structuring a text or even to find their own research questions and to choose adequate methods for answering them.

3. Enhancing curiosity and motivation: This aspect is related to all measures that contribute to increased motivation, for instance, linking a theoretical question to a practical example or presenting.

4. Learning by doing: Students learn by creating a kind of "product". Depending on the discipline, this might be a presentation, an interview, a questionnaire, a machine, a website, a computer program or similar. Students act like "real" researchers.

5. Evolving multi-perspective thinking: Learners overcome thinking within the limits of their respective disciplines or prejudiced thinking. Along with that, they automatically learn to consider an issue from different points of view and to use thinking methods which prevent their brains from being "structurally lazy" [42].

6. Reaching for original ideas: Learners aim to obtain new, original ideas and prepare themselves to be as ready-to-receive as possible. Although acquiring original ideas cannot be forced, the reception of original ideas can be fostered by applying appropriate creative techniques and by creating a suitable environment (allowing students to make mistakes and to express unconventional ideas without being laughed at or rejected).

5. **Creative learning with E-Portfolios and tele-operated experiments**

A commonly expressed challenge in association with open learning concepts is that a teacher is in need of a sophisticated concept in order to document and evaluate the learners' behavior as well as achievements throughout the learning processes taking place in the laboratory. Obviously, such a concept requires different approaches for the instructor to accompany the learner along the learning process and, above all, to evaluate the achieved learning outcomes. As mentioned above, the e-portfolio is a frequently discussed software solution for open learning contexts [43] which has been methodologically well established by its predecessor without the leading vowel: "e-portfolios are hardly a new idea in the fast developing field of Technology Enhanced Learning" [44].

By creating and designing personal portfolios like a multimedia field diary, learners can document their own learning and research processes [45], [46]. They get the chance to:

– arrange all data and information they would like to collect or share with others in different orders
– present experiments and their results or show photos from the test set-up
– write notes and reflections on their experiments during their research-based learning processes
– explain their research results and thoughts to themselves and others
– collect ideas in creative moments, and to organize and improve them whenever needed
– support collaboration by allowing other learners and teachers to have access to their e-portfolios
– prepare, write and revise the lab report as a living document based on their learner-generated multimedia content.

This reflection on learning processes and outcomes is an important aspect required/needed to foster the students' personal creative learning cycles [47]. Especially for learners, the e-portfolio as a personal learning documentation and field diary can always provide orientation and a checkpoint in topics of their own inquiry [48], [49].

In the same way, teachers have the option to evaluate the actions of learners by observing/considering and reviewing their students' e-portfolios. Since other selectable persons or groups are able to view the collection in the portfolio, it can be stated that the e-portfolio is not only a versatile instrument for both individual learning documentation and learning-related reflection processes, but also an especially valuable tool for collaborative communication.

In the following chapters, different task-based scaffolding scenarios will be presented in order to explain how personal learning environments featuring the combination of remote labs, e-portfolios and mobile devices can enrich secondary STEM education and formal classroom activities. These scenarios differ mainly in terms of teacher-led or self-directed individual and collaborative learning processes. The scenarios are based and premised on the model of the six facets for faceting creativity, as presented above.

A. *Facet 1 - Developing self-reflective learning skills: Evolving critical thinking by harnessing technological pitfalls*

One severe and often misleading disadvantage for users of remote labs or simulations is the option to conduct experiments which might be harmful or impossible to perform under real circumstances. In order to raise critical awareness of this technological pitfall, a misleading environment can be harnessed to make students familiar with a critical approach to information as well as invalid use of ICT tools. In order to achieve this goal, teachers can assign tasks to their students which are impossible to solve, or can provide false information that leads to seemingly correct but erroneous results of the experiments. In both cases, the students will be irritated while performing the experiment and they will be challenged to find the cause.

A common teaching topic in secondary STEM education is the area of digital process control. In order to foster self-reflective learning, teachers could ask their students to develop a set of traffic lights for a strongly frequented road intersection. The simulation system MSM PLC3D offers an interface for the connection of a programming language and a simulation so it can be used for simulating the traffic lights. In order to enable a critical attitude towards given information, teachers can provide students with a faulty programming code so that all cars might have a green light simultaneously (or, to spice it up, cars and pedestrians have green lights at the same time). Simulated accidents would be the result and students would have to verify the given information as well as identify the mistake and reprogram the system. The achieved learning outcome would be (besides the computer control topic) that students mistrust and reflect on given information rather than simply receiving it, as they can experience the consequences of applying misleading information without putting it into question.

B. *Facet 2 - Developing independent learning skills: Improving self-reliance and self-confidence towards technical issues*

Remote experiments combined with PLEs make it possible to let students learn more independently. They enable them to search for information, to plan and to conduct experiments as well as make decisions

on their own, facilitating the 'flip from teaching to learning'. Photovoltaics are another typical secondary STEM topic used in order to illustrate the feasibility of conducting task-based learning scenarios featuring the combination of remote labs, e-portfolios and mobile devices. Instead of simply giving the students information about solar power, teachers could ask them a relatively open question, for instance: "What is needed to charge an iPhone by solar power?" The information needed to accomplish this task is available on the Internet; furthermore, students can access remote labs for solar electricity (e.g. TU Berlin University has established a remote lab for solar cells [50]) and perform related experiments on the influence of different light sources on power output in order to provide adequate answers for the iPhone-question. Admittedly, the open question represents a quite challenging and possibly confounding and time-consuming scenario, especially in the early stages of the problem solving process and hence is not suitable for inexperienced learners. In order to give assistance, teachers have to carefully monitor their students' learning progress. If they notice difficulties or confusion among their students, teachers will have to help them "to help themselves" without providing completed solutions. For this purpose, PLEs are valuable tools that enable teachers to monitor their students' learning steps and provide feedback to them, while students on the system's other end can ask for help at anytime. As a reward for using a learning scenario, students not only incorporate a wide range of aspects about solar electricity but will also learn to plan a small research project, as well as putting it into practice and feeling responsible for it and their respective learning success. In the long run, performing small learning tasks on their own will improve their self-reliance and self-confidence towards technical issues.

C. *Facet 3 - Tackling curiosity and motivation by intertwining technical issues with students' environmental experiences*

Generally speaking, learning with experiments (remote or not) and real-world questions are a suitable combination to support students' motivation to learn, compared to sitting in a classroom and being restricted to receiving information presented by a teacher without active multi-directional participation. Remote labs have several advantages regarding students' creativity: they are readily available throughout the

day, so students can carry out experiments whenever they have a good idea and therefore do not have to wait for the next STEM lesson to test their respective ideas. Besides, they do not have to bother to ask the teacher for permission to perform an experiment. They can conduct it whenever they wish and, if they own a mobile device, wherever they are.

Nevertheless, the question of rendering subject matter more interesting for students in order to tackle their curiosity and motivation is always worth asking. A well-known approach towards increasing students' motivation is to utilize practical questions and tasks. Therefore, combining practical issues taken directly from the students' daily environment as well as remote experiments or simulations might be the silver bullet of situated experimental learning. For example, one thing which almost any student has done in her or his life without using higher science is that of making a paper plane. A possible task in secondary STEM education would be to develop the most effective paper plane as part of a small competition or –in technical terms– to experience the correlation between drag and shape. Students could be asked to use a wind tunnel simulation in order to test different wing shapes while creating their paper plane. By doing so, they should parenthetically be enabled to determine the drag coefficient and could use the simulation to try several varieties of their paper plane, in order to increase its range by reducing its drag. Finally, they could build the real paper plane based on their wind tunnel experiments and hold the competition by measuring the respective range of each plane under similar conditions. All flight tests can be recorded with the camera inside the mobile device and be analyzed at a later time. The inventors of the most effective paper plane (is it really the one with the lowest c_d value?) would receive a small prize. This is just one example of how to combine technical issues with students' environmental experiences.

D. *Facet 4 - Learning by doing: Designing and building functional models*

Once again, the use of (remote) experiments and simulations can basically foster students' creativity through their emphasis on learning by accomplishing a task. Since experimental learning as a means of scaffolding always features some sort of product to be created, this

learning method appears suitable in order to achieve this goal as it might also strengthen the students' awareness of their creative potential. Besides, exposing the learning outcome to a larger interest and external assessments are valuable factors in tackling students' intrinsic motivation. For this purpose, the PLEs can be used to render the readily documented learning process accessible for externals.

Designing and building fully functional models of wind turbines is another regular STEM education issue. In order to accomplish this task, students need some knowledge of suitable materials for this purpose. Wind turbines –especially under off-shore conditions– are exposed to severe weather conditions and yet have to endure them as proof of their reliability. A conceivable learning assignment for students in this area could feature the use of remote experiments with an emphasis on material properties. Students could be asked to develop and present a model of a wind turbine which simultaneously incorporates the particularly contradictive attributes of resilience as well as energy and economic effectiveness (altogether with the performed experiments) in their PLE. In order to make it a "real" product and to release the didactic scaffolding, authentic engineers from a wind turbine company could be asked to have a look at the PLEs and to provide brief feedback. To conclude the project, it would be a great idea –in order to raise intrinsic motivation– to visit the wind turbine company together with students and to have them talking with engineers who deal with the same issues. Of course, wind turbines are just one example. The teacher's key challenge for this scenario is to find a company whose representatives could function as external role models in order to focus students on the final outcome and to strengthen the product idea in STEM education.

To summarize, this task-based scenario resembles a case study but enriches it with authentic professional role models (the cooperating engineers) as well as the remote or simulated material sciences laboratory as a means of learning enhancement for relevant subject matter.

E. *Facet 5 - Evolving multi-perspective thinking: Overcoming cognitive barriers*

This scenario can foster students' ability to think about their questions from different perspectives: imagining a student who had performed an

experiment assigned to him by the teacher, he/ she contingently does not know why the experiment did not show the expected results or does not know how to interpret them correctly. He asks himself why the experiment did not work according to plan but cannot find a satisfactory answer. While writing his e-portfolio as documentation for the teacher's evaluation, he could start the "creative-help app.", a *de facto* wizard application within the PeTEX LCMS intended to help him develop different perspectives on the same problem:

- The student is asked to do a (mental) headstand following the question: "What else could I do to get the wrong results from experimenting?"
- If this should not suffice, he will be asked to describe his experiential design and assumptions in a way that a ten-year-old could understand it.
- If those methods, which are fairly close to the problem, still cannot help him, the "creative-help app." will suggest a force-fit technique by showing a picture that does not have anything in common with a problem (for example, a lady beetle or a daisy chain for younger pupils, a choice selection of wine bottles for an older student who wishes to feel like experienced scholars do) and asking the student to find relationships between the picture and his experiment.

This set of methods can help students to leave the well-trodden paths and forces them to look at their problem from completely different perspectives. This often results in unconventional or provocative ideas, but rethinking the obviously unsuitable solutions sometimes leads to the one really good idea, which would not have appeared without making the detour.

F. *Facet 6 - Reaching for original ideas: Breaking rules and posing one's own questions*

The permission for "breaking all rules and posing one's own questions" is the supreme discipline in creativity education. There are several options available to make for learner-led inquiry, investigation, discovery and reasoning. One fictional but already possible case in the creative STEM classroom of the future, inspired by reading the chapter "Earth" in [51], is presented as follows:

Imagine that the student "Marty McFly" [30], who had gathered a lot of experience in learning with remote labs over time, had almost completely finished his course and had enrolled in the final stage of his STEM program: the "Breaking all Rules and Posing one's Own Questions" course. To formulate his own research question, McFly had evaluated his e-portfolio, including all materials, comments, notes, unanswered questions and interesting ideas he had collected and assembled over time. Now, what should he do with it? What valuable inquiry could he condense from all that data? He started incubating.

While McFly was watching a video in his e-portfolio of the oxyhydrogen test from the last chemistry class and manipulating the sound of the bang over and over again with the mixer console of his laptop, he suddenly got an idea: Marty McFly had been interested in 'sustainable engineering' and 'circular economy' for quite a long time and he was still very impressed by a TV documentary he had downloaded into his e-portfolio on uncontrolled natural biomass/gas emission and their negative effects on global warming. Biomass and biogas as unimpeded by-products of cattle farming would become more and more critical for the chemical composition of the atmosphere and also proved capable of accelerating the greenhouse effect. In order to reduce the production and consumption of meat ("eating less steaks and burgers") by causing a reduction in unimpeded methane emission, a change in the attitude and eating habits of young consumers would be indispensable to take the tiller, considered Marty. This debate could be initiated and reinforced among the "youngsters" in school by means of experiential laboratory learning to understand the basic underlying chemical processes of methane production and emission. These learning processes could generate more awareness of and insight into the negative environmental consequences that increasing meat consumption in the western world would yield.

McFly decided to contact two university professors, Gus McHardy and Jeff McLaurel, since they gave lessons in the "Breaking all Rules and Posing one's Own Questions" course at Marty's school from time to time. They worked in the field of advanced online engineering and experimentation. McHardy and McLaurel preferred a radically student-centred approach and were already convinced that the creativity of youngsters may still not be too "polluted" with "formal science education and restricting administration". Their basic assumption for transformative

higher order learning was that the best way to deeply understand the epistemological core of experimentation is to not only carry out experiments but to actively design them. To this end, they challenged the creative attitude of their students by letting them develop some form of creative concepts for remote labs, regardless of what they might come up with. While creatively discovering and solving all the who, for whom, how, what, when, where, and why-problems that would emerge during such a design process, students would definitely learn and generate the most valuable competences needed to understand science and technology in a higher-order mode. As a special reward, the best proposal of each year would be put into practice as a remote experiment at Deusto Weblab in Bilbao, Spain and prospectively be distributed online to STEM courses at schools, science museums and universities all over Europe. Motivated by this chance of success, McFly elaborated the idea of a sophisticated remote lab for conveniently analyzing the unimpeded by-products of cattle farming to question its effects on the chemical composition of the atmosphere. To this end, students from all over Europe would collect cow droppings or even cow flatulence probes during class outings or special biology class field trips, simply send the probes to Weblab-Deusto and later on analyze their respective compositions, as well as methane percentages within a kind of remotely accessible fully automated experimentation cabin. Being quite convinced that this lab could really change the meat eating habits and attitudes of future mankind if all school kids were educated with it, McFly booked an online consultation with Prof. McHardy and Prof. McLaurel to present his idea of a "Cow Emission Learning Lab (CELL)" for Weblab-Deusto.

While Prof. McHardy was proudly emphasizing that Prof. McLaurel could transform nearly every idea for an experiment into a real remote lab, McLaurel looked only cautiously optimistic (see Fig. 4). His first appraisal was that this "valuable approach" would be "far beyond the financial framework" and would need "the permission of his head of department or even the rector of his university". Finally, the paper work involved in receiving such an approval would be time-consuming and bristled with a lot of unexpected difficulties and obstacles. He had experienced that once and had decided to never face it again. But he recommended McFly to search for books in the library with topics like "ingeniously failed", or "fates of great explorers and inventors". Reading this would explain a lot.

Figure 4

Marty McFly (small window on the tablet device) presented a video of a biogas inflaming experiment done in his little home laboratory to the two professors McHardy and McLaurel (from left to right on Marty's mobile phone screen). While Prof. McHardy (l.) emphazised that Prof. McLaurel (r.) could transform nearly every idea for an experiment into a real remote lab, McLaurel looked only cautiously optimistic. He stressed that this "very creative approach" for a Europe-wide analysis of unimpeded byproducts of cattle farming in a cow emission learning lab would certainly need a lot of cost-extensive novel lab equipment, logistics and secure storage capacity for all the probes. Plus, insufficient odor protection or uncontrolled ignition of leaking gases could cause major inconveniences for those who have to stay on site. Marty showed an annoyed facial expression, but this was not caused by the rejection of his idea but from a faulty operation: instead of starting another video of the biogas inflaming experiment to persuade McLaurel, he tapped the wrong icon on his touch screen and the pad camera immediately took a picture of him while staring directly into the flashlight. Moreover, since he was never interested in all the privacy settings, the pad automatically uploaded the picture to the digital public space of his course, amusing his classmates rather a lot.

McFly, always optimistic, did not interpret this answer as a complete rejection of his idea but as valuable feedback for improving his concept according to the depicted hurdles and constraints. Writing down all his

ideas, reflections, notes, comments after the conversation into his portfolio, he suddenly came to the conclusion that being creative by *really* "Breaking all Rules and Posing one's Own Questions" may also create a lot of *real* resistance from teachers, superiors, institutions and others who still need to be involved and convinced to transform an idea into innovation. He started incubating again on his lab… "What about the production and consumption of cow's milk e.g. in comparison to soya milk?"

6. **Conclusion**

In this chapter we explained how the integration of remote labs and e-portfolios into mobile personal learning environments can offer novel opportunities to foster students' creative learning in STEM education. Generally speaking, personal learning environments and remote experiments are adequate opportunities to perform, document and share experiments whenever students wish to do so and, if using mobile devices, wherever they please. Moreover, allowing students to learn in this way already incorporates fostering their creativity with respect to the six facets of creativity in education. Each (remote) experiment is some sort of a product (facet 4, learning by doing), is supposed to increase students' curiosity and motivation (facet 3, compared to just sitting in a classroom and listening to the teacher) and fosters their self-reliance (facet 2, by doing something on their own). However, we have shown that there are still a few ways to promote creativity even better with carefully designed task-based learning scenarios which focus on students' self-reflective learning, their life world, practical issues, external ("real world") reviewers, their independence and even self-responsibility for the learning process, as well as their ability to use multi-perspective thinking. Some examples were given to show how easily these goals can be achieved by means of remote experiments or simulations, combined with mobile devices and a personal learning environment as well as scaffolding scenarios. This is one essential way for students to reach high level learning outcomes and thereby develop the basis of fundamental competences for their future personal, school, academic or professional life, as well as tackling attitudes like curiosity, creative self-efficacy, agency and responsibility. If students are allowed to evolve their own research questions, choose suitable experimentation designs and finally

perform the experiment, they will be able to develop a kind of "spirit of inquiry and research" [52]. This spirit is one important premise for developing original ideas.

Ultimately, the example for facet 6 (reaching for original ideas) is not as fictional as it seems. A Web inquiry in a multi-perspective mode (facet 5) during a STEM class on topics like "cow emission" and "cow emission labs for kids" would present a lot of apparently uncommon examples of what is already going on in informal environmental STEM education. Only the presented synthesis within a remote lab cannot be carried out as yet.

> "*The creative attitude is the desire to go against the mainstream. But such desires are stopped by parents, in school, at work–nearly everywhere. The creative attitude entails posing one's own questions, not answering the questions of others, and it is not always easy to get away with such a point of view*" [1].

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Mobile remote experimentation applied to education

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1. Introduction

We live in an "information and knowledge society" that is growing continuously but, paradoxically, we see a persistent and increasing lack of interest in scientific and technological professions among the youth of today. This is reflected in the number of graduates from university courses in the fields of science, technology and the various engineering specialties. According to the Brazilian National Confederation of Industry (CNI–Confederação Nacional da Indústria), young people are generally not interested in engineering, and the main reason is the deficiencies of the Brazilian educational system, which does not offer adequate concepts of mathematics and physics during basic and middle education, leading to this deficiency preventing many young people from developing in these subjects and reaching higher education.

Engineering is the determining factor for the economic development of countries and the capacity for innovation depends on several factors, including the existence, quantity and quality of engineers and other professionals in the field of technology. It has been noted that Europe, the United States and other countries or regions have had an increasing deficit of engineers in the last few decades. This may have grave implications for the future.

The lack of interest among young people in choosing scientific careers for their professional development has been a subject of the

agendas on education and science in Ibero-American countries. At the 18th Ibero-American Summit held in El Salvador in 2008, for instance, it was peremptorily declared that it is necessary to run programs to promote the teaching of science and technology, in order to motivate young people for science from early age and ensure the training and transition of new generations of researchers, innovators and scientists in Ibero-American countries. Education Goals (Metas Educativas) for 2021 already converge with the strategies of the Ibero-American Knowledge Space (Espaço Ibero-americano de Conhecimento) and the reinforcement of research capacities in the region proposes encouraging the scientific professions. For instance, indicator 18 establishes the need to increase the percentage of youths who choose scientific or technical education at the end of their compulsory schooling, and stipulates as a goal that this proportion of students should increase by 10% by 2015, and be doubled by 2021 [9].

In Brazil the topic is recurrent in the press in general, mainly due to issues such as the discovery of the pre-salt oil and gas reserves and preparations for the country to hold the World Cup in 2014 and the Olympic Games in 2016. Data from the Census of Higher Education (Inep/MEC) show that in Brazil 38 thousand engineers graduated in 2010, a much lower figure, for instance, than its partners in the BRICS, where China had 650 thousand graduates, India 220 thousand and Russia 190 thousand. According to the Brazilian National Federation of Engineers (FNE-Federação Nacional dos Engenheiros do Brasil), by 2015 the country will need 300 thousand new professionals, which means an annual number of 60 thousand new specialists, i.e., the reality is 63% below the level required.

There are many explanations for this problem. They range from rapid economic growth, passing through the low number of Engineering course entrants and lack of interest, to dropouts from higher education courses in the fields of engineering (around 60%). Because of the low number of students entering Engineering courses, a great number of places offered by the Higher Education Institutions (HEIx) are not taken up. For this reason, it is necessary to think about the possible factors that do not motivate young people to study engineering.

When the profile of entrants into engineering careers is discussed, teachers at the Higher Education Institutions (HEIs) generally expect a student with a certain amount of prior knowledge pertaining to the subjects of their chosen profession. They should be able to transfer

knowledge to new situations, understand scientific texts, solve problems applying different strategies, carefully and independently perform calculations of basic mathematics, think and critique. However, this is not what happens. They have insufficient knowledge of mathematics, physics and chemistry from basic education, i.e., their real profile is far from appropriate for them to move seamlessly into obtaining an education in an engineering field at university.

Returning to the subject of the "information and knowledge society", we see the highly significant presence of mobile devices in people's lives, and the major changes this has brought to the lifestyles of society, particularly for young people. Because of the ubiquitousness of mobile devices and their continuous use, this technology is a common element among the young, through multiple practices that include managing and handling the technology and also collaboration. Although these are practices that potentiate the development of essential competencies in current society, they are still contained in an informal context. [7] says that "it does not make sense that in an educational system with limited technological resources one should not try the get the utmost advantage from what the young bring to classes". Therefore, it is reasonable to think about using these technologies massively employed by the young, and highly personalized in informal contexts, as they may connect informal and formal learning contexts. Thus the use of teaching-learning environments in M-learning scenarios can certainly bring youths closer to their everyday life, in this way bringing the school closer to their everyday reality [7], [13], [14].

In the following sections we shall be focusing on the presentation of the research project developed in the Laboratory of Remote Experimentation (RExLab) at the Federal University of Santa Catarina (UFSC), whose main objective is to contribute to awakening the vocational interest of Basic Education students in the engineering professions and in scientific and technological research by means of interaction with HEIs.

The project developed by RExLab and co-executed by the Maria Garcia Pessi School of Basic Education covers access to teaching contents on mobile devices, complemented by access to remote experiments in course subjects of physics in Basic Education at a public school from the municipality of Araranguá, in the state of Santa Catarina. We believe that this proposition may contribute to the current educational models, motivate and instigate the students in these subject, and possibly

help prevent students from dropping out during the first years of undergraduate engineering courses.

2. Mobile learning (M-learning)

Technological advances open doors to new forms, opportunities and challenges for the development of new methods designed to support the teaching and learning process. The development of mobile technologies and their implications and applications in the field of education, in particular, have recently appeared as a field of research focusing on a new way of using ICTs to access information via mobile devices. This approach is commonly known as Mobile Learning (M-learning), that is, learning with mobility by using mobile devices such as basic mobile telephones, tablets, PDAs, MP3 players, USB memories, electronic reading devices and Smartphones.

Mobile devices alone are not useful educational tools, and it is essential to research their pedagogical use to be able to employ them interactively and collaboratively for teaching and learning by their users. [6] mentioned that the teaching resources available through mobile devices can potentiate the context of the teaching and learning processes by creating new methods, practices and developments that take the particular technological caracteristics of these devices into account. These characteristics are evidenced through the portability of the device, potentiated by its capacity to connect for spontaneous and collaborative communications, the capacity to provide information from device to device, immediate obtention of data and information, and the multimedia resources embedded in it.

M-learning has advanced as a field of research in the last decade seeking consolidation, but opinions regarding its concept are not unanimous [2]. For authors like [17], [10], mobile technology and learning appear indissolubly united, and they perceive M-learning as the application of mobile devices for educational purposes. Other authors consider M-learning to be an evolution of B-learning by incorporating the value of the ubiquitousness of learning, ie., the possibility of accessing the contents to be learned at any time and in any place ([17], [10], [12]). And, finally, other researchers regard M-learning as a new modality of distance-learning focused on the student, based on two central aspects:

mobility and learning context. This concept associated ubiquitousness of learning with mobility, relating them to a context of teaching and learning of the students made easier by mobile devices. Authors like [13] consider that the important factor is not technology but the concept of mobility. For these authors, the terminology of the concept of M-learning has three implications: physical mobility, technological mobility and social mobility. Authors like [5] cite as advantages that M-learning:

- – Allows learning at any time and in any place.
- – Can improve didactic interaction in the synchronous and asynchronous form.
- – Potentiates student-focused learning.
- – Allows multimedia enrichment of learning.
- – Allows personalization of learning.
- – Favors communication among students and educational institutions.
- – Favors collaborative learning.

We are part of a culture and a technological society in which education cannot remain on the outside. The mobile devices are in the hands of students and teachers, and this means a saving in investment in technological equipment at teaching institutions. Thus, one must think of using mobile devices through M-learning as an opportunity to encourage the use of technology in education. However, E-learning must not be considered an end, but rather a means to facilitate learning opportunities, especially when there is physical movement, since the movement will change the context of learning.

3. **Remote experimentation**

Remote Experimentation (RE) in the teaching-learning process focuses on the idea of making real experiments available via Internet, so that students will have free access and be able to interact with real processes [5]. RE is a fairly common resource at Higher Education Institutions (HEIs), and is frequently used to complement classes given in the form of lectures in sciences, technology and engineering, since it enables students to observe dynamic phenomena that are often difficult to explain using written material. RE increases the students' motivation by developing a realistic approach towarsd solving problems because,

different from the virtual laboratories where processes are simulated, the remote experimentation laboratory enables interaction with real processes, allowing the user to analyze the practical problems of the real world [17].

The characteristics of access and handling a common laboratory are attractive and fascinating in teaching science. However, due to the insufficient number of laboratories, the usual alternatives in the school environment are virtual laboratories or simulators that only return recorded or previously calculated values and observations. This forecast of results fails to demonstrate important aspects of reality and the real application of the experiment with the other natural factors.

This dynamic of real mode interaction is a difficult substitution and fails in the concepts of theory application, at the same time as holding experiments in a laboratory generates costs, and it is difficult to find space or maintain them at public schools. On the other hand, some institutions have various applied experiments with a lot of interaction for observation and use by students in basic education, but are prevented from interaction due to the geographical distance or availability of time for visiting, ie., interesting experiments, located and hidden in laboratories and students who need this practical application of studies performed in the classroom.

Based on the idea of making real experiments available for free access by students, and so that they can interact, observe, perform their experiments and apply their knowledge, some laboratories have made their experiments available for remote access by Internet.

This resource is quite common in many Higher Education Institutions (HEIs). Lectures in sciences, technology and engineering are often complemented by remote experimentation laboratories where students can observe dynamic phenomena that are often difficult to explain with written material. Remote experimentation plants increase the students' motivation and also develop a realistic approach to problem-solving. As opposed to virtual laboratories, where all processes are simulated, the remote experimentation laboratory enables interaction with real processes, allowing the user to analyze practical, real world problems. It gives these laboratories a certain advantage compared to virtual laboratories since, according to [1], "remote laboratories allow the student to interact with real processes".

Thus, it is concluded that these laboratories are those in which the elements are real, their access is virtual and their experiences real. According to [8], we can find the following advantages in remote laboratories:

– The information is real;
– There is direct interaction with real equipment;
– There is feedback on the result of on-line experiences.
– There are no restrictions regarding time or space;
– There is an average cost for assembly, use and maintenance.

To enable easy use of these resources, RExLab seeks to implement low cost research and development solutions, prioritizing the use of open-source and open-hardware to create, manage and disseminate knowledge.

A. *Remote experiments*

These experiments are adaptations of real equipment connected with actuator circuits allowing interaction via Internet. Therefore, remote experiments are real experiences with physical elements that interact by virtual commands, which means there are no time or space restrictions. Interactions take place directly with real equipment, there is feedback from the results of the online experiences and, a very important point, at a low cost for assembly, use and maintenance [16].

The user can activate the experiences that are available remotely using the browser of the apparatus itself and with a wireless connection that has access to the Internet. The site is developed in PHP and uses JavaScript for the interface, enabling interaction with the experiments that are linked to the Web microservers with an Ethernet portal.

When interacting with the experiment via Internet, data are sent to these devices which actuate relays and these, in turn, control actuators and make the experiment work physically. In this way, the remote environment allows the controlling of different devices such as motors, circuits, sensors and security systems, while dynamic effects are observed that are often difficult to explain, but they are comprehensible in realistic approaches to solving problems.

B. *Hardware*

The hardware for the remote experiments used in the project is developed and constructed at RExLab using low cost solutions. Basically it is constructed from the Web Microservers (MSW) developed and

constructed at RExLab, sensors and actuators –depending on the purpose of the experiment– and an IP-Cam for external viewing of the experiments. Fig. 1 shows the hardware used in the experiment provided for remote access, called "electric panel", as previously mentioned. The experiment can be accessed via http://rexlab.ufsc.br.
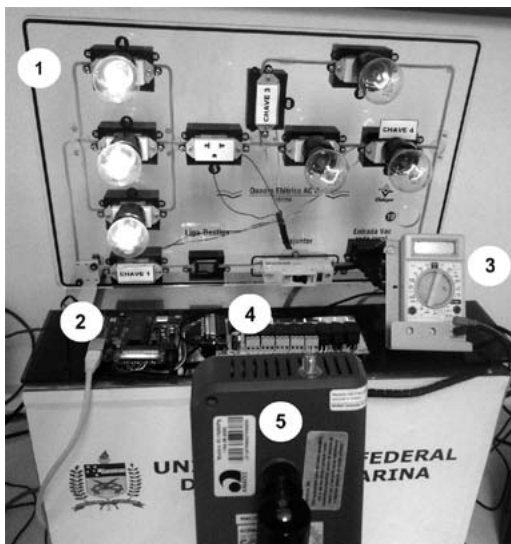
Figure 1

Hardware used in the "electric panel" experiment.

The remote experiment hardware of the "electrical panel" is made of an acrylic panel where lamps configured in parallel and mixed installation series are installed (1), an embedded Web Server (2), a multimeter to display AC voltage input in the experiment (3), a board with relays for driving the lamps (4), and an IP camera for remote viewing of the panel lamps (5).

The central device of the experiment is the MSW (Fig. 2), constructed at RExLab. It can be described as an autonomous device that can connect electric devices to an Ethernet net. It is based on a low cost microcontroller with low consumption (40mA), in-circuit programming though the SPIe interface, and support for development based on a free operational system. MSW supports protocols TCP/IP, POP3, SMTP and HTTP to communicate data. Both the TCP/IP pile and HTTP Server are of the

open source type, and allow acquiring, controlling and monitoring the devices used remotely in the experiment in a safe, efficient and economic manner, but using a standard Internet browser.
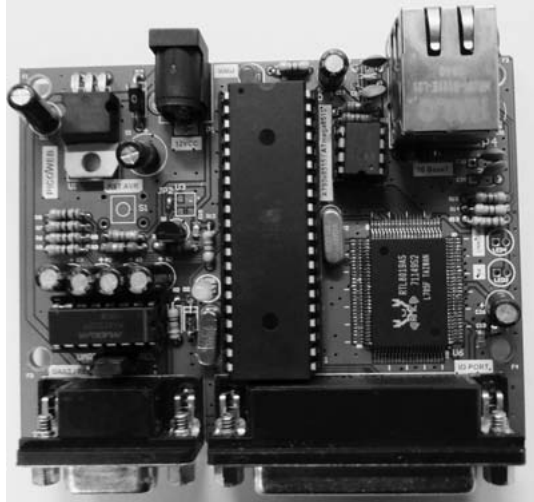
Figure 2

WEB Microserver (MSW) developed by RExLab

Software for MSW involves its firmware (starting and I/O routines stored in ROM memory) and the applications code. The firmware used comprises a simple kernel where the Ethernet controller provides support for the two lowest control layers (Link and Physical) and the microcontroller takes care of those above them (Network, Transport and Application). The Network layer provides support for the IP, ARP, BOOTP and PING protocols, the Transport layer to the UDP and TCP protocols and, finally the application layer is the HTTP Web server.

The functionality of the MSW can be easily expanded by adding applications to it that will give it the capacity to monitor and/or control devices. For this, the MSW allows using JavaScript (embedded or in HTML code, or as separate files) and Java applets, together with the HTML code, CGI routines and images. In this way, by accessing the webpage that contains these codes, the user will have access to the current status of the device controlled by the MSW or of the environment that it monitors.

The devices are observed by video streaming from an IP Camera connected directly to the network. This type of image is commonly used in image monitoring systems.

C. *Software*

The project presented uses the RExMobile application developed at RExLab for access via mobile devices (Fig. 3). The development of this application used resources of the HTML5 (Hypertext MarkupLanguage, version 5) language integrated to the CSS3 (CascadingStyleSheets, version 3), a variant language of XML (ExtensibleMarkupLanguage) that allows patterns that are light, has a good appearance and design, and is an interesting experience for the user.

These interesting HTML5 and CSS3 resources are integrated by the framework jQuery Mobile, which uses a unified system appropriate for Web applications in mobile apparatuses and the implementation of high level JavaScript which generates codes compatible with iOS, Android, Windows Phone, Symbian, BlackBerry, among other important mobile Operational Systems. In Fig. 3 it is possible to view the access to the "means of heat propagation" experiment through mobile devices using the RExMobile application [3].

Figure 3

Interface of the RExMobile application

4. **Integrating remote experimentation and mobile devices**

RE provides opportunities for an interesting study format which brings together practice in laboratories, even when the user is far from them. The experience of interaction with real experiments in remote laboratories allows a real immersion that distinguishes them from simulators or virtual laboratories that provide recorded experiences and simulated results [15].

The availability of RE in mobile device resources allows a new space for interaction, favorable for the development of an environment aimed at ubiquitous education. From a mobile device with access to Internet, the students can access experiences available in the laboratories at any time, interacting with the real equipment and looking at the concepts that are studied in the classroom. They can relate this knowledge to the observation of the experiments. Fig. 4 illustrates the architecture implemented in the project.
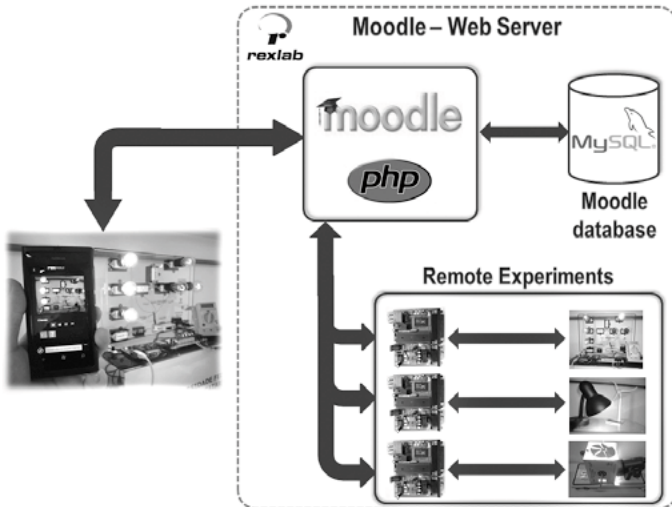

Figure 4

Architecture implemented

Remote experimentation provides the opportunity for an interesting format of study that brings together practice in laboratories even if the user is far away. This experience of interacting with real experiments in

remote laboratories allows a real immersion that distinguishes these laboratories from the simple simulators or virtual laboratories that only provide recorded experiences and simulated results [5].

The availability of these important resources of remote experimentation in mobile devices allows a new space for interaction that joins together precisely the idea of ubiquitous environments, –the immersion of the user into accessing a laboratory at any time and at any place– and using their own smartphone.

This is because, when making it possible to overcome the barrier of the classroom, one seeks a difference in relation to the simple use of virtual laboratories, which only simulate situations and do not interact with real equipment. From a mobile device with access to the Internet, the student will be able to access the experiences available in the laboratories at any time, interact with real equipment and look at the concepts that are studied in the classroom, and they will also be able to relate knowledge to observation of experiments.

By giving the students this interaction, the RExMobile application (Fig. 5) has enabled a new means of interaction for remote experiments and teachers who use this resource as an aid for their classes, especially science classes in basic education.

Figure 5

RExMobile – Access to RExLab and RExMobile

As in a real laboratory where the user is present, this model of application deals with the problem of physical limitation: the experiment can be consulted simultaneously by different users. Some alternatives, such as scheduling, queues, priority or even recording have been suggested for the remote laboratories. The limitation of time and control by queuing is a useful alternative, since it allows immediate access without the need to wait for a long time. The user has free access for as long as necessary until others enter the queue, in which, if this happens, a time period is determined until the user exits.

The idea and development of the RExMobile application was awarded second place at the Campus Mobile exhibition held by Instituto Claro [4] as one of the most innovative among more than 1,300 ideas from all over Brazil. Its use in science classes in basic education, with RexMobile, enables students to interact with the experiments through their own smartphones (Instituto Claro, 2012).

5. **Use in basic education**

The RExLab model of remote experimentation uses elements of E-learning in presential teaching to make distant physical experiments available in a classroom that does not enjoy these resources or where it is impossible for them to attend laboratory spaces.

The project, which is supported by the National Council of Scientific and Technological Development (CNPq), is being applied at Prof. Maria Garcia Pessie Elementary School and its purpose is to create an interest in engineering through more applied teaching using mobile technologies, precisely because of the widespread use of mobile devices even in schools.

One of the fundamental aspects of teaching in the field of natural sciences is the practice that the students can acquire when they handle different devices and electronic and mechanical instruments, etc. This will allow them to develop the theoretical knowledge that they have acquired. The implementation of the project is expected to:

- Increase practical activities in physics classes so that the students can access them at any time, not only when in class;
- Integrate teaching applications of practice, experimentation and work in the laboratory with teaching activities proper in the same

environment by integrating materials, simulations and access to equipment and devices;
– Contribute to strengthening technologies in teaching, research and extension in the field of project development.

About 150 2nd-year Middle school students from a school of basic education in the south of the State of Santa Catarina have been using the resources provided by the project.The students have the teaching materials used in classes at their disposal and perforrm activities such as forums, computer chats, questionnaires, lessons, etc. related to them in the virtual learning environment (VLE). Here they can also perform practical experiences remotely using computers, smartphones or tablets. In VLE there are also tasks and questionnaires available (Figs. 6, 7) where they relate the observation of the experiments to the contents studied and to the everyday work of their course subjects**.**

Figure 6

Teaching Material

Figure 7

Teaching Material

In order to optimize the use of the resources provided on the platform implemented, 80 students were enrolled in workshops and minicourses promoted by RExLab aiming at a better understanding of the usability and knowledge of the laboratory where the experiments are installed. Some students reported that they were surprised to observe through the cellular phone that they really could control the experiments and described the experience as "amazing".

Among the activities developed by the teacher in the classroom, the students performed experiments on differences in temperature, thermo-dynamics and convection, controlling and observing the experiment on heat propagation. During classes, simulators, also available in VLE, were used to observe the molecules' agitation and a sensory experience with simple materials submitted to different temperatures.

A few methodologies are being discussed and implemented so that they can be adapted to the teachers' needs for implementation. Therefore, the application must add the resources available and not simply replace the teaching method, and understand which contents and which experiments can be used [11].

A. *Remote experiments used in schools of basic education*

For practical activities in schools RExLab provides three experiments that were jointly developed with teachers and schools participating in the project. The experiments are defined in relation to specific content taught in the subjects and which are included in lesson plans for teachers. These experiments are simple applications that are introduced in the educational content highlighting their operation and what happens, as shown in the following sections.

A.1 PHOTOELECTRIC EFFECT

In this experiment (Fig. 8) the following are performed: the study of energy transformations, conversion verification of solar energy into electrical energy and mechanical energy, photovoltaic effect, checking the selectivity of the operation according to the region of the incident radiation spectrum .

On the functioning the user simply activates the experiment by pressing the "Start Experiment" button on the RExMobile application. This action triggers the lamp and the experiment will remain on for 30 seconds. When triggered, the lamp directs light to the photoelectric cell, which captures light energy and transforms it into electricity. This energy is transmitted to the top of a wind turbine, where it is transformed into mechanical energy, while lighting up reduces the turbine shut down for lack of energy. Thus, several studies can be performed through a simple experiment that involves integration between subjects like photovoltaic cells, power generation and energy conversion.
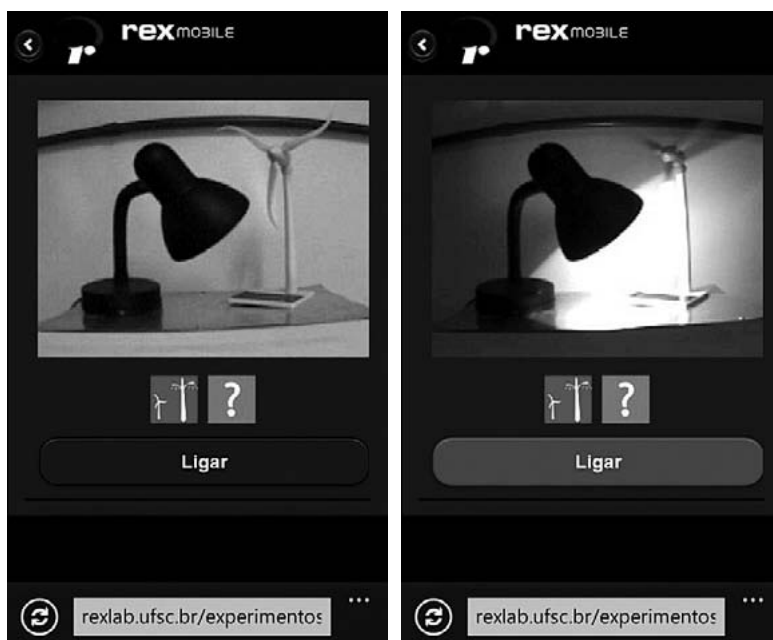
Figure 8

Photoelectric effect Experiment

B. *Electrical panel*

The way that electricity travels alters circuit properties. In this experiment the user observes the connections and properties of electrical circuits. They study topics such as voltage, current, power and influence of the activation key at strategic points. The electrical experiment diagram shown on the mobile device is presented in Fig. 9.

Being operated, the user can remotely activate four keys that are installed at strategic points in the electrical circuit of the experiment, the six provided bulbs are connected in series or parallel mode to make different circuits (Fig. 9). This is an interesting feature for use in classes involving the electricity issue. Such matters as types of circuits, the current path and how the voltage or current affects power lamps are all easily observed by light intensity. The experiment on remote access using mobile devices is shown in Fig. 10.
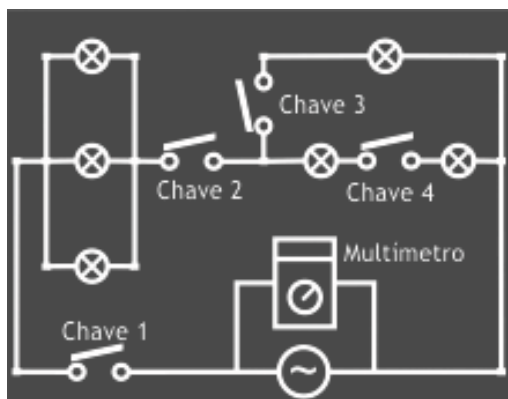
Figure 9

Wiring diagram of the experiment electrical panel

Figure 10

Experiment Electrical Panel

C. *Means of heat propagation*

In the means of heat propagation study propagation by conduction, convection and radiation, and a degree comparison of insulation between different materials are demonstrated. The experiment was implemented using a sensor that monitors the temperature inside the metal structure and a temperature adjustment is made through the mobile application. If the set temperature is higher than the current temperature, the lamp is switched on until it reaches the set value. Meanwhile, temperature rise and possibly the rotation of the propeller are observed.

The lamp acts as a heat source, transferring energy to the air around it, thus raising the temperature. This step involves heat propagation by conduction and irradiation. The pressure difference between the air layers adjacent to the propeller, which have different temperatures, cause the rotation. This last step demonstrates that the heat is propagated by convection. In the sea breeze study a similar analysis is performed on how the temperature difference between the land and sea influences the breeze. Mobile access via the experiment is shown in Fig. 11.

6. **Conclusion**

In this work we present the integration of M-learning into remote experimentation as an alternative use of mobile technologies that allow the enhancement of teaching and learning activities inside and outside the classroom. This offers mobility, connectivity and personalization. These factors in themselves promote and potentiate the obtention and generation of knowledge. The use of mobile devices in the educational context presents both technological and pedagogical challenges. However, the popularization of mobile technologies and the continuous increase in their capacity and proportional cost reduction transform M-learning into a viable alternative with a potential to extend and enrich teaching and learning processes anywhere and anytime.

The initiative presented in this document aims to provide new resources to support and enrich the teaching and learning process, trying to make use of the portability, ubiquitousness and connectivity supplied by mobile devices. The project presented focuses on the experience of integration of mobile resources and remote experimentation in basic

Figure 11

Experiment Propagation Heat

education physics courses in the public education system, for the purpose of expanding the opportunities for education, increasing the access of students and teachers to the educational content, improved quality of learning experiences and the expansion of the learning environment beyond the traditional school environment.

Considering the Brazilian and worldwide scene as regards training engineers, this project will certainly contribute towards arousing an interest in topics concerning physics in basic education students, motivating them to take up a possible professional career in this field. Furthermore, the use of mobile technologies to improve education –based on the use of experiments, simulators and the availability of teaching material that can be accessed even from outside the classroom– will allow a higher quality teaching of physics, making it possible, in future, to lower the dropout rates from the engineering courses we have become accustomed to seeing in Brazil.

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Remote laboratory for serious games deployment based on a mobile robot platform

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1. **Introduction and contextualization**

In the last few decades, technology has evolved at an ever-changing pace. With these developments, the need has also arisen for education to evolve and incorporate new contents and methodologies, but it has often found itself lagging behind. Recent studies and surveys have found that few students are interested in taking up careers in science, technology, engineering and mathematics (STEM), when compared to the current needs for professionals in these fields expressed by the industry [1]. As such, the educational community faces a pressing need to adapt to this reality and develop new curricula, platforms and resources to attract and inspire learners. It is the belief of some researchers intimately related to these fields that remote education and laboratories could present a solution to this problem [2].

Engineering education has seen Remote Laboratories grow rapidly in the past few years and becomes a true alternative to traditional experimentation and teaching methods. These remote environments seek to provide a viable substitute for or complement to on-campus laboratory exercises by connecting real physical experiments to the Internet, which means they can be accessed from anywhere in the world. In this way, students can continue working on their practical exercises from their homes or anywhere else with Internet access. Additionally, teachers do

not see their practical lessons hindered by lab material unavailability or safety issues. One could ask oneself how this is different from a simulation. Here, the answer is that Remote Laboratories, contrary to virtualization and simulation, provide users with a real experiment. In theory, this means that a Remote Lab should be no different from physically measuring the indicators of an experiment –it will actually use a physical measurement device to obtain this reading, with the only difference being that this is then transmitted to a server that then sends this information back to the client, that is, the student. Moreover, remote laboratories pave the way for the "democratization" of education, whereby any person with access to the Internet can take part in the experiments. They cross national boundaries, economic boundaries, connect universities and reduce the time constraints of users. They allow students to continue their work from outside the university campus. Remote lab federation –the sharing of these environments across institutions– allows universities and schools to access equipment that could otherwise be well beyond their budgets or their space constraints. Another advantage of this approach to practical learning is that the more educational institutions there are that standardize them and replicate them in several locations, the more users that are simultaneously supported, and therefore the better the quality of the service provided.

Separate from the technical and engineering view of education is that of the pedagogical community. Here, a significant approach to renewing educational methodologies comes in the form of *Serious Games*. Supporters of this view aim to abandon lecture-based materials in favour of interactive content that also conveys learning in a context of entertainment and fun. There is long-standing consensus among pedagogues that, if appropriately applied, games can help to improve learning [3]. A key concept here is that of *flow*, defined as a state where consciousness of space and time are reduced, and the person becomes deeply focused on the subject at hand [4]. It is believed that by creating suitable game elements to surround education, the learner can enter such a state, which has been shown to enhance performance and also better engrain understanding of the concepts learned during the activity [5], [6]. In order to generate and maintain this state, however, it is necessary to carefully and properly design the learning game, so that it presents the equilibrium of several elements. Kiili, based on an Experiential Gaming Model [7], [8], identifies three such constituents of game design, namely: storytelling, game balance and optimization of

cognitive load (Fig. 1). A story is fundamental to integrating gameplay within a larger context and can also be used to provide important factual information. In this case, it is important to properly connect the story to the actual gameplay, and not let it be a forced, artificial relation. Game balance is crucial for achieving player involvement and maintaining it throughout the game experience. In this sense, challenges should be tailored to the skill level of the player, which should be carefully monitored throughout the gaming session. Here, it is essential that the challenges require critical thinking and creative solution generation if the player is to learn properly; i.e. solutions should not be reached merely through memorization and repetition (unless this happens to be needed for the subject). Lastly, optimization of cognitive load has to do with the fact that our visual and auditory memory processing channels are limited [9]. In keeping with this, it is not advisable to overload the game player with too much visual and auditory information in the form of flashy graphics and sounds, since this can have a negative effect on their ability to learn. A balance between this must therefore be sought.
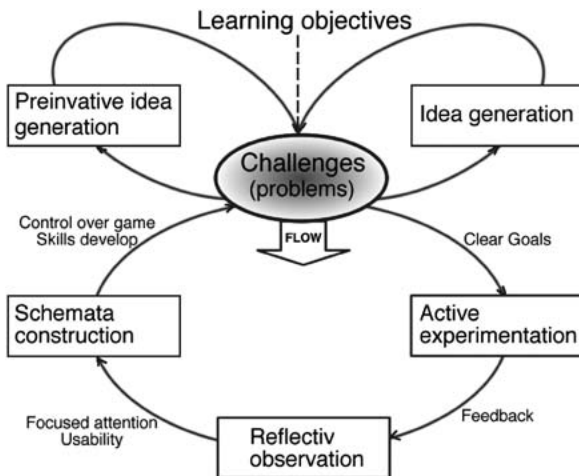
Figure 1

Kiili's Experiential Gaming Model

This chapter presents an initial approach to the blending of Remote Laboratories and *Serious Games* currently deployed at WebLab-Deusto

at the University of Deusto, which attempts to apply pedagogical game design criteria to a remote experiment, with the objective of creating a platform for programming education. The experiment allows users to control a mobile robot in a labyrinth environment and take part in an interactive game where they must locate and correctly answer several questions, the subject of which can be adapted to educators' needs. It also integrates the Google *Blockly* graphical programming language, allowing students to learn basic programming and logic principles without needing to understand complex syntax.

2. **Previous work**

This project is a direct continuation of the subject of [10], which hypothesizes integrating remote laboratories and *Serious Games* by developing a platform where students must use a mobile robot to locate several items scattered around a maze. The story setting for the game revolves around a situation in the distant future in which a spaceship has been forced to make an emergency landing on an unknown planet. Seeing that the ship has lost several key components, which have been scattered on the planet's surface, and that these pieces are critical to rebuilding the ship and leaving the planet, the crew must deploy a reconnaissance robot to recover them. Once all the pieces have been retrieved, the spaceship can be repaired and it can leave the planet. However, there is also a need for fuel for the robot. In order to gain the necessary currency to buy this, the crew can answer questions as part of an intergalactic trivia contest. Furthermore, in order to succeed in the game, they must first learn to control and program the robot to navigate a hostile environment and find the pieces. The condition to end the game successfully is that of finding all (five) of the RFID tags representing the parts of the spaceship. Once all have been gathered, the ship can be repaired and leave the planet for good.

Currently, the implementation of the laboratory does not yet provide all of the game elements described above. Nevertheless, it sets the ground for them by providing a suitable environment for the development of the game. Moreover, it takes care of most of the technical requirements of the system. Thus, future work of the project can focus mostly on the pedagogical side, without the need for much technical development.

At its current state of development, the remote experiment allows manipulation of the robot in two different ways:

– Direct control of the robot can be exerted by means of arrows controlling movement in the primary directions. RFID tags representing different parts of the spaceship are scattered around the maze, and whenever the robot reaches one, it can be retrieved, and the user can answer a question related to various educational and cultural subjects.

– The robot can be programmed to navigate the labyrinth and search for the pieces autonomously. The player can use a graphical programming language (Google Blockly) to do so in an intuitive and unobtrusive way, while learning basic programming principles without the need to understand the syntax of a textual language.

3. Experiment architecture and technologies

There are three main layers that make up the architecture of the experiment and its technical implementation, each directly related to one of the main components of the WebLab-Deusto architecture:

– Microbot: This is the physical part of the experiment and the main component in the system. It consists of a small robot enclosed in a wooden labyrinth. The robot has the necessary sensors to follow lines, detect walls, and read RFID tags. The robot delegates most of its intelligence to the Experiment Microserver Control Computer, thus reducing its own duties to merely following orders received from the computer.

– Experiment Microserver: This computer is in charge of direct communication with and control of the robot. Orders are sent through Bluetooth indicating movements. The microserver also provides the user client GUI and controls. The Microserver is where the main intelligence of the robot lies: Google Blockly programs actually run locally on this machine, and are interpreted as a series of simple Bluetooth movement commands sent over to the Microrobot for execution.

– WebLab-Deusto: The WebLab-Deusto Server takes care of user authentication, queuing, security, system logging and several other

administration tasks, and directly communicates with the experiment microserver. It is based on the open-source architecture developed at the University of Deusto.

A. *Microrobot*

A key factor in design choices for the micro-robot was making the platform as low-cost as possible and easing maintenance and handling, in order to reduce possible experiment down-time due to repairs or the need to redesign part of the software. For this reason, the choice of parts was based on components provided by generally well-known manufacturers. Furthermore, Arduino was chosen as the main microcontroller system, due to its widespread popularity, open-hardware philosophy and ease and quickness of development.

The whole robot structure was based on the *MSE ArduBot* [11] kit, which uses the *Pololu RRC04A* circular chassis as the main building component. The *RRC04A* allows easy assembly of motors, sensors and other components, and is also designed to be able to be stack various copies of itself on one another, thus providing a modular building block that can be used to create various levels for component placement. The robot built in this project used three such chassis. The lower level housed the *Pololu 150:1 Micro Metal Gearmotors* included with the kit, as well as all the infrared sensors used for line detection (and navigation in the labyrinth) and the RFID reader module. The middle level included the *Arduino UNO* microcontroller, as well as a custom-designed *Arduino* shield including a motor driver, Bluetooth module and voltage regulators, which will be explained in the following sections. The top level was where the battery providing power to the whole robot and the webcam that transmitted the robot's view to the Experiment Computer was placed. A critical aspect in the location of the battery was balancing the robot. It was centred horizontally, but moved towards the back of the chassis so that it would compensate for the weight of the camera and to prevent the robot from tripping over forwards. However, in the end, the battery was found to be so heavy that, instead, the robot tended to tilt backwards; it was therefore necessary to add two follower drive-less wheels at the front and back of the robot's lower level to keep it steadily balanced on the ground.

Placement of the infrared sensors for line detection was a crucial feature of the implementation phase. Throughout development, several different sensor configurations were tried before the final one was chosen. Factors influencing the position of sensors are:

– Space constraints due to chassis design.
– The ability to precisely follow a black line.
– Detecting intersections and stopping the robot exactly in the middle of one of them.
– The speed at which the robot will move.
– Whether the robot is to move only forward, or also backward.

The final position of the infrared sensors can be seen in Fig. 2.
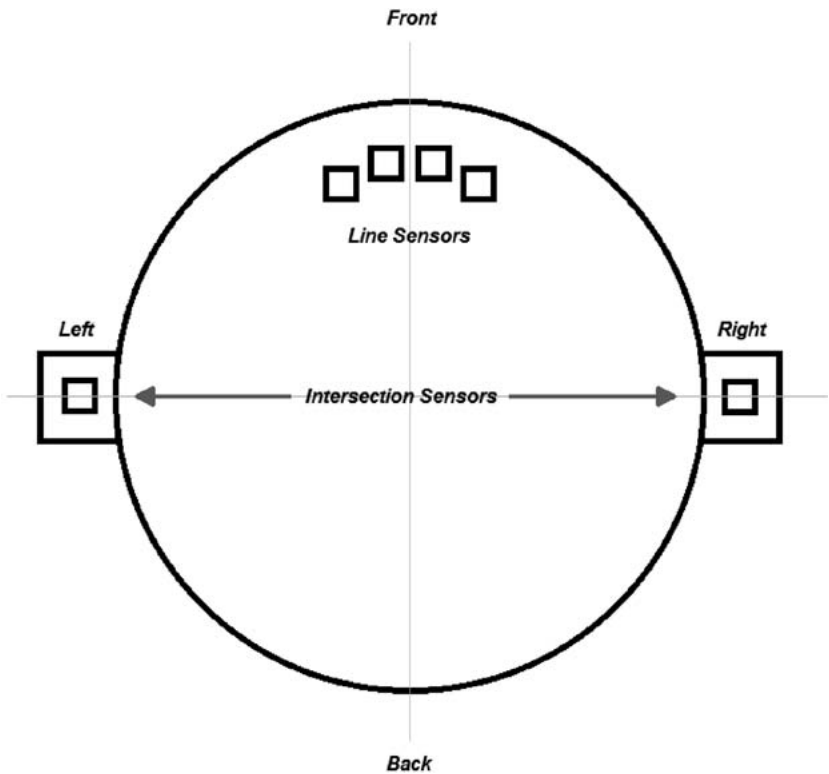
Figure 2

Sensor placement for the microrobot

All external electronics required by the robot were placed on a separate printed circuit board. To enable easy connection of the board with the Arduino UNO microcontroller, the PCB was fitted into one of the standard *Arduino Shield* form-factors, pin-by-pin compatible with standard Arduino microcontrollers. The shield was designed to house the electronics responsible for motor driving and control, Bluetooth communication and general voltage regulation and supply to all other sensors and electronic components. The chosen motor driver was the *Microchip MCP14E5*, based on MOSFET technology, thus providing very fast switch and response times. The circuit was designed to provide control lines for motor turn speed and direction and to incorporate an electronic brake.

The Arduino UNO board was programmed with a fixed software (firmware) incorporating the basic execution routines required by the robot. This basically consists of the robot following the line until it reaches an intersection, stopping at the intersection, attempting to read an RFID tag and sending it to the Control Computer, awaiting Bluetooth commands from the Control Computer, and then performing the actions indicated by these commands. Therefore, the robot's intelligence is delegated to the Control Computer and the robot simply follows the commands it receives.

B. *Experiment microserver*

The Control Computer, or Experiment Microserver, was programmed using Python. The philosophy behind this language makes it well-suited to quick development phases and also offers a very clear and readable syntax. The resulting code is usually simple and efficient, thus being optimal for ongoing development and for modular projects. There also exist a wide variety of useful software libraries that provide ready-built frameworks and components, facilitating many areas of the development process.

The core of the Control Computer is based on the Django Web Framework for Python. This eases the creation of web-services and the integration of databases within them. The software also uses the Pybluez library, which provides access to the Bluetooth stack in Linux systems under Python, and Twitter Bootstrap is used as a framework to provide HTML, CSS and JavaScript templates to ease in the implementation of the client, which was written as an HTML webpage.

Within Django, the *views.py* module is perhaps the principal component of the system. It is responsible for rendering the HTML pages, handling HTML requests and receiving and processing POST and GET commands. It also manages Bluetooth communications with the robot and receives commands from an optional *joystick_handler.py* module that allows the robot to be controlled with a joystick, but only if the lab is running locally. Finally, it implements the Google Blockly functionality that translates a series of stacked graphical program blocks into actual Python code. This code is then executed in the Control Computer and sends commands to the robot, processes information coming from its sensors and essentially allows the user to feel as if he were programming the robot with a series of graphical blocks. In reality, the program is not running on the robot's Arduino UNO, but on the Control Computer, corresponding to the delegation of intelligence described earlier. This greatly simplifies the implementation by removing the need to access the Arduino Bootloader every time the robot is re-programmed.

The remaining module, *urls.py*, is in charge of redirecting calls to the various sub-files within the server to the correct URL.

There are two main HTML files in the client: *index.html* and *blockly.html*. The first corresponds to the first instance of the game where the user directly controls the robots movement, while the second integrates the Google Blockly graphical programming workspace into the User Interface, corresponding to a more advanced player's skill profile (Fig. 3). The GUIs for these two modes of control will be described in following sections.

Google *Blockly*, included within *blockly.html*, is a graphical programming language very much in the vein of *Scratch* or *SNAP!*. It is visually very similar to *Scratch*, but differs significantly in its implementation: whereas *Scratch* is written in Squeak, a dialect of Smalltalk, and therefore requires the execution of a Smalltalk virtual machine in the host machine, *Blockly* is written entirely in JavaScript and is thus better adapted to the web. From the developer's point of view, *Blockly* allows easy creation of new graphical function blocks by writing them in straightforward JavaScript syntax (or using an online editor called *Block Factory*, written in *Blockly* itself), and then defining a series of Generators that translate these blocks into other text-based programming language. *Blockly* includes methods that generate code from the blocks and translate it into JavaScript or Python, which can then be executed as a normal program file (Fig. 4).
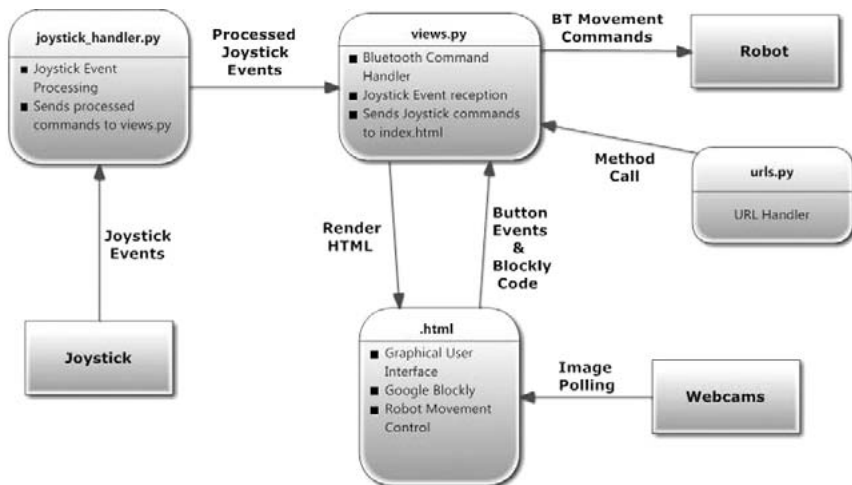
Figure 3

Architecture of the experiment.
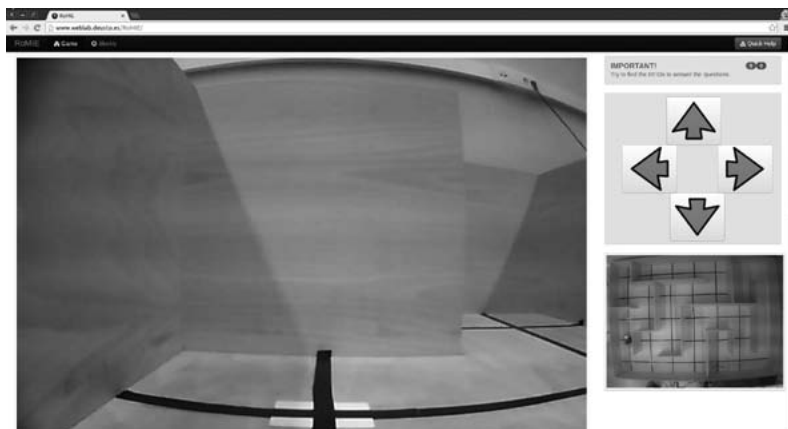
Figure 4

Movement Control GUI for the experiment

Within *blockly.html* is the Google Blockly client (Fig. 5). This is a graphical programming language that allows users to create fully functional programs by dragging and joining coloured blocks that carry

out specific functions. There are blocks for logic statements, for loops, for conditions, for arithmetic, etc. This is similar to other graphical programming environments, such as SNAP! or Scratch. The latter were also considered for the project, but they were discarded as they incorporate too many restraints on the developer. Some of these were for security reasons, but a significant fact was also that they are written in Squeak, a dialect of Smalltalk, which requires the execution of a virtual machine in order to deploy the client, thus greatly complicating development. Blockly, on the other hand, is written entirely in JavaScript, making it optimal for use in web applications. This language also makes it incredibly simple to develop new graphical blocks by either writing them in JavaScript or using an editor called Block Factory (which incidentally uses the Blockly GUI itself). A set of blocks can then be easily translated into JavaScript, Python or XML by defining a set of language generators. This generated code can then be executed on the Experiment Microserver, which sends a series of commands to the robot.
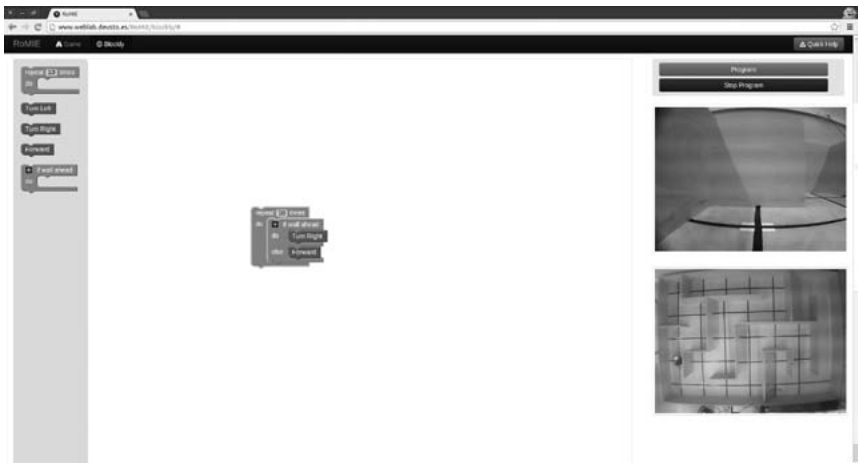
Figure 5

Graphical User Interface integrating Google Blockly with the robot

An important consideration when accepting code from third parties is safety issues and preventing the injection of malicious code. For this purpose, the implementation of Blockly deployed at WebLab-Deusto has

several security checks when translating block code. First, the blocks are translated into XML. The very explicit syntax of this language makes it easy to check for dangerous segments, and to filter the code so that it only accepts a series of very well defined statements. Once the XML has been properly checked and filtered, it is fed into a Python interpreter, which translates it into a structure of function calls related to robot functionality, e.g. move forward, turn left, turn right or check a sensor. This Python code is then written to a temporary file, which is then executed as a separate process within the Experiment Microserver. In order to prevent infinite loops and lock-up of the machine, the computer also incorporates a timeout, which kills the process if it exceeds a pre-specified amount of time. Additionally, the user may also choose to terminate the program at any time by clicking on the "Stop Program" button.

C. *WebLab-Deusto*

The WebLab-Deusto framework [12] is the basis for this remote experiment. The WebLab-Deusto server is connected to the Robot Control Computer and allows easy implementation of laboratory management functionality simply by using the WebLab API. In essence, if an experiment is deployed as a managed laboratory under WebLab-Deusto, it will benefit from the following advantages [13]:

- There is no need for the experiment developer to manage communications, as these are taken care of by methods in the client API. These propagate information to the server securely under SSL. All commands are pure HTTP, so they can cross any firewalls and proxies.
- Storage of used information in a database. This is useful for teachers and pedagogues to track use of the experiments and commands sent to the laboratory by their students.
- Local load balancing, so that, in the case that there exist multiple copies of the same laboratory, the WebLab-Deusto server will internally manage messages sent by the client to the appropriate copy of the laboratory that is currently being used.
- Authentication of users is automatically handled by the WebLab-Deusto server.
- Queuing is internally handled by WebLab-Deusto.

– Sharing of laboratories among different institutions –*Remote Lab Federation*– is supported, and is a major design goal.

4. **Educational Value**

The developed experiment provides an educational tool now applicable in three different scenarios:

1. Development of multidisciplinary questionnaires.
2. Experimenting with programming skills using a block-based graphical interface.
3. Experimentation with control structures of different high-level programming languages.

For the first scenario of the game a plot is proposed:

On the way to Triangulum Galaxy, the control devices of an inter-galaxy ship have begun to work unpredictably and strangely. The first pilot of the expedition decided to stop on the closest planet so the team could rest, research the planet environment and repair the equipment. During the landing, the environmental robot Max375v.11075 (or simply Max) was destroyed and his parts were scattered across the surface of the planet. From the first environment research, the expedition team understood that the air on this planet was highly acidic and the robot, Mini200v.468 (or simply Mini), should find all parts necessary to reduce the damage to Max in a very short time.

The task of student is to find, collect and assemble all the parts of Max in the correct way. The game is multidisciplinary, supporting different subjects for teaching and learning. For instance, the plot presented above is applicable to the teaching of Technology in secondary schools. Through a game authorizing tool a teacher can modify the task that student should collect and put together. A Chemistry assignment could be used to find necessary parts of chemical elements and compound them into the correct chemical formula. The English teacher can create vocabulary allowing students to collect only those words that could be used for building meaningful sentences or even a brief story. Using the graphical interface enables direct control of the robot, and any teacher can design a support questionnaire relating to their subject by defining a set of questions and

their answers. These questions can be grouped into different categories, each linked to one RFID tag. Every time the robot detects a tag (in the game it is part of Max), a question related to the corresponding category will pop up. The teacher can set the initial number of robot movements each student is allowed, game-time restriction and the reward the player gets every time he answers a question correctly. The student has to complete the game answering at least one question of each category correctly, collect the parts of Max and assemble him (Fig. 6). Those users with a teacher role can access a control panel where they can define the questionnaire and review the results of all experiments performed by the students in the same group. In this approach the serious game is only the vehicle that provides the questionnaire and controls the times and movement of robot *Mini*. GUI Movement control allows the student to find different tags and, every time a question is correctly answered, a new part of the spaceship is recovered. Once all missing parts have been collected (the entire questionnaire is filled in) or the appointed game-time is up, the game is over and the teacher can access all information about the robot movements, number of errors when answering questions and time used by each student to complete the game. As users are grouped, different teachers can provide independent questionnaires to students from different classes but access the same remote laboratory (robot *Mini)*.

Figure 6

Questionnaire GUI

The second scenario is based on integrating programming principles such as logic and code writing into the teaching concept with a simple game setting. The environment suitable for the learning of basic programming skills and for introducing young students to the logic required from an engineering professional is developed. At the same time, the acquisition of programming abilities is intended to be gradual and objective-driven, with students seeing the codes as a means of reaching the goals of the game, thus presenting the programming discipline as a means of problem-solving and as eminently practical. Furthermore, by providing a responsive and real environment in the form of a mobile robot, users receive immediate feedback that they can use to judge their performance within the game. Since the robot operates in a real environment, the feedback that the user receives is consistent with this scenario (it is also real), and this means that the user's debugging experience and dealing with his mistakes is deeply enriching and promotes learning from and working on improving the mistakes made. This is also intended to act as a reward system of sorts when students can see that they are able to successfully tell the robot how to autonomously navigate the areas of the labyrinth.

The choice of a graphical programming language over a textual one allows a larger audience to use this activity, since the limitation of the programming-language-literate is reduced with the Google *Blockly* approach. This means that people of younger ages, as well as enthusiasts that lack engineering backgrounds, can also benefit from the game-laboratory. Furthermore, the complications of syntax are eliminated, bringing logic and not language to the spotlight. It is this logic, and not the strictness of syntax, that is the key to developing the right mindset needs of engineering professionals.

Another advantage of the Google Blockly graphical programming language implemented in the remote experiment is that it can easily be tailored to suit the needs of a particular laboratory session or user. Several difficulty levels or practice sessions can be implemented where the user is limited to a particular number or type of function blocks. For instance, a level can centre on the use of conditional statements, branched conditionals; another on conditional loops, another for loops executed a specific number of times, for loops with changing starting and ending conditions, etc. In this way, logic concepts and the programming of students' vocabulary can be introduced gradually and in an incremental

fashion, providing a sense of empowerment by actually making complex things that work with simple elements, and by working up step by step to something powerful and more advanced.

At the same time, the addition of a real robot to this platform is a significant element when it comes to student engagement. The robot provides a real goal-driven testing ground for the programs. Having assembled the blocks, users can execute the code on the robot, thus seeing the response of a real system to their commands. By providing a back story and a clear objective to be achieved (in the form of finding the five RFID tags –spaceship parts– needed to rebuild the spaceship), the experiment aims to motivate and reward clear critical and logical thinking. The fact that there are varying levels of complexity for the blocks involved and their function makes it suitable for a wide variety of players from different skill levels and backgrounds.

5. **Conclusion**

If the STEM educational community is to appropriately react to the needs of the industry, it must find new ways to attract students and new methods to teach them the concepts that will be required of them as professionals. The merging of remote laboratories and *Serious Games* could perhaps be one such way.

WebLab-Deusto has developed a platform integrating game elements within the context of a platform for the teaching of basic programming logic within a STEM education context, without the need for students to first learn tedious programming syntax. As a remote laboratory, it allows ubiquitous access through the Internet, and is connected to real equipment that responds in a real way. Like the foundations of a *Serious Game*, it provides a goal-based environment for the development of learning objectives. This experiment's current state of development allows users to use the Google Blockly graphical programming environment to combine function blocks that translate into code what allows a mobile robot to autonomously navigate a maze, while finding and reading a series of RFID tags. This is set in the context of a game: a spaceship has crashed on a lost planet and must recover all five of its scattered parts (tags) to complete the game. In order to do this, students first need to learn the logic structures used in programming.

Even if the technical part of the experiment is mostly complete, there is still much future work left to do in the project. This will mostly centre on improving *Serious Games* design methodology and applying it to remote experimentation, with the objective of fully immersing students in an entertaining experience that enhances their critical thinking programming capabilities and deeply focuses their attention. When the main gaming elements have been incorporated into the laboratory, it is the objective of the project to deploy it and test it in several schools in order to verify and further improve its usability and teaching effectiveness.

The possibilities of merging *Serious Games* and Remote Laboratories, which have been clearly distinct lines of research up to now, show great potential for the STEM educational community, and could significantly redefine the methods currently employed and open new doors to study methodology.

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Acquisition of higher-order experimental skills through remote and virtual laboratories

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1. Introduction

Remote laboratories are physical spaces with real apparatus and real instruments connected to the Internet. They allow both students and teachers to remotely conduct real experiments through a simple web browser. Aktan *et al*. [1] first described the concept of remote experimentation in 1996, and since then many other authors have converged on the idea that remote labs play a significant role in the acquisition of experimental skills if successfully combined with real, hands-on laboratories and virtual laboratories [2-6]. More recently, Feisel and Rosa [7] clarified the sort of experimental skills associated with laboratories. In this paper, Feisel and Rosa describe thirteen fundamental objectives of engineering instructional laboratories, serving as a guide when considering the sort of skills students should acquire after running a particular experiment in a real, virtual or remote laboratory. In the case of a remote experiment, if the provider is able to clearly identify the learning outcomes and the skill gained, then it is possible for a student successfully completing such a remote experiment to acknowledge having acquired the associated skill. This is especially relevant if one considers the following scenario:

1. There is a lack of experimental facilities in secondary schools that impairs students from acquiring experimental skills that are relevant for the fields of Science, Technology and Engineering. This causes students to exhibit a lack of such skills in those fields when entering Higher Education (HE).

2. Increasingly less time is being devoted to lab classes in HE due to: (i) the Bologna process; (ii) cost savings associated with labs, which represent a major cost component in institutions of HE; (iii) an increased use of virtual labs (i.e. simulations), as these imply lower costs when compared to real laboratories.

3. Although simulators represent a powerful and flexible technology-enhanced learning tool, they fail to allow students to interact with Nature, as they interact with mathematical, computer-based models instead. This is a flaw in the educational plan for scientists and engineers who need to be fluent in the language of Nature. Students become fluent in this language by doing and repeating many experiments, where the trick seems to reside not in interpreting the answers obtained from Nature, but rather on asking the right questions so as to better understand the answers obtained [8].

4. Remote labs imply interacting with real apparatus and real instruments. This means that, despite being computer-mediated, the experiments provide results dictated by the nature of such instruments and apparatus under experimentation.

5. The two previous points allow one to think about a sort of higher-order experimental skill associated with the ability to distinguish whether the results obtained from a given experiment clearly allow one to distinguish if one is in the presence of a virtual or a remote lab, in a situation much similar to that proposed by Alan Turing, in 1950 [9].

6. In a scenario where education seems to be shifting from traditional classrooms to everyday-everywhere situations, for instance when accessing Massive Open Online Courses (MOOCs) [10], one is led to think that students may acquire several skills which may be difficult to recognize by traditional HE institutions. In fact, some of those skills may also be related to experiments or laboratory-based materials and procedures [11].

Such a scenario implies the need to promote and recognize the acquisition of experimental skills through informal and non-formal learning activities, such as those acquired through remote and virtual labs [12]. If students and teachers are able to mutually recognize such skills or competences, then personalized experimental learning paths may become a reality in HE, thus allowing students to become fluent in the language of Nature, following their own reasoning and learning pace. Finally, the use of haptic devices may form part of the whole picture, in particular when mentioning experimental skills involving hand-controlled movements or the need for tactile feedback.

This chapter, therefore, addresses the acquisition of higher-order experimental skills through online experimentation. Section 2 discusses aspects related to tagging informal learning activities carried out with online laboratories; section 3 describes the acquisition process in correlation with the fundamental objectives of engineering instructional laboratories (stated in [7]); section 4 focuses on online experiments involving sensorial information; and, finally, section 5 concludes the chapter.

2. **Tagging informal learning activities with remote and virtual labs**

Given the background, it is possible to perceive situations where, by completing a given virtual or remote experiment available on the web, individuals are able to tag an informal learning activity and associate a gained skill with it. The question resides in how to tag that activity and provide evidence of actually having done it. This is particularly relevant with remote experiments –as opposed to virtual ones– because, depending on the nature (resolution, influence of noise, etc.) of the data returned from the lab, results are likely to be unique.

Taking an example from informal learning activities promoted under an initiative named STEM (Science, Technology, Engineering and Maths) Scouts [13], young individuals first (1) study online a given subject, following a recommendation by a teacher or mentor. They then (2) buy an experimental kit to practice the associated practical component (build a scale model, perform a given chemical experiment, etc.) and finally (3) demonstrate the result to the teacher or mentor, who (4) recommends individuals for a STEM Scout badge. Individuals may then (5) add the badge gained to their STEM Scouts electronic portfolio.

Tagging informal activities executed in remote laboratories and adding them to an e-portfolio may follow a similar process, with the exception that no teachers or mentors are involved in it. The main requirement resides in the need for all experiments performed in the remote laboratory to be permanently stored in an associated, Internet accessible and searchable open database containing the following information:

- who did the experiment (requires registration and login credentials): <user id>
- which experiment[1] was done: <experiment id>
- when the experiment was performed: <timestamp>
- what the experiment input parameters & output results were: <experiment setup & results>

Additionally, the remote laboratory should also contain information about the pedagogical framework associated with each supported experiment, i.e. what the experiment is about, the prerequisites, the learning outcomes, etc. Tagging a remote experiment thus simply requires two (optionally, three) actions, namely:

1. Transferring the unique URL identifier of the remote experiment pedagogical contents to an Informal Learning Collector (ILC);
2. Transferring the unique URL identifier of the remote experiment execution data to the ILC;
3. (Optional) Inserting an image illustrating the remote experiment interface to facilitate the reader's comprehension.

A remote laboratory under development which is addressing these specifications, namely by supporting the database with the identified items (who, which, when, what), is described in [14]. The remote laboratory in question allows an individual to perform projectile launch experiments with a number of user-configurable parameters, which enable different pedagogical scenarios, all having in common the physics laws that rule the trajectory of a falling object with a variable launch speed. Fig. 1 provides an overview of the remote laboratory, and Fig. 2 illustrates the user interface, where the elements that will form one record entry of the database are depicted in detail.

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[1] A remote laboratory may host a number of different experiments.
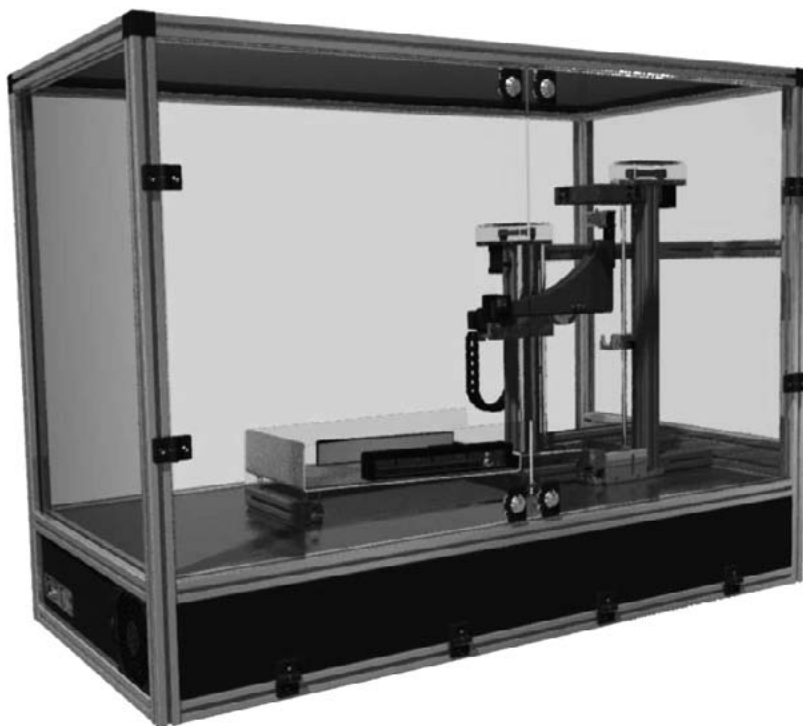
Figure 1

Overview of the physical apparatus for remote projectile launch experiments

A fundamental aspect to be considered is the sort of higher-order experimental skills students may acquire with such a remote experiment. In the presented example (projectile launch experiments), it is possible, for instance, to define a set of didactical problems leading students to navigate through the several "tasks" (or learning scenarios) depicted in Fig. 3. Each learning scenario (pen and paper exercises, online simulations and online lab experiments), and the different (sequence of) transitions among them, is able to provide students with different skills and knowledge. A higher-order experimental skill, in light of Fig. 3, would be the ability to predict and explain the differences among the results provided by each learning scenario, in particular between (online) simulations and (online) lab experiments, as already mentioned in point 5.
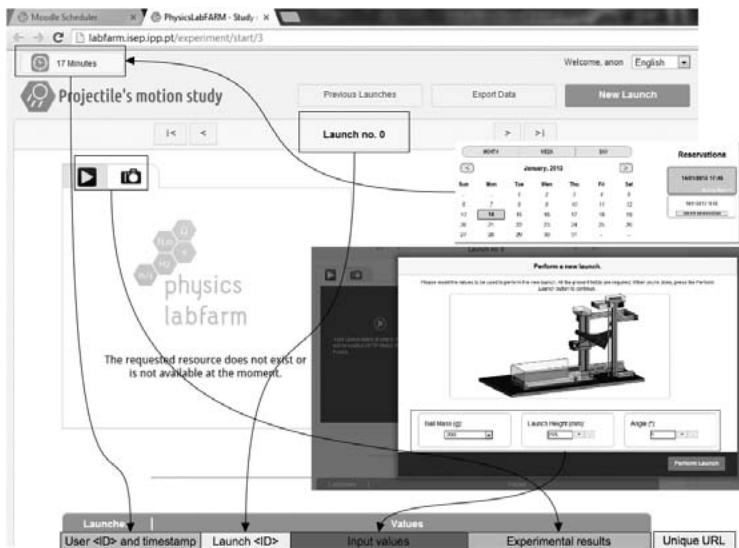
Figure 2

User interface depicting the elements forming a database entry

Figure 3

Learning scenarios for acquiring knowledge and skills in Science, Technology and Engineering

3. **Attaining higher-order experimental skills with online experimentation**

By the mid-eighties computers had been introduced in engineering labs for research, training and education. It is in this context that one of the authors built her own acquisition system for intelligent automated tests of stepper motor driven valves in open and closed loop working mode [15], in order to evaluate their design and performance 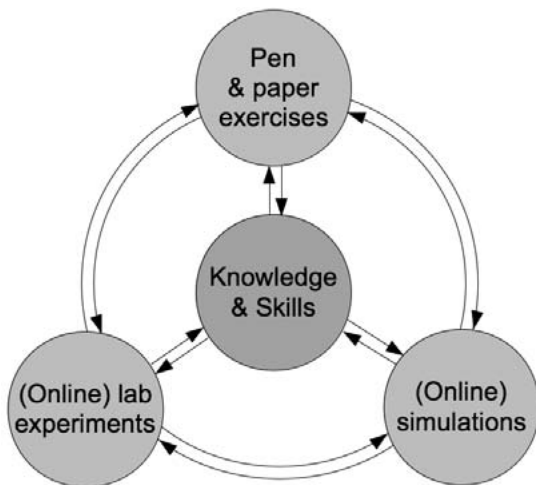which were, at the time, under development at the Mechanical Engineering Department of the Faculty of Engineering at the University of Porto. And just for fun it is interesting to remember that a BBC microcomputer was used and its 6502 microprocessor was programmed using assembly language [16]. By the beginning of the nineties, LabVIEW was already in use in universities and in engineering labs [17-22]. Therefore, the computer became everyday laboratory equipment everywhere either to process, analyze and evaluate results' correlation and finally to present them, or to acquire experimental data and to control experiments at research [17-22] or at educational levels [23-26].

LabVIEW and H-P HPVEE software became able to communicate with instruments by using the IEEE 488 communication protocol, which can be looked at as a first standard approach for remote access to the equipment. In the late nineties, LabVIEW and MatLab/Simulink software packages incorporated web server functionalities allowing users to gain remote access to experiments through the Internet [27], and since then many works reported initial activities in the learning context [28-34]. This has been a big step soon after the evolution of the meaning of distance learning education [35], bringing a priceless contribution by providing remote access to experiments within the distance learning process.

However, when ABET had to deal with the accreditation of distance learning education courses, mainly for those at undergraduate level, it was considered essential to establish a clear criterion for defining the role of experimental activities [7]. A group of "some fifty distinguished engineering educators, representing a range of institutions and disciplines" were called to study this perspective, and finally they "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" [7].

Hoping to add some more material for discussing these topics, in the following paragraphs two case studies will be presented with provocative statements.

A. *The case of hands-on vs. remote experiments*

Using two different solutions as a basis (one being an example of hands-on activity and the other its remote version), a case study will be worked out in order to check how they accomplish these thirteen objectives. This case study integrates one example of complementary instructional resources, with the remote experience being an additional offer to the students' traditional hands-on activities. The selected examples come from the Instrumentation for Measurement course in a Mechanical Engineering integrated MSc. The work is entitled Mechanical Material Characterization, and is related to concepts such as material strain, stress, deformation, Young Modulus, specimen geometry characteristics and bending tests.

Next, a brief description of the activities offered will be given. And, following that, the analysis of the identified outcomes will evaluate what is expected from each solution.

A.1 Young Modulus Determination

Hands-on activity

During the hands-on activity a very simple system for obtaining the Young Modulus of a material is used. It consists of a specimen used in a simple cantilever beam mounting (Fig. 4). The specimen is instrumented with two resistance strain gauges oriented along its longitudinal axis and symmetrically bonded on the top and bottom surfaces respectively. The electrical strain gauges are integrated in a half bridge circuit. Known loads are successively applied on the free end of the cantilever beam, at a distance L from the geometric centre of the strain gauges' grid, and for each applied load the strain is calculated based on the signal output of the bridge circuit, the respective load value and the beam geometry dimensions [36]. A regulated and stabilized power supply, a voltmeter and a bridge circuit are the equipment required.
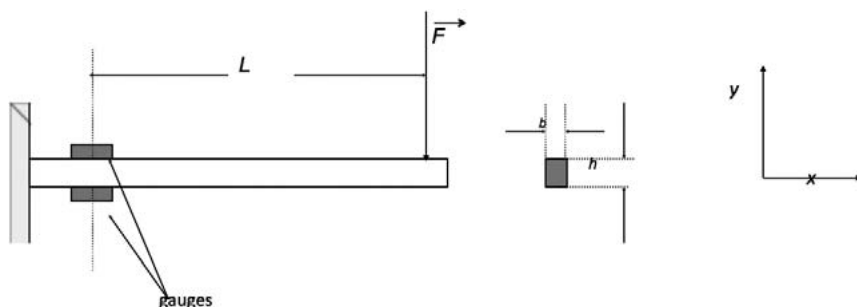
Figure 4

Cantilever beam mounting

Remote experiment (named Mechanical Material Characterization)

The set-up was designed in order to provide the built-in end of the cantilever aluminium beam with a properly tight and stable grip (otherwise, fixed end conditions will not be ensured and relative sliding may occur), as well as the accurate positioning of the motor coil shaft for point load application. The beam is vertically positioned to minimize self-weight effects during measurements. The beam is loaded by a linear motor of coil type in a closed loop control in order to guarantee the load value imposed by a voltage source. A miniature load cell located in serial mounting with the motor shaft provides the reaction force of the beam under load conditions. The strain is measured by electrical strain gauges mounted in a half bridge circuit with a two-wire current transmission circuit. A digital gauge continually gives the deflection of the beam (referred to as the applied load point) for any applied load.

The user interface (UI) is developed in LabVIEW and the acquisition hardware is from National Instruments. The UI is organized into three areas. The main area offers the input actions, either in automatic or manual mode. In both modes, output data is displayed either in graphical or in numerical form, as well as additional information such as test stages, stabilized state, measured values. In the top right-hand corner the system real time video is provided. Below it, a picture of the complete mechanical system is available (Fig. 5), [37].
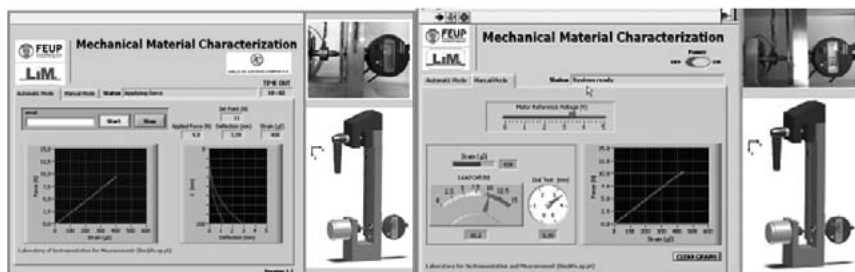
Figure 5

Cantilever beam mounting

Looking at the way the above works were conceived, according to [36], an attempt will now be made to examine how their outcomes accomplish the set of thirteen objectives collected bellow. The first five of them are within the cognition domain; the next two within the psychomotor domain; and the last six are within the affective domain, according to Bloom's Taxonomies [38]. Later discussions on these had by members of the expert group of engineering educators [7] have pointed out a general agreement among engineer educators on the "thirteen objectives'" exhaustive characteristics and their relevance for designing lab courses to aid the evaluation of lab activity and its effectiveness validation, even in distance learning courses. In this context, these objectives will be now considered and, for each experiment, the achievements obtained will be listed in order to evaluate whether there is a clear difference between the two available experimental activities: hands-on and remote.

Objective 1:

Instrumentation: Apply appropriate sensors, instrumentation and/or software tools to make measurements of physical quantities.

– Hands-on: 1) electrical strain gauges are sensors for measuring strains; 2) strain gauges must be integrated into bridge measuring circuits; 3) power supplies need to be of adequate range, regulated and stabilized; 4) measurement accuracy is improved by using some typical measuring techniques and an adequate voltmeter.

– Remote: 1) & 2) similar; 3) loads are applied by a specific controlled device; 4) a miniature ring-type load cell in series with motor shaft is used for guaranteeing load values; 5) the use of some typical measuring techniques and adequate data acquisition resolution improve measurement accuracy; 6) deflection at a specific point is measured by a digital gauge; 7) acquisition cards are essential for obtaining analogue and digital inputs and outputs of and from the system; 8) measurement resolution is defined by analogue/digital converter resolution.

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.

– Hands-on: 1) the experiment needs to follow a specific protocol for this type of test in order to obtain results for expressing Hooke's law in the elastic region; 2) accuracy in dimensional values is very important for the result; 3) good results are expected; 4) Young Modulus value is highly dependent on material production.
– Remote: 1) to 4) are similar; 5) if the protocol is not respected using stabilized conditions in the manual mode, measurement will lead to affected results; 6) the use of the available deflection value leads to a less correct Young Modulus value due to second order approximations of the model.

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.

– Hands-on: 1) the model is based on a cantilever beam under bending test; 2) determination of Young Modulus of a material is based on the

slope value of its stress-strain curve in the elastic deformation region; 3) the experiment needs to follow a specific protocol for this type of test in order to obtain results for expressing Hooke's law in the elastic region; 4) the use of spread sheets is advised for performing calculations; 5) the selection of convenient scales is important.
– Remote: 1) to 4) are similar; 5) the system makes it possible to obtain values and to visualize the deflection along the beam; 6) using manual interactive mode and it being possible to have a fine load adjustment, it produces evidence of measurement errors due to a very small strain resulting from small applied loads; 7) if the available deflection value is used to calculate the Young Modulus, a less correct value will be attained.

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.

– Hands-on: the Young's Modulus calculation is highly sensitive to the geometric evaluation of the specimen. This has to be done with some values being of the order of 10^{-5}m! Mistakes and incorrect units will substantially distort the order of magnitude, which is within a well-known value.
– Remote: same type of data; 1) specimen dimensions, loads and strains are automatically provided in the "automatic mode" for analyzes and calculations; 2) by using "manual interaction mode" without respecting the protocol carefully, it will provide good examples of obtaining clear mistakes and allow the exploration of mistakes also coming from applying very small loads; 3) the use of the deformation value will lead to less acceptable results, which will make the influence of the model used evident.

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; testing and debugging a prototype, system or process using appropriate tools to satisfy requirements.

– Hands-on: 1) the test framework has to be assembled – errors in the assembling process will lead to bad results; 2) wrong electrical connections will invalidate results; 3) procedure for nulling offset is mandatory for the final results; 4) scale selection.
– Remote: 1) user interaction and its observation will encourage the student to idealize a much more complex solution to gain remote access to the same type of experiment, therefore contributing to concept integration; 2) wrong functioning observed needs to be identified and reported to the responsible element.

Objective 6:

Learn from failure: Identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process or design, and then re-engineer effective solutions.

– Hands-on: sensing integration, powering and connections could be wrong. If so, results will be affected. The situation should be identified and a solution found.
– Remote: sensing integration, powering and connections could be wrong. If so, given the different types of results provided, the evaluation of those that may be affected should be made. The situation should be identified and reported.

Objective 7:

Creativity: Demonstrate appropriate levels of independent thought, creativity and capability in real-world problem solving.

– Hands-on: it is usually recommended to build a scale based on the instrumented beam. Added open questions are also available in order to force the reflection.
– Remote: available explorations are mainly concentrated when using the manual mode.

Objective 8:

Psycho-motor: Demonstrate competence in selection, modification and operation of appropriate engineering tools and resources.

– Hands-on: this experience implies a hands-on activity to assemble the whole system, the electrical circuitry implementation and connections, as well as the correct application of loads, which involves specific requirements.
– Remote: not applicable presently. However, it is possible to suggest a set of easy experiments to be worked on by the user at home.

Objective 9:

Safety: Identify health safety and environmental issues related to technological processes and activities, and deal with them responsibly.

– Hands-on and Remote: Not applicable in either case!

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.

– Hands-on: Groups involved in an experimental activity have to produce oral reports on their findings for all other groups in the lab. A very short report (a synthesis) is asked for. The performance of the group is also based on these elements. A final experimental test will place all students face to face with teachers in which situation they should execute a randomly selected task; they also have to answer questions related to the topic.
– Remote: group activity is still possible either during the remote access or for results discussion, mainly based on using different approaches. Syntheses of this work are frequently asked for in the final exam or during a lab exam.

Objective 11:

Teamwork: Work effectively in teams, including structuring individual and joint accountability; assign roles, responsibilities and tasks; monitor progress; meet deadlines; and integrate individual contributions into a final deliverable.

– Hands-on: work in a group for the experimental tasks, for the final oral report and to later produce the short and realistic report.
– Remote: considering this work is offered as an additional resource, its evaluation is performed, currently, in the written exam. In the past, online experimentation has been a topic for a poster assessment component. An interesting example of student involvement is reported in [37].

Objective 12:

Ethics in the Laboratory: Behave with highest ethical standards, including reporting information objectively and interacting with integrity.

– Hands-on: group and individual continuous evaluations foster accountability between group elements. Final experimental exam has a mandatory self-evaluation step.
– Remote: when questions are included in an exam, the explanation has to be objectively given. It will not be possible to do this without having performed real access to the experiment or without having used it and explored it. It will foster responsibility in self-regulation of his/her activities.

Objective 13:

Sensory Awareness: Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

– Hands-on and Remote: Not yet explored.

The first five objectives are rich in content and it is possible to conclude that this remote experiment expands the content even more. Objectives 6 and 7 also have a reasonable balance. However, objective 8 is not respected by the remote solution, according to its inherent remote condition but future steps could integrate improvements in this perspective. Objective 9 is very specific and is not applicable to many lab experiments. Objectives 10, 11 and 12 are balanced and objective 13 has not yet been explored in either situation.

This reflection shows that, in general, most of the objectives are observed in these two versions of the Young Modulus work, which means that both accomplish these important guidelines. Looking in more detail, it is possible to see that, except for objective 9, which is not suitable for many of the lab experiments, and for objective 13, which will be explored for both modalities in the future, all the objectives are fulfilled. Furthermore, in general, it is possible to conclude that the remote version even offers more content for the objectives related to the cognition domain.

Finally, it is possible to argue that with the exploratory interaction possibilities offered, the added training offered with the remote solution will contribute towards "attaining higher-order experimental skills with online experimentation".

B. *The case of remote vs. virtual experiment*

A remote experiment uses real equipment from a physical laboratory, enhanced by software application and technology, connected by the Internet, whereas a virtual experiment is a software application simulating experimental procedures and devices. It can be remotely accessed or even downloaded to the user computer. These concepts are easily available in [39, 40]. A virtual experiment could be just a 2D simulation implemented in Macromedia Flash. But it could also be considerably more complex, using a set of techniques making it possible to interact with a 3D virtual reality (only existing in the computer world). In the "true" virtual reality concept, user perception will use mainly eyes, ears and hands and his/her immersion in the virtual world could reach a high level of realism. The focus will be on virtual reality systems of screen-based simulator type. In this case if virtual reality involves software

applications or even techniques which replicate real environments with such a high level of realism that fosters user immersion, then it can lead the user to a higher cognition level compared to when considering a real system.

The case study used for illustrating such an example will analyze a remote experiment of a Michelson Interferometer and its virtual replica. A brief description of both systems will be followed by a comparison of the user actions and feedback they provided.

Basically, a Michelson Interferometer (MI) has different components: a laser, lens, mirrors and one beam splitter. When the laser is on, it generates a monochromatic light beam. A beam splitter, if angled at 45º to the laser beam, is used for splitting it into two beams at the same point in space; one half of the beam intensity is partially refracted through the beam splitter and the other half will be reflected at an angle of 90º. These two half beams will travel along different optical paths and each one will reach the surface of a mirror (one being a fixed mirror and the other a moving mirror). Both will be reflected and they will merge together and combine to produce interference fringes visible when reaching a screen. A diverging lens receiving this final beam before the screen can be used to magnify the interference fringes on the screen. Every time the moving mirror changes its position the optical path will change and this will cause successive light and dark fringes. The fringes will be sliding from bright to dark. For moving mirror changes in position (at the meter magnitude) the fringes will shift. Moving the mirror in the opposite direction will shift the fringes in the opposite direction, too. This system is very interesting not only for viewing and understanding the phenomenon but also because it is the basis of the standard for measuring displacements at micrometer level in metrological labs. In industry it is also relevant in many areas. For example, the calibrator equipment for machine tools is based on the MI working principle. However, an MI is not a common set-up in labs these days because it involves costly equipment, needs to be in a dark room, is very sensitive to any kind of vibration and requires patient and expert tuning. For all these reasons, an MI was prepared to be online. Mechanical interfaces were carefully designed and produced, a special anti-vibrating table was used, a screen was sensorised and a remote application was developed to make it remotely available any time.

Figure 6

Remote Michelson Interferometer

The user interface offers the interaction area with the available selectable parameters and outputs of numeric and graphical type. In the upper right corner the live video shows the fringes on the screen and how they follow the imposed displacement. In the lower right corner a picture of the complete set-up is shown in Fig. 6.

There are two modes of actuating the interferometer: manual and automatic. In the automatic mode it is possible to choose the velocity for the sliding stage of the moving mirror and the time interval for this movement. These two parameters will impose the displacement. It is possible to introduce the user e-mail to obtain the results (number of fringes, time interval of the displacement) and work with them in order to determine the final real displacement. It is possible to follow the succession of dark/light fringes in the graphical window. In the manual mode, the user can move the sliding stage forwards and backwards, step by step with the resolution of 30 nanometres. This is a great possibility for users.

However, any other action over the system will involve the integration of additional sophisticated equipment and would make it very expensive. For overcoming these limitations a virtual MI (Fig. 7) was built and it is available from http://onlinelab.fe.up.pt/otherexperiments.html
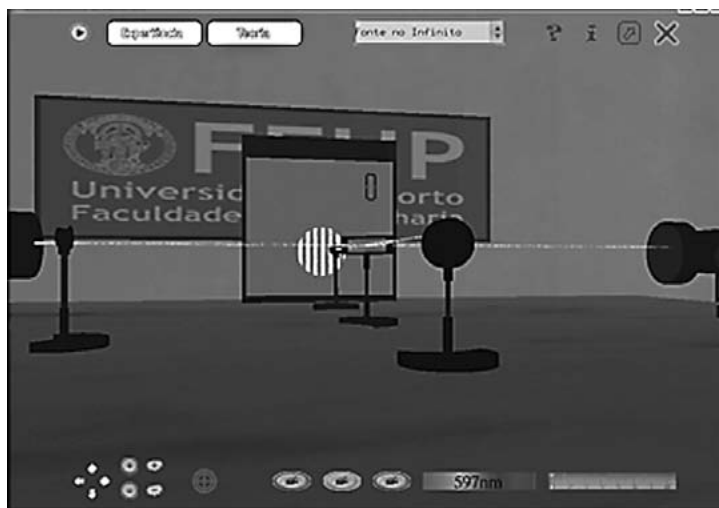

Figure 7

Virtual Michelson Interferometer

The software application can be downloaded easily. A video clip and a tutorial will allow anyone to operate the system and then to explore all its details.

The Virtual MI, Fig. 7, intends to recreate the real interferometer installed in a small, dedicated room. It is essential to switch off the room light and to switch on the laser so that the user can select the laser light beam colour. After making the light sufficiently visible by using some commands, the system can be explored by rotating the scene 360º for the three different cameras. Having decided which camera perspective to use, the next step will be how to tune the beam splitter either using an analogue dial or a fine tuning key for adjusting it at 45º to the direction of the laser beam. The lens near the screen makes it possible to magnify or shrink the fringe pattern. Simultaneously, by clicking on it, the user activates the control slider and, by using this, can observe how its movement produces

changes in the fringe's pattern. It is also possible to decide the source type: by selecting a "point source", the fringe pattern will be of circular type and, by selecting "source at infinite", the fringe pattern will be of parallel fringes. By clicking on the sliding mirror, an analogue dial control is activated, whose rotation moves the sliding mirror backwards and forwards. Based on these possibilities, many types of interaction are possible to explore the MI in a richer way and so it encourages the users to become involved and feel confident with the system.

By using all these commands, the user can actuate them and observe the different component functionalities and the MI working principle.

In the present example, students are not allowed to enter the small room where the MI is mounted, so as to avoid any type of interaction with such a sensitive system to any slight misalignments which would immediately make its use impossible. In the present case they can remotely interact much more "safely" than in the lab. Yet, their interaction with the virtual replica is richer and leads to a better understanding of how the whole system works and the role of each component, contributing towards "attaining higher-order experimental skills with online experimentation". The examples visited in the previous sections A and B show that remote and virtual experiments, used in a complementary way, can also contribute to higher-order experimental skills even with their condition of being online experimentation. More complex virtual reality, one offering the user the perception of different types of sensorial information derived from his/her interaction with the virtual world by using kinaesthetic systems, will also contribute to attaining higher-order experimental skills with online experimentation.

4. Online experimentation involving sensorial information

Today, simulation software has been produced to accurately provide virtual replicas of many systems as well as processes in all areas of knowledge. In particular, those in technical and physical areas have been playing an important role in engineering education over the last 30 years. User actions on virtual reality systems may involve the perception of different types of sensorial information such as reaction to the action performed in the virtual world. Therefore, the user needs to face kinaesthetic systems, better known as haptic devices. Virtual reality and

haptic interaction is another promising area, mainly due to the increase of user immersion within applications for training purposes either in industrial or medical areas. It may be noticed that virtual reality and haptic interaction are inevitably linked to the development of flight simulators. During the second half of the 20th century the universal systems for training pilots for the most sophisticated aircraft before real flights were developed.

Historically, the use of technology to simulate physical phenomena probably found its first serious use in the "Link Trainer" developed by Ed Link in the 1928, now considered an ASME National Landmark" [7]. Interesting videos of the Link Trainer are available at YouTube (http://www.youtube.com/watch?v=fKYyWS9Yfr0 and http://www.youtube.com/watch?v=MEKkVg9NqGM). The pilot inside the "Link Trainer" experienced the sensation of an actual flight experimenting high immersion and it "was used to train thousands of military aviators before and during World War II, saving millions of dollars and more than a few lives" [7].

In recent decades, with the development of IT and of high-resolution graphics, high-speed computer processing, high-speed communications, at the same time as a diversity of interaction devices (haptics, glasses, helmets, gloves, eye-tracking systems, sound), Virtual Reality became a new key technology in use in many fields and to be explored in many others. Virtual reality and haptic interaction, after pilot sophisticated aircraft simulators, have also been used in the Navy for ship or submarine piloting and for training emergency situations (a fire on board, an incident on a submarine, etc.) [41], and for ROV guiding [42], for operating sophisticated equipment at CERN, and for training in nuclear power plants [43] and in complex chemical processes [44], etc. The engineering education areas in which haptic interfaces could be relevant are those based on simulations or virtual reality applications offering the user the possibility of applying and/or responding to the force feedback information to or from the system, and using touch through haptic technology as a powerful tool in computer-based education. However, the cost of those devices is high and dissemination of haptics has not been so extensive. Nevertheless, reported works show a broad range of uses, from traditional dynamic systems where a low-cost haptic of 1DOF was used to interact with an unlimited number of *virtual systems*... "By adjusting the magnitude of the virtual spring constant (Kp) or the virtual damping constant (K_n), students could immediately feel the effects of greater stiffness and greater

damping..." [45], or the use of an Omni haptic device where "the user interacts with the VR application through a haptic device, imposing and feeling the reaction forces on the beam, which are related to the mechanical characteristics of the material" [46], or even those described in "nanomanipulator applications for tactile feedback and to manipulate objects such as viruses that are nanometer-sized" [47].

In fact, the first author was first involved in the use of haptic interaction with a remote experiment between Brazil and Portugal reported in [48]. In this case, a live video of the behavior of a Portuguese experiment was available in Brazil, where the user was also receiving the corresponding force feedback by actuating the remote experiment. Using a lighter communication protocol with a network communication velocity of around 60Kbps, the mean rate of haptic communication data loss was 10% and the measured delay in response was 3.9 s. Simultaneously, video delay also had to be considered. Although the study proved to be exciting for all students and teachers involved, the mentioned constraints were not so positive for the "proximity sensation" which the authors intended to induce in users. Therefore, a hybrid solution (an application integrating the remote experiment and its virtual replica all together) was developed for use within Ethernet. In this solution, and to minimize additional delays, the feedback information available in the user interface would also feed the virtual reality. Even so, the delay between live video and the simulated device was still one constraint. Finally, a totally virtual system was used with haptic interaction.

By offering the students the combined use of both systems (remote and virtual experiments) and traditional lab sessions, some interesting conclusions arose. Students' free comments reported that the use of haptic interaction makes the experiment interesting, allows a new interactivity with a system, "feeling" the material (reaction) and so increases perception and consequently studying efficiency. In fact, "feeling the beam reaction force in the user hand, he/she gets immersed in the experiment and this additional sense will help the user knowledge of Young modulus of materials together with the association of force magnitude/strain magnitude both displayed in the interface" [46]. These aspects arising from the virtual experiment strongly enrich the real one if they are used in a complementary approach. Returning to the "thirteen objectives", it is clear that objective 13 is now totally observed by the virtual experiment as opposed to the other previously discussed

experiments in section A. Many of the other objectives are still observed. Deeper evaluation of these potentialities will require a very well structured survey, now in preparation, in order to convey reliable results. In any case, it is possible to state that the use of all these tools in complementary ways will provide the students with better opportunities and complementary knowledge. This means that, once again, online experimentation may contribute towards attaining higher-order experimental skills.

5. **Conclusion**

Carefully conceived online laboratories provide a valuable contribution to the acquisition of higher-order experimental skills in Science, Technology and Engineering. Although the offer of online laboratories is increasing, there is still a long way to go, namely in pedagogical and didactical terms, i.e. on how to best combine the potential of virtual and remote labs in order to help students become fluent in the language of Nature; in particular, allowing them to learn how to predict the sort of results virtual and remote labs return, in a situation similar to the Turing test, i.e. without knowing in advance which lab type (virtual or remote) they are accessing.

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Olga Dziabenko and Javier García-Zubía (eds.)
IT Innovative Practices in Secondary Schools:
Remote Experiments

Technologies play key roles in transforming classrooms into flexible and open learning spaces that tap into vast educational databases, personalize learning, unlock access to virtual and online communities, and eliminate the boundaries between formal and non-formal education. Online –virtual and remote– laboratories reflect the current IT trend in STEM school sector. The book addresses this topic by introducing several remote experiments practices for engaging and inspiring K12 students.