Remote Electronic and Acoustic Laboratories in Upper Secondary Schools

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Abstract

During a substantial part of their time young people of today actually live in a virtual world. The medial evolution has also influenced education and today much research work basically concerns the transfer of the physical world into the virtual one. One example is laboratories in physical science that are available in virtual rooms. They enable students to sit at home in front of a computer and on screen watch and operate the physical equipment in the laboratory at school. It is a general agreement that laboratory lessons are necessary in subjects such as physics, chemistry and biology. Physical experiments provide a great way for students to learn more about nature and its possibilities as well as limitations. Experimental work can be provided by laboratories in three different categories; 1) hands-on, 2) remote and 3) simulated. This thesis concerns the usage of remotely controlled laboratories in physics education at an upper secondary school. It is based on work carried out in a joint project between Katedralskolan (upper secondary school), Lund, Sweden, and Blekinge Institute of Technology (BTH). The object with this project is to investigate feasibility of using the VISIR (Virtual Instruments System in Reality) technology for remotely controlled laboratories, developed at BTH, in upper secondary schools.

This thesis consists of an introduction, followed by three parts where the first part concerns the introduction of the remote lab to students and the usage of the remote lab by students at the upper secondary school, Katedralskolan. Both first year students and third year students carried out experiments using the remote lab.

The second part concerns activities carried out by 2 teachers and 94 students using the remote laboratory VISIR. An integration of VISIR with the learning management system used at school is described. Teaching activities carried out by teachers at Katedralskolan involving the VISIR lab are discussed, e.g., an exam including problems of experimental work using the VISIR lab and an example of a student report. Survey results on student satisfaction with the VISIR lab at BTH and the perception of it are presented, indicating that VISIR is a good learning tool. Furthermore, the survey resulted in a proposal of improvements in the VISIR lab user interface.

Finally, the third part focuses on enhancements of the VISIR lab at BTH. An improved version in the VISIR user interface is presented. New iPad and smart phone availability of the VISIR lab is presented. Electronic experiments for upper secondary school students are described in detail and examples of suitable configurations are given. A new VISIR acoustic lab has been implemented and initial experimentation by upper secondary school students have been carried out. The outcomes from these experiments are discussed.

Preface

This licentiate thesis summarizes my work within the field of remote laboratories conducted at Blekinge Institute of Technology. The thesis is comprised of three parts.

Part

A Remote laboratory experiments at the upper secondary school Katedralskolan in Lund.

B Using an online remote laboratory for electrical experiments in upper secondary education.

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

Acknowledgements

The research presented in this thesis has been carried out at the Department of Applied Signal Processing, Blekinge Institute of Technology (BTH), Karlskrona, Sweden in collaboration with the upper secondary school Katedralskolan in Lund. My supervisors have been Professor Lars Håkansson and Senior Lecturer Ingvar Gustavsson.

This thesis would never have been written without the support from all the wonderful and skilled people I have had the pleasure of knowing throughout this journey. I am truly grateful for getting to know all of you and for having brought me here with your great presence, wisdom and inspiration. With no motivation for the order of the acknowledgements I first would like to thank my Principal Advisor Professor Lars Håkansson who has taught me so much about research and signal processing. Thank you for believing in me and for all our fruitful discussions about research, work and life in general, your door has always been open for me. Special thanks also to Ingvar Gustavsson for sharing your high competence in remote laboratories. We share the same passion for implementing and improving remote laboratories for experimental work of students in science.

Thanks to all of my former and current colleagues at BTH in the department of signal processing. I particularly want to thank Kristian Nilsson and Johan Zackrisson for taking the time to discuss the design of the remote electronic laboratory and helping me with implementing hardware and software improvements of the lab. I would not have been able to do it without you. Also thanks to Imran Khan for teaching me about the remote acoustic lab. Special thanks to Linda Mattson who let me use her distance students in my research.

During my PhD studies I have worked at Katedralskolan in Lund and hereby would like to thank my students who have participated by using and giving me feedback of the remote labs. Also thanks to my colleague Roland Johansson for collaboration and participating with his students. A special thanks to Kennet Flennmark and Martin Gustavsson for your support and for letting me undertake PhD studies.

Finally, and most of all, thanks to my family; my husband Rickard and our four wonderful children Niklas, Oskar, Viktor and Tilda for support, inspiration and love. This is all for your futures.

Lund, April 2014
Lena Claesson

Table of Contents

Thesis disposition.

This thesis summarizes my work within the field of remote laboratories, conducted at Blekinge Institute of Technology. The thesis includes an introduction and parts A, B and C. The parts A, B and C have been slightly reformatted from their original publication to fit the format of the thesis but the content is unchanged.

Part A is published as:

L. Claesson, K. Nilsson, J. Zackrisson, I. Gustavsson and L. Håkansson, "Remote laboratory experiments at the Upper Secondary School Katedralskolan in LUND", *Proceedings of the Seventh International Congress on the area of remote engineering and virtual instrumentation (REV 2010)*, Stockholm, Sweden, June 2010.

Part B is published as:

L. Claesson and L. Håkansson, "Using an Online Remote Laboratory for Electrical Experiments in Upper Secondary Education", *International Journal of Online Engineering (iJOE)*, vol. 8, pp. 24-30, 2012.

Part C is published as:

L. Claesson, I. Khan, J. Zachrisson, K. Nilsson, I. Gustavsson, L. Håkansson, Chapter 7 – "Using a VISIR laboratory to supplement teaching and learning processes in physics courses in a Swedish Upper Secondary School" *in IT Innovative Practices in Secondary Schools: Remote Experiments*, O. Dziabenko and J. Garcia-Zubia (ed.), University of Duesto, Bilbao, Spain, 2013, ISBN: 978-84-15759-16-4.

Other publications.

The following work has been published during the PhD studies but is not appended to the thesis.

I. Gustavsson, L. Claesson, K. Nilsson, J. Zackrisson, J.Z. Garcia, J.U. Hernandez, L. Håkansson, J. Ström Bartunek, T. Lagö, I. Claesson, Chapter 15 – "The VISIR Open Lab Platform" in *Internet Accessible Remote Laboratories: Scalable E-learning Tools for Engineering and Science Disciplines*, M. E. Auer, V. J. Harward and A. K. M. Azad (ed.), IGI Global, 2011, ISBN-10: 1613501862, ISBN-13: 978-1613501863.

L. Claesson, Fjärrstyrt fysiklaboratorium [Remote-controlled physics laboratory], Verksamhetsbeskrivning och övningskompendium till en workshop på den fjärde konferensen om Framtidens Lärande [Activities description and exercise compendium for a workshop on the Fourth Conference on Future Learning] (Framlar 2012), Stockholm, maj 2012.

L. Claesson, Benefits and Pitfalls of Using Cloud Laboratories, Proceedings of the 17th international conference on technology-supported learning and training (Online Educa Berlin), Berlin, Germany, December 2011.

L. Claesson, An online remote laboratory for electrical experiments in education, Proceedings of the Nordic Physics day, 12th -14th of June 2013 in Lund Sweden.

L. Claesson, Elevanvändarmanual till det fjärrstyrda laboratoriet VISIR electronic lab [Student user manual for the remote electronic lab].

L. Claesson, Elevlaborationshandledningar för experiment med lik- och växelström [Student lab instructions for experiment with DC and AC circuits].

L. Claesson, Läraranvändarmanual till det fjärrstyrda laboratoriet VISIR electronic lab [Teachers user manual to the remote electronic lab].

1. Introduction

This thesis describes remotely controlled laboratories in physics education for Swedish upper secondary schools. The thesis addresses how to implement remote labs as a teaching methodology. It presents examples of experimental work of students and their evaluation of remote labs regarding usability, sense of reality and technical problems.

From a societal perspective the study originates from the recognized problem of upper secondary schools pupils failing interest in science studies. Citizens in a modern society need some understanding of the nature and scientific knowledge in order to evaluate claims that may affect their everyday decisions on health, diet and energy resources use. Another motive for this study is that the recent curricular reform [1] in Sweden has brought about a larger emphasis on experimental skills, including planning and design, as well as assessment of these skills. In school there is a need to improve and vary teaching methods. Extending experimental work in remote environments using tablets and computers to connect to the laboratory is one good alternative to attract students to physics studies.

Remote labs are becoming a major component of school teaching and learning experience since they enable students to use real equipment which is always accessible, and at a lower cost. They provide students with free experimentation resources. Students now want extended accessibility to learning resources and an increased freedom to organize their own learning activities. This means usage of communication devices and infrastructure such as learning management system for remote access to labs and other activities.

1.1 The role of experimental work in the teaching and learning of science

First, and most fundamentally, we might ask: what is science, and what are its characteristics? The distinctive characteristic of scientific knowledge is that it provides material explanations for the behavior of the material world, that is, explanations in terms of the entities that make up the world and their properties. Physics is a science that deals with the study of all experimental and measurable processes in nature, as well as their mathematical description.

Introduction

In learning physics the student seeks to understand the major elements of a body of pre-established, consensually agreed knowledge. In physics education the teachers introduce physical theories and scientific methods in a variety of teaching methods helping the students to acquire this body of knowledge. Hands-on and minds-on activities play an important role to develop the students understanding of the methods by which this knowledge has been gained. In understanding physics information and communications technology (ICT) provides useful tools for conceptual understanding, lab activities and data collecting in experiments.

In [2] the authors argue that experiments in a laboratory are an essential part of learning experience in science. Multiple objectives of the physics course can be reached through conducting experiments. The students learn how to obtain the data needed and how to interpret data. Laboratory work also develops practical skills and foster teamwork abilities. Such skills are some of the learning objectives of the Swedish physics courses in upper secondary school and available at [1].

Laboratory work is used with a number of different aims for student learning, often only implied, but not communicated, nor evaluated. The student laboratory work can be; 1) investigation, 2) verification of a formula, 3) learning the technical equipment, 4) learning scientific methods, 5) learning to ask research questions or 6) designing an experiment.

It is not expected that students at upper secondary schools discover new additions to science nor that they develop new devices. The aim is to learn laboratory workmanship and to see whether the models of physics are useful descriptions of nature or not, even if a model is imperfect.

In [3] a laboratory unit for a year 10 class that involves the students planning and conducting experiments is described. The students are subsequently encouraged to write in such a way that other students can repeat the experiment. The aim is to develop students understanding about the role of experimental work in establishing scientific knowledge. In particular, the role of communication and replication of experimental work in the acceptance of knowledge by the scientific community are emphasized. It is concluded that while teachers often emphasize the scientific aim of a laboratory task, it is equally important that students are aware of the purpose to achieve successful learning.

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 obtain the same results; variation 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, an average result can be observed more clearly.

1.2 Categories of laboratories

Educational laboratories are divided into three different categories;

1) local laboratory at school with equipment to perform hands-on laboratory work
2) remote laboratory often placed elsewhere with real equipment that is remotely controlled with a computer by the student
3) simulated laboratory, a computer simulation that can mimic laboratory procedures

There is a vivid ongoing debate about the value of the different categories of laboratories. In [4] a review of current research on laboratory education with focus on the three categories is summarized. The debate over different technologies is confounded by the use of different educational objectives, such as design skills and conceptual understanding. Today remote labs and simulations can be used as an effective replacement for hands-on labs to promote understanding and learning of concepts. The results of [5] suggest that the three types of labs are not equivalent. Conceptual learning outcomes are roughly equivalent in the traditional hands-on and technology-mediated laboratories. Regarding satisfaction, however, students often commend the convenience of remote labs but still express a preference for hands-on laboratories. In [5] it is also suggested that students may collaborate differently in remote labs, simulations, and traditional hands-on labs. Differences in the social process and the work patterns may affect cognition and learning. Such patterns play a role in determining the learning effect for the different lab formats. The study in [6] compared learning activities, learning outcomes, students rating of satisfaction and convenience for hands-on, remotely operated and simulation-based educational laboratories. The study showed that the learning effect of different lab formats may depend largely on social and motivational factors.

Local labs are still the most common ones in upper secondary schools in Sweden. But often the experimental data are obtained by information and communications technology tools, sensors connected to virtual instruments and software that display the result of the measurements. And, according to [4], many laboratories are presented by computers.

For example, at the Katedralskolan in Lund, a LabQuest measurement equipment connected to a computer [7] is used for measuring temperature with the aid of two sensors. The measurement result is displayed on the computer screen, see Figure **1**. One experiment my concern energy absorption from a lamp by one black and one white object. In such experiment the temperatures of the two objects are displayed as a function of time in a diagram on the computer screen.

Figure 1. Experiment collecting temperature of one white and one black object. In the diagram, on the computer screen, the temperature of the two objects is displayed as a function of time.

The LabQuest and different probes for measuring temperature, voltage etc., may be considered as expensive for schools. Furthermore, the interactive quality of laboratory work using such laboratory equipment may not differ much irrespective of if the student is co-located with the equipment or not.

Hence remote labs are becoming a major component of school teaching and learning experience since such tools enable students to use real equipment 24/7, and at a lower cost. Another advantage with remote laboratories is that many local laboratories do not have enough equipment to perform advanced experiments. In [8] and [9] remote labs in use worldwide are presented.

Simulated laboratories also play an important role in the teaching and learning of physics. Some advantages are that the experiment can be started, stopped, examined, re-examined or re-started under new conditions. The University of Colorado Boulder has started the very instructive Internet site PhET with many interactive simulations, covering the usual scope of physics [10]. Figure 2 shows an example of a simulation of an electrical circuit. Students can quickly and easily wire circuits, test them and process data quickly. In [11] the authors highlight a few ways how to use PhET simulations in class, based on their research and experiences using them in secondary school and upper secondary schools. The web site [12] has a more complete guide for teachers how to use PhET simulations in the classroom.

A major difference between experiments in a remote lab and a simulated lab is that in the remote lab the experimenting is carried out with real equipment and experimental objects while in a simulated lab the experimentation relies on mathematical models, etc. For instance, experimenting in a remote lab with real equipment will give different values each time a measurement is carried out while in a simulated lab the measuring of data are based on mathematical calculations usually giving the same answer to the student each time a measurement is carried out. Therefore simulated labs can serve as an introduction to a science section, verifying or investigating a formula. However, they can never serve as an investigation of truly real behavior of nature.

Another comparative study of remote labs versus hands-on is presented in [13]. The paper presents a model for testing the relative learning effect of hands-on, simulated and remote laboratories. It also presents a preliminary assessment study, comparing different versions of remote labs versus hands-on labs in a junior-level mechanical engineering course on machine dynamics.

The role of the laboratory in teaching and learning of science points out that a laboratory should involve both investigations, hands-on or remote, and also minds-on reflection [14].

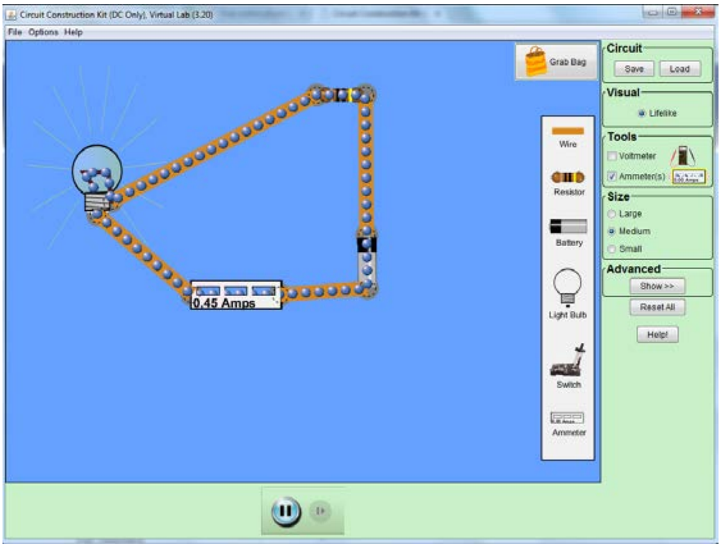

Figure 2. Simulation of a DC circuit, with an amperemeter measuring current through a bulb.

1.3 Remote laboratories

Remotely operated equipment has long been desired for use in dangerous or inaccessible environments such as radiation sites, marine and space exploration. To prepare students for future employment, a remote lab is useful. A remote laboratory generally allows students and teachers to use networks, connect with cameras, use sensors and controllers, to carry out experiments on real physical laboratory apparatus that is located remotely from the student.

Hands-on laboratories are becoming increasingly interfaced by computers. For example, an experiment may involve measuring an certain output using a computer connected via LabQuest to the experimental apparatus or components [7]. The experimental data can subsequently be analyzed with the software LoggerPro [7]. In such a case, the interactive quality of laboratory work participation may not differ much irrespective of if the student is co-located with the equipment or not.

Granting off-class access to the remote lab takes off the time-pressure on the students allowing them to conclude and repeat tasks which they were not able to finish during class. In [15] a comprehensive overview is provided on several aspects of remote development and usage, and the potential impact in teaching and learning processes with selected e-learning experience. The chapters 8-11 in [15] describe remote labs in use in the area of control systems, such as measurement of water and air flow in a heat exchanger and electrical circuits.

At present, at the department of Applied Signal Processing, Blekinge Institute of Technology (BTH), the VISIR laboratories comprise laboratory setups for electronics and signal processing. These also include experiments on mechanical vibrations and on acoustics. It is the VISIR laboratories dedicated to experiments on electronic circuits and acoustics that are currently used for students at upper secondary level at Katedralskolan in Lund, Sweden. BTH offers remote laboratories based on other principles than the VISIR platform as well; a remote lab that concerns antenna theory, and a remote lab that concerns security. The VISIR electronic lab [16] is used in the courses physics 1 and 2 at upper secondary level for remote experiments in electronics. The VISIR acoustic lab [17] is used in the same physics courses and for remote experiments in signal processing and acoustics as well.

1.4 What is a VISIR electronic lab?

VISIR means Virtual System in Reality. It was developed by the Signal Processing Department at Blekinge Institute of Technology (BTH) in Sweden [18]. The main goal of the platform is to offer an online workbench where students can perform electronic experiments remotely. The VISIR electronic lab strives to make experimentation-based learning as natural as experimenting in a real laboratory. To achieve this, there is a variety of "real-like" instruments in the following flash client modules:

- Breadboard for wiring circuits;
- Function generator;
- Oscilloscope;
- Triple Output DC Power Supply;
- Digital Multi-meter.

The experiments performed with VISIR are highly interactive and allow real-time control of the equipment. VISIR is a client-server architecture, where measurements are carried out on a server and the instrument front panels are displayed on the client computer screen [19]. Virtual front panels depicting the front panels of the desktop instruments and a virtual breadboard displayed on the computer screen can almost give distance students the impression that they are working in the real laboratory. Examples of interfaces for these instrument panels are shown in Figure 3. Users are able to interact with these instrument images, which include animated controls and displays.

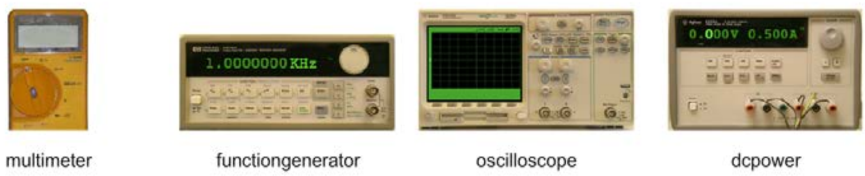

Figure 3. Interfaces of instruments at the remote electronic lab VISIR at BTH

A significant difference for remote students compared with students in a hands-on laboratory is the wiring of circuits and the connection of instruments. At a web site [20] there are video clips demonstrating how to wire circuits and use the instruments in the VISIR lab. One of the most interesting aspects of the platform is that the VISIR electronic lab features an expandable relay switching matrix, see Figure **4**, where lab instructors can attach several electrical components as well as whole circuits depending on the experiments to be performed [21]. The matrix is a card stack to make the wires as short as possible. The size of the boards is standard PC/104. A node bus is propagated from board to board. Starting from the top, the component board has a number of holes for wiring. Components with more than two leads can be installed in a 20 pin IC socket.

The teacher defines the possible branches to be installed by wires on a component board. The switching matrix is equipped with controllable switches, i.e., electro-mechanical relays. Figure 5 shows a component board where relays are placed before the resistors to switch them on and off.

With the aid of a virtual breadboard implemented as a VISIR client module, students can assemble several different circuits with different component sets available, pre-configured by the laboratory administrator. Figure 6 shows the virtual breadboard with a DC circuit, a resistor in series with an amperemeter, to measure current through the resistor. There are two Digital multimeters (DMM) which make it possible to measure voltage over the resistor as well. The task for the lab administrator is 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 Max Lists. A Max List is a list of current virtual instructor rules to prevent equipment damage. These lists should support teachers prepared experiment. The possible connections are specified in the components list.

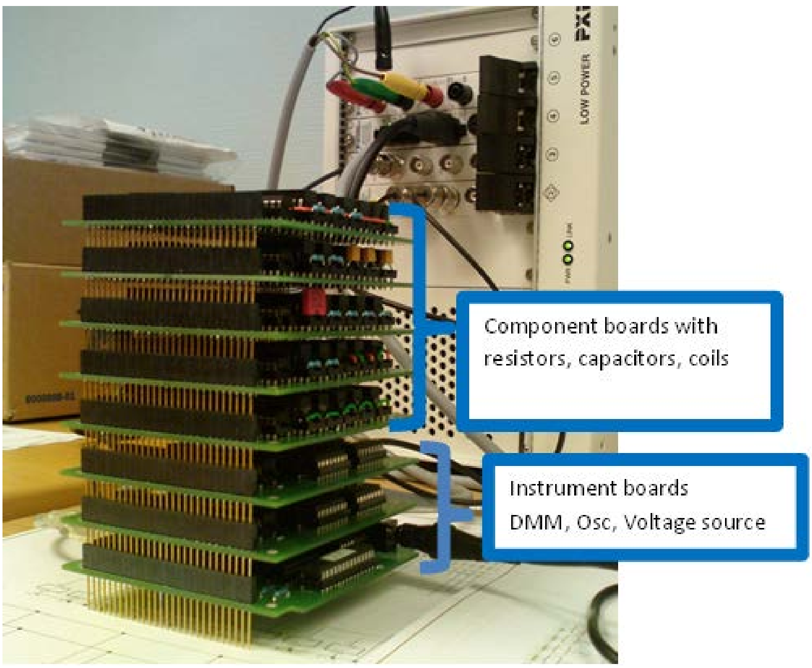

Figure 4. Switching matrix with component boards on top and instrument boards at the bottom of the card stack.

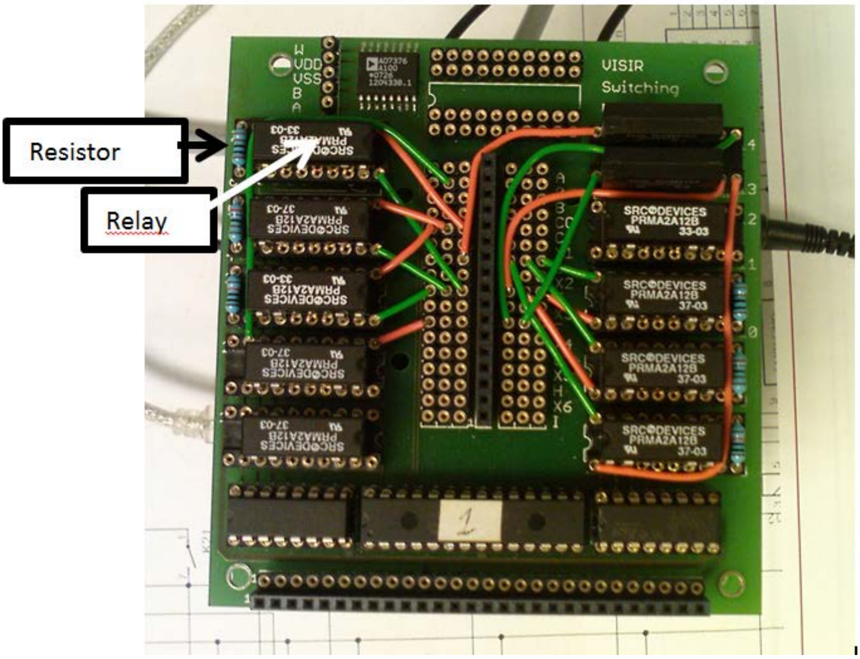

Figure 5. A component board with relays placed before the resistors to switch them on and off.

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) that students have at their disposal to construct and test circuits. Beyond this, the VISIR platform is remarkable in the interactivity it facilitates students with. Moreover, one of the most important aspects of the platform is that electronic circuits can be wired 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 students hurting themselves.

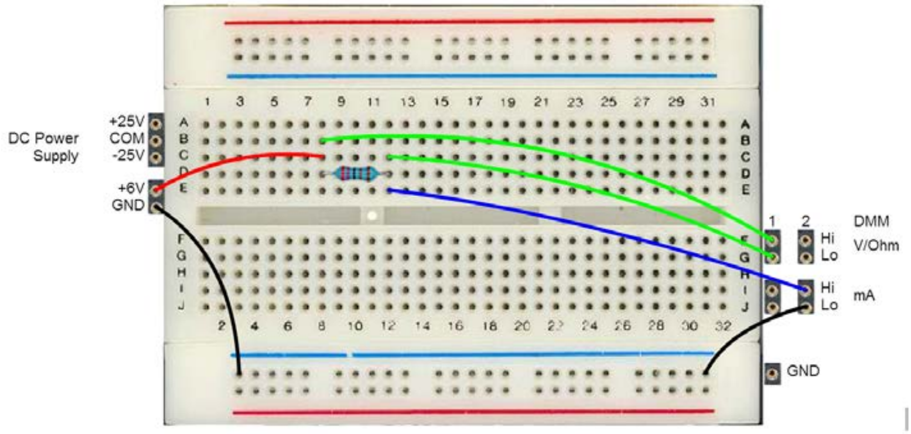

Figure 6. Virtual breadboard with connections depicted.

In the literature, several approaches to build remote labs for electronic circuits have been addressed. In [22] a remote lab is developed for measurement and monitoring of static circuits. The lab only permits changing the instrument parameters of the circuit and not the building circuits from scratch, as in the VISIR electronic lab.

Another feature of the VISIR electronic lab is that the lab allows 20 users at the same time. 20 users are not an upper limit. Therefore it is possible for students to conduct experiments or experimental exams in class. However, the VISIR electronic lab does not handle collaboration between students at different places in the same time slot. It is of course possible for the students to do collaborate work when they are in front of a computer in real life, either together or using e.g. Skype to communicate. How can a single lab equipment serve 20 users simultaneously? This is enabled by the fact that you are only connected to the remote lab server when sending your circuit layout and doing the actual measurements. You do not occupy the remote equipment when you are wiring the circuit or troubleshooting.

In [23] the authors present a remote electronic laboratory called NetLab, developed at the university of South Australia. Unlike VISIR, NetLab is from the beginning designed as an interactive collaborative environment where a number of students can access the equipment remotely from different places in the world and collaboratively wire circuits, connect and set up instruments and perform measurements. Anyone logged on has full control of the system. Since NetLab is an interactive learning environment, students are required to coordinate their actions. Unlike in a real laboratory, where students see what everyone is doing, collaboration in remote laboratory is not a trivial task. To enable this collaboration, NetLab has a number of features to support interactive collaborative work [24]. Up to three students can collaborate in the same experiment at any given time slot.

In [25] mechanical experiments are presented with springs and also experiments with light. In this laboratory, for the same experiment, only one student or a collaborating group can use the lab in each time slot. More examples of experiments using mechanical remote labs are: free falling objects, simple pendulum, natural and driven oscillations and the inclined plane, see [26] and [27].

Apart from BTH, five universities in Europa have implemented VISIR remote laboratories for electrical experiments;

1) University of Deusto, Bilbao, Spain [28], [29]
2) The National University of Distance Education, Madrid, Spain [29], [30]
3) Carinthia University of Applied Sciences, Villach, Austria [31], [32]
4) FH Campus WIEN, Austria [33]
5) Instituto Politécnico do Porto, Portugal [29], [34]

Outside Europe, the Indian Institute of Technology Madras in India has also set up a VISIR laboratory.

1.5 How can students work with a VISIR electronic lab?

When including remote labs in physics courses the teacher has several possibilities. These possibilities depend on students' knowledge in the area, the aim of the lab work and the degree of freedom that the teacher wants to allow the students.

The students can do laboratory work at school during learning hours under supervision of a teacher or at home as an alternative method to extend their knowledge.

The VISIR electronic lab is used as a complement to the traditional workbench in the hands-on laboratory. 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. Students can continue lab work at home with an assignment not finished during scheduled school time.

Another option with the remote lab for electrical experiments is that it can be used by many students performing different experiments simultaneously. Moreover, it is convenient to use remote labs for exams with exercises of experimental work. The hands-on lab can serve as an introduction and be used for experiments not available in the remote lab such as experiments with a bulb or experiments using analog instruments for measuring currents and voltages.

Before the students start to use the remote lab it must be introduced by the teacher. If the students already have used electronic equipment in a hands-on lab they only need a small presentation of the VISIR electronic lab web interface and an explanation on how to use it. Further, help for the student is provided by manuals on the web.

How can students work with the remote lab?

a. As a listener when the teacher uses the VISIR electronic lab for demonstrating a phenomenon, see Figure 7. An option with the remote lab for a teacher is to integrate experimental work in a theory lecture by logging on to the VISIR laboratory web site and carry out remote experimental work in real time during the lecture. Thus, the theory for electronic circuits may be confirmed with experiments from the remote lab also during theoretical lectures.

b. Pre-designed circuits in the VISIR electronic lab breadboard can be used for the students to learn the instruments which measure current and voltage. In this case the students do not need knowledge about making connections and their interaction with the platform is minimal.

c. Lab instructions with pre-defined circuits to be constructed by the students. For this choice the students need knowledge on how to design circuits for different tasks. The degree of freedom is bound to a restricted number of components defined by the teacher. In this way the interaction between student and VISIR is visible and the student experience is similar to a hands-on experiment.

d. Students are allowed to choose the circuit elements on their own. Students can independently solve any application by themselves. To solve the lab assignment, the 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 that will allow the measurement. This option is generally possible in a VISIR electronic lab, but has not been used yet for students at Katedralskolan. However, the teacher can use this option to prepare a lab assignment with a set of components available for the students.

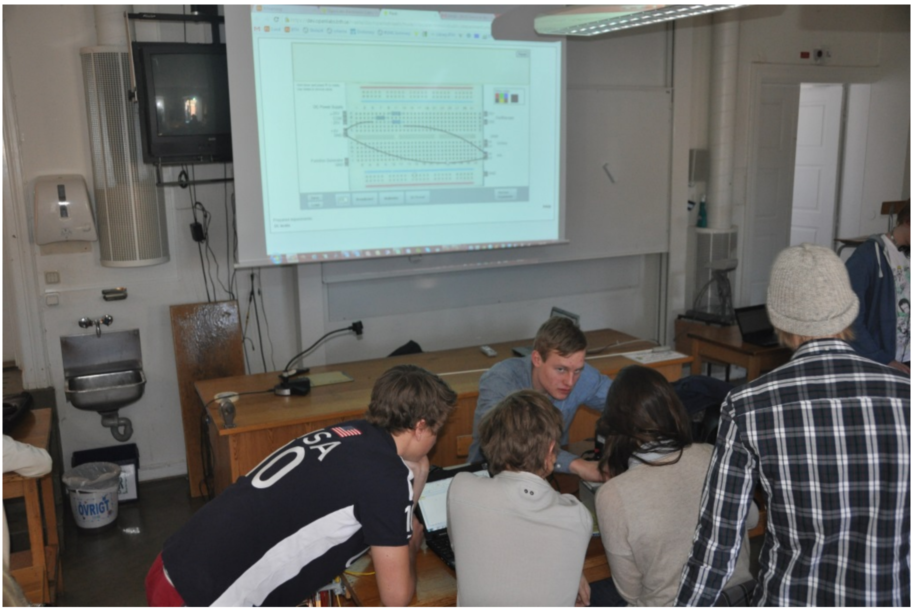

Figure 7. The teacher uses the VISIR electronic lab to demonstrate circuit design.

1.6 Teaching with a VISIR electronic lab compared to a hands-on lab.

In Figure 8, a group of students is shown working with traditional electronics equipment in a hands-on laboratory. There are ten workbenches in a typical classroom for physics studies. Very simple breadboards are in use to connect the resistors. In Figure 8, the web interface for this equipment is also shown. The bulb is not implemented in the remote lab, because the warm-up time for a lamp is too long to enable relevant measurements of the current through it. Most instruments in the remote lab have a remote control option but the solderless breadboards do 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 matrix is shown in Figure **4**. Virtual front panels depicting the true front panels of the desktop instruments and a virtual breadboard displayed on the computer screen can give distance students the impression that they are working in a real laboratory.

The bulb and the resistors at the left in Figure 8 belong to the component set delivered by the teacher. Except for the bulb, these are installed in the component sockets of the matrix, see Figure 5. When the students make a lab assignment choice in the remote lab, a set of virtual components provided for that lab assignment is displayed in the area of components, shown at the right in Figure 8. The teacher has beforehand, as in a hands-on lab, prepared a lab assignment with a set of components available for the students. A hands-on lab is time-consuming in preparing components and instruments for each lab session. In the remote lab you do this preparation only once and you can reuse the setup avoiding a waste of time.

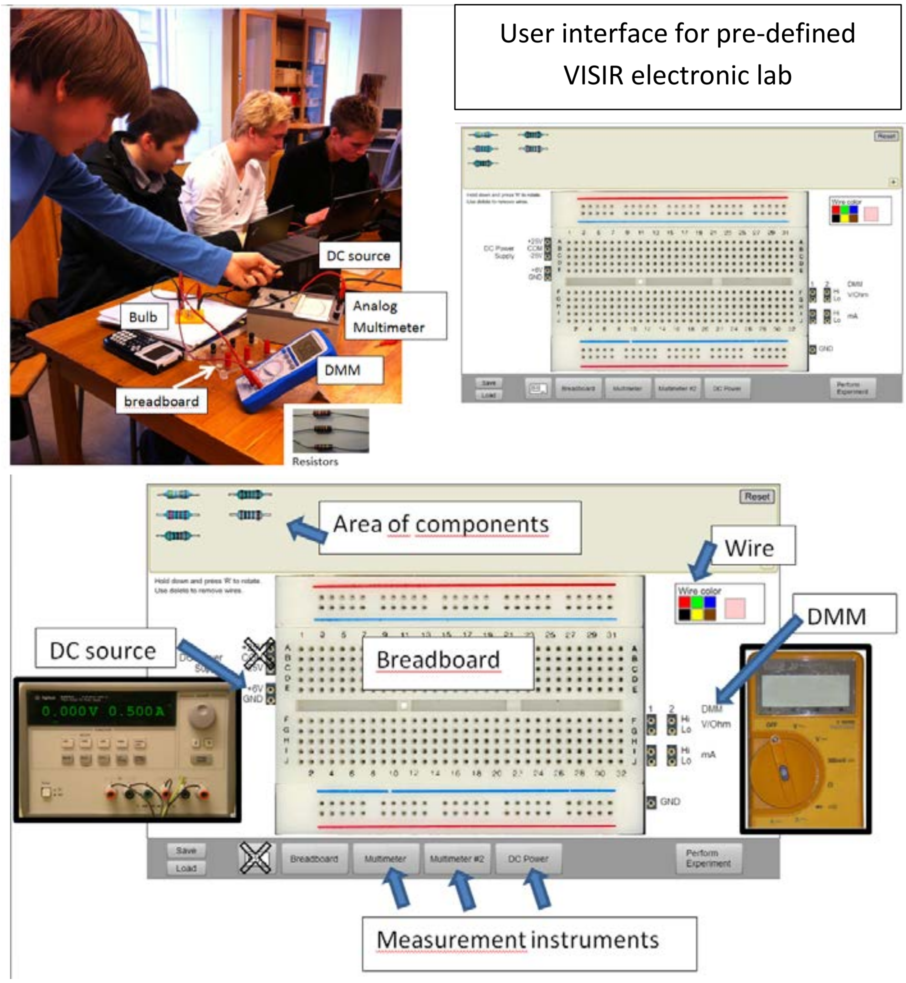

Figure 8. Top left; some students working in a pre-defined hands-on lab.
Top right; the user interface for pre-defined VISIR lab.
Bottom; snapshots of instrument interfaces placed at connection points in VISIR electronic lab.

1.7 The VISIR acoustic lab

The VISIR acoustic lab is a novel and unique laboratory setup developed by BTH on the foundations of VISIR with some modifications demanded by active noise control (ANC) applications. The laboratory is designed to support experiments in the fields of 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. The laboratory setup is divided into two main categories, i.e., the actual hardware or equipment in the laboratory and the graphical user interface presented remotely to the user on the computer screen for configuration and control of the equipment. Figure 9 illustrates what is displayed on the client computer screen when entering the acoustic lab web site. In [17] the VISIR acoustic lab is described and in [35] the latest important developments are presented.

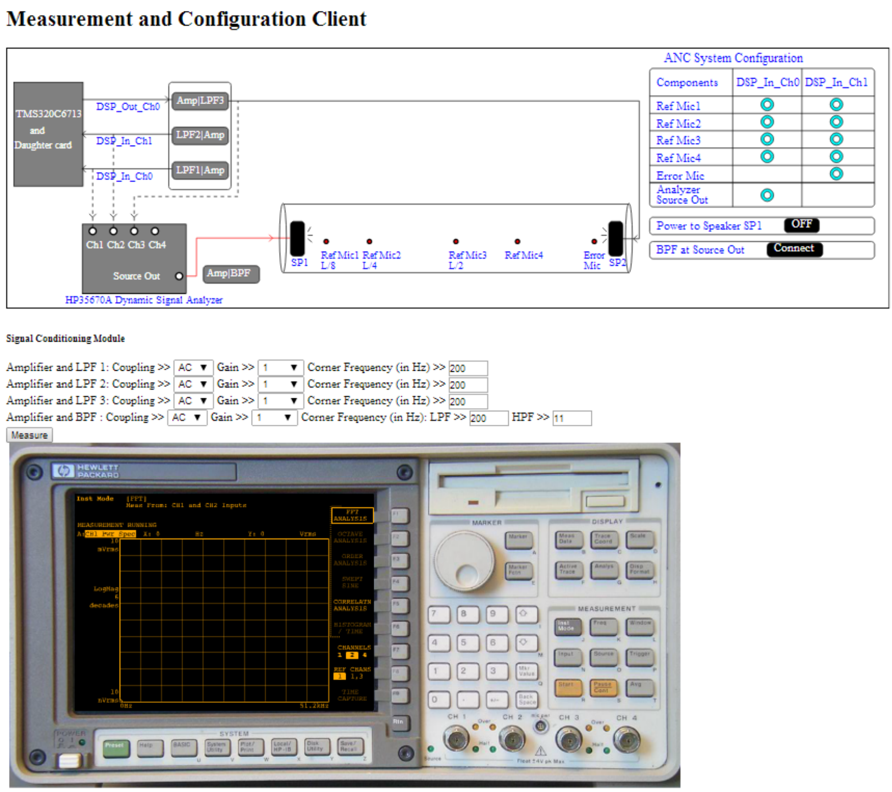

Figure 9. A snapshot of the remote acoustic lab measurement and configuration client.

2. Summary of appended parts

The thesis in applied signal processing has a focus on development and design of remotely controlled laboratory experiments in science for upper secondary school and university with emphasis on didactics. The aim of the thesis is to develop strategies and methods for implementation of remotely controlled laboratory experiments in education with the purpose of increased quality and education efficiency, as well as the stimulation of student interest in science. This section presents a summary of the appended parts.

2.1 Part A - Remote laboratory experiments at the upper secondary school Katedralskolan in Lund

Part A is published as:

L. Claesson, K. Nilsson, J. Zackrisson, I. Gustavsson and L. Håkansson, "Remote laboratory experiments at the Upper Secondary School Katedralskolan in LUND", *Proceedings of the Seventh International Congress on the area of remote engineering and virtual instrumentation (REV 2010)*, Stockholm, Sweden, June 2010.

Summary:

The aim of this paper was to introduce and use the online workbench for electrical experiments created at BTH for the students at Katedralskolan in Lund. The remote lab gives the student laboratory experience that is as genuine as possible, despite the lack of direct contact with the actual hardware.

The teacher in this study first had to learn the remote VISIR electronic lab system to be able to act as an administrator. There are three different levels of access to the remote lab system, administrator, teacher, and student. The administrator is responsible for the general management of the system; he/she creates courses and decides the limitations of resources for this course. As a teacher you are responsible for a course and handle all administrative tasks concerning the course such as registering students and preparing experiments.

Two groups of students have carried out online laboratory experiments in this study. These experiments have been prepared in advance with theory lessons and real experimental work, in a hands-on lab. Hands-on laboratory work is used at an early stage to build confidence in remote technology used in later teaching. When a student is familiar with the real instruments and components and has done some hands-on experimental work in school the online laboratory can be conveniently used for;

a) further investigations of new laboratory assignments,
b) the finishing of an unfinished laboratory experiment,
c) preparations for an exam.

At this time, 2010, the students did not have a computer of their own. The school was equipped with forty computers divided between two classrooms. The computers were available in a booking system for the teachers at school. Group 1, first year students, carried out experimental work on direct current. The assignments were;

a) Investigate if the current is the same before as after a component. A common conception is usually that an electric current is "used up" in a component.

b) Investigate the relationship between voltage and current for a resistor. The students have experience from an initial hands-on lab with a bulb instead of a resistor. The task was to compare the results from a bulb with a resistor.

c) Find out how voltage is distributed over resistors in a series connection. Calculate the total resistance (sum of the resistors in series) and check by measurements of the current and check by calculation.

d) Find out how the voltage and current are distributed in a parallel connection of resistors. Calculate the total resistance in the circuit and the current in main wire and then compare with measured current.

Group 2, third year students, performed laboratory experiments on alternating current.

a) The first assignment was how to use and read the remote oscilloscope.
b) The next task was basically to investigate how the impedance depends on frequency for capacitors and coils.

The remote laboratory work was evaluated with a questionnaire. The majority of the students were satisfied. The students showed great interest in the laboratory experiments, and appreciated that it was not simulations but took place in reality. However, a few students did not realize that it was real experimental work. The success of utilizing remote labs in the education is likely to be related to, e.g., the engagement of the students, the level of entertainment it provides and how convenient it is to use.

Contribution of Author:

The author led the development and writing of the paper and also presented it at the REV conference in Stockholm, Sweden, in June 2010.

2.2 Part B - Using an online remote laboratory for electrical experiments in upper secondary education

Part B is published as:

L. Claesson and L. Håkansson, "Using an Online Remote Laboratory for Electrical Experiments in Upper Secondary Education”, *International Journal of Online Engineering (iJOE)*, vol. 8, pp. 24-30, 2012.

Summary:

This paper continues the work in paper A with one more teacher involved and three more groups of students. In total two teachers and 94 students at Katedralskolan participated. It describes the activities carried out by teachers and students using the remote laboratory VISIR. Examples of students remote laboratory work are presented. A difference from the first study is that in this study some of the student groups had access to a computer of their own. Another difference is that the students now had access to supplementary material, such as videos and instruction manuals on the web.

The web sites used for institutional and teaching and learning purposes at Katedralskolan in Lund are presented. It is possible to launch the remote lab directly from the learning management system. All the steps that a teacher needs to prepare before a remote assignment are described. The students utilize the application program Excel with results from the remote lab for presenting their results, yielding tables and diagrams for the lab report. A typical practical student session in VISIR is described with the four steps; configure the circuit, configure the instrument (DMM), run the experiment, and analyze and document the results.

Most of the students managed to finish the laboratory assignment in school during a three hour lab-session in physics. The rest completed the assignment at home. The amount of accesses per student indicates a typical student usage of the VISIR laboratory during outside scheduled hours. It was compulsory for each student to write a lab report, where they had to include theoretical calculations, VISIR laboratory measurements, and screen dumps of the circuits.

One group had exams with exercises of experimental work using the VISIR electronic lab. They had to do the experimental assignments in 75 minutes. Every student downloaded a lab instruction guide from the Itslearning describing the three experimental assignments in the exam, one assignment for a DC circuit and two assignments for an AC circuit. They had to document the measurements from the VISIR laboratory with a screen dump, and also upload a screen dump of the circuits into the lab instruction guide.

After the sessions a questionnaire was passed to the students to acquire their opinion about the VISIR remote electronic lab. The questionnaire has 13 items and covers four characteristics of a remote lab; 1) usability, 2) sense of reality, 3) usefulness and 4) quality of the service. VISIR is accepted by the students as a good learning tool. Usefulness and usability get high marks considering the fact that not all students at this age have developed an interest in electrical and electronic circuits.

Contribution of Author:

The author led the development and writing of the paper and also presented a slightly different first version of the paper at the 1st Experiment@ International Conference in Lisbon, Portugal in November 2011.

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

Part C is published as:

L. Claesson, I. Khan, J. Zachrisson, K. Nilsson, I. Gustavsson, L. Håkansson, Chapter 7 – "Using a VISIR laboratory to supplement teaching and learning processes in physics courses in a Swedish Upper Secondary School" in *IT Innovative Practices in Secondary Schools: Remote Experiments,* O. Dziabenko and J. Garcia-Zubia (eds.), University of Duesto, Bilbao, Spain, 2013, ISBN: 978-84-15759-16-4.

Summary:

In this book chapter improvements and augmentations of the VISIR electronic lab at BTH are described. The results from a survey at Katedralskolan concerning the satisfaction with the VISIR lab at BTH and the perception of it resulted in a proposal of improvements in its user interface. The improvements were implemented and from now on only the instruments that are actually used in the experiment are shown in the user interface. Another improvement is that there are two DMMs available; this is used in experiments concerning Ohm's Law.

In the enhanced version of the VISIR electronic lab you can choose to use flash or html5. Html 5 is working on handhold devices e.g., iPad and smart phones. The new tools in html5 also allow you to use the front panels in new ways, such as several front panels on the same web page. The use of handheld devices with touch screens also makes it possible to investigate the interaction with your fingers.

Electronic experiments are described in detail with questions addressing the students. Examples of students' circuit configurations are shown.

The VISIR acoustic lab is described and several acoustic experiments are possible on the HVAC duct, primary speaker, microphones and the signal analyzer setup. The students can generate a sinusoidal signal from the signal analyzer, measure the signal using a microphone and display the same sound on the signal analyzer. The experience so far is that the signal analyzer is technically too complicated for upper secondary school students. Improvements in the acoustic remote lab user interface are necessary. Another enhancement would be to make it possible to listen to the generated sound from the signal analyzer.

Contribution of Author:

The author led the development and writing of the chapter.

3. Conclusion and future work

This thesis describes how remote labs can be used in upper secondary school education and it shows that it is possible to use the remote labs as a replacement and/or complement to hands-on labs. Traditional hands-on laboratories have always played an important role in physics education and for some students, not all, it is a good learning environment. However, in school the students have limited access to traditional laboratories. If the school offers access to remote laboratories 24/7 there will be more students attaining the learning objectives of the course. Maybe even some students that are not initially interested in the subject area might be attracted. This thesis includes examples of electronic and acoustic experiment suitable for upper secondary school where the remote lab is a popular way to explore physical phenomena. The main observation of the project is that the remote laboratory is easy to implement and use by both teachers and students. It is possible to integrate with the existing learning management system of the school. However, pitfalls are accessibility and lack of an available a teacher when students make failures. A virtual instructor can never replace a "real" teacher. Another disadvantage is the flexibility of placing components in a circuit.

An issue that seems to be of importance to address in future work is to further improve the remote electronic lab with optional location of components when designing circuits. Another is the developing of strategies and methods for implementation of remotely controlled laboratory experiments in mechanics for upper secondary schools. Further work includes more experiments and the carrying out of more evaluations concerning usage and experience of the remote laboratory. Other work includes update and expansion of the remote acoustic laboratory for secondary school. The part describing evaluations that have been carried out concerning student usage and experience of the remote laboratory in electronics in the distance course, FY1105, will be further compiled and analyzed.

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Part A

Remote laboratory experiments
at the upper secondary school
Katedralskolan in Lund

Part A is published as:
L. Claesson, K. Nilsson, J. Zackrisson, I. Gustavsson and L. Håkansson, "Remote laboratory experiments at the Upper Secondary School Katedralskolan in LUND", *Proceedings of Seventh International Congress on the area of remote engineering and virtual instrumentation (REV 2010),* Stockholm, Sweden, June 2010.

Remote laboratory experiments at the Upper Secondary School Katedralskolan in LUND

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Abstract—This paper is intended for people who are interested in using online remote laboratories in education. Blekinge Institute of Technology (BTH) have started a cooperation together with the Upper Secondary School, Katedralskolan, in Lund, Sweden. The purpose of the cooperation is to introduce remote laboratory environment for students at Katedralskolan. A remote laboratory (RL) in electronic is used as a complement to the traditional workbench. It is open 24/7 and the students can carry out laboratory assignments without any risks of damaging any equipment. When a student is familiar with the instruments and components in a laboratory assignment, and carried out parts of the experiments in the hands-on laboratory in school she/he may use the RL to finish the laboratory assignment. The students may also carry out additional experiments remote laboratory or use it to prepare for an exam.

Index Terms— education, electronics, remote laboratory,

I. INTRODUCTION

In January 2009 a project started at the upper secondary school, Katedralskolan Lund, Sweden, together with Blekinge Institute of Technology (BTH), Sweden. The initial purpose of the project is to introduce and use the online laboratory workbench for electrical experiments created at BTH for the students to Katedralskolan.

BTH has opened a local instructional laboratory for undergraduate education in electrical and electronic engineering for remote operation and control 24/7 as a complement and a supplement to traditional laboratories. It is equipped with a unique virtual interface enabling students to recognize the desktop instrument and the breadboard on their own computer screen most of them have already used in the local laboratory. The open laboratory is used in regular courses in circuit analysis for distant learning students from all over Sweden and for campus students as well. The RL gives the students laboratory experience that is as genuine as possible despite the lack of direct contact with the actual laboratory hardware [1].

A detailed description of the BTH Online remote laboratory is e.g. given in [2]. The Online remote laboratory is already frequently in use at BTH and one of the objectives with this project is to develop it to suit upper secondary level. The research is focused on development and design of remotely controlled laboratory experiments in science suitable for upper secondary school. Nowadays, when students have access to computers both in school and at home it is both necessary and a challenge to change the pedagogy so that computers become a natural part of the education.

It is of great importance for upper secondary school to maintain regular contact with universities. The students should get knowledge about how research is carried out and have the opportunity to meet researchers. The Katedralskolan have active and interested students who should be up to date with the latest developments in Information and Communication Technologies (ICT). The interest and knowledge of the students in science is, however, decreasing. By using computer environment in the education we can hopefully increase the students' interest for science studies.

The students still prefer face to face education. The success of utilizing ICT in the education is likely to be related to e.g. the engagement of the students, the level of entertainment it provides and how convenient it is to use.

II. KATEDRALSKOLAN AND EDUCATION IN SWEDEN

Katedralskolan in Lund is the oldest school of Scandinavia, see Fig. 1. It was founded by the Danish king Canute in 1085. In 1985 during the last week of May the school celebrated its 900th anniversary by a visit by the King and Queen of Sweden and the Queen of Denmark. The school was housed in buildings fairly close to the Cathedral until 1837 at which time it was relocated to its present premises at Stora Södergatan. Today Katedralskolan in Lund is a modern upper secondary school. The number of students is approximately 1200. The number of teachers is about 120 and the number of staff with other types of employments is 40.

Figur 1. Katedralskolan in Lund, Sweden

Upper secondary schools, in Sweden, are divided into 17 different national programmes with centrally defined programme curricula that have between two and four centrally defined orientations. The programmes are divided into two general categories, preparatory and vocational programmes. All programmes provide basic qualification's to attend university, while the preparatory programmes typically satisfy a broader range of different special qualifications that may be required to attend some university courses and programmes. The students at Katedralskolan are distributed amongst four different programmes of study as follows:

3-year National Programmes

- Natural Sciences Programme, 510 students
- Social Sciences Programme, 440 students
- Business Administration Programme, 120 students

3-year International Programme

- International Baccalaureate, 130 students

The courses that a student takes depending on programme and orientation, and can be divided into four levels: Core subjects, programme-specific subjects, orientation subjects and individually selected courses. Core courses are courses that everyone, regardless of programme, has to study to satisfy the requirements for a student degree. Programme-specific courses are the additional courses that a student is required to take to fulfil the programme requirements [3].

The students at the science programme, a preparatory programme, study two courses of Physics; Physics A is a programme-specific course and Physics B is an orientation course. These courses add up to ten percent of the Natural Sciences Programme courses.

In physics A the students study mechanics, thermal physics, optics, electric currents and potential difference. Physics B concerns electric and magnetic fields, electromagnetic induction, alternating current, oscillations and waves, wave phenomena, atomic and nuclear physics, momentum, motion in circles, two dimensional motions.

Four grades in the examination are currently used in upper secondary school: Did Not Pass (*Icke Godkänd* (IG)), Pass (*Godkänd (G)*), Pass with distinction (*Väl Godkänd (VG)*) and Pass with special distinction (*Mycket Väl Godkänd (MVG)*). The grades are usually referred to by their abbreviation. The Swedish educational system is regulated by the Government of Sweden and the National Agency for Education has published criterions for all courses [4]. The criterions for the grades in the physics courses contain theoretical and practical knowledge. It is a general agreement that laboratory lessons are necessary in subjects such as physics, chemistry and biology.

III. LABORATORY EXPERIMENT AT KATEDRALSKOLAN

The size of the class at Katedralskolan is maximum twenty students in the science courses. In all science-classrooms it is possible to have hands-on laboratory work. The teacher can decide when it is suitable in the course to have hands-on experimental assignments. Two classrooms are equipped with computers for the students. In august 2010 all the new students will have a personal computer provided by the school.

In a typical classroom for physics at Katedralskolan there are ten workbenches allowing a number of students to perform experiments simultaneously supervised by one teacher. In science-courses at Katedralskolan there are maximum twenty students in the group, which gives two students at each workbench. All instruments and components for all type of experiments are in a cupboard in the classroom. Before the hands-on experimental work is started the teacher or the students have to take out all instruments and components required for the laboratory assignments. Fig. 2, shows a workbench prepared for electronic laboratory experiment.

Afterward all the instruments and components must be returned back into the cupboards. Furthermore in practical exams each student has his or her own workbench.

Figure 2. Workbench prepared for electronic labs.

Fig. 3, shows a group of students carrying out laboratory experiments in a classroom at Katedralskolan. The students performing the circuit wiring with voltage source, three resistors, a digital multimeter and an analog multimeter. In the topics electric currents and potential difference the students learn about the components and electrical circuits.

Figure 3. Classroom at Katedralskolan, Lund, Sweden.

IV. REMOTE LABORATORY EXPERIMENTS.

Only Internet access and a web browser with a Flash player are required to access the experimental resources. The client software is automatically downloaded from a web server. The equipment provided comprises a dual channel oscilloscope, a function generator, a multimeter, a triple DC power supply, the switching relay matrix, and a number of components such as resistors, coils and capacitors installed in the matrix.

As in a hands-on laboratory experiment, every student is provided with a set of components in each laboratory experiment. The set is displayed in a component box on the top of the virtual breadboard.

Fig. 4, shows an online workbench at BTH. The workbench is equipped with a unique virtual interface enabling students to recognize the desktop instruments and the breadboard they have already used in the local laboratory on their own computer screen. The physical breadboard, widely used in electronics laboratories, cannot be controlled remotely. It has been replaced by a telemanipulator, i.e. a switching relay matrix, which the student can control by wiring on a virtual breadboard. This breadboard displayed on a student’s computer screen is shown in the Fig. 5. Unfortunately the breadboard is not so widely used at Katedralskolan. In Fig. 2, the plastic board, with red and black sockets, that usually replaces the breadboard at Katedralskolan is shown.

When the user has made all wiring and setting of the instruments she presses the “Perform Experiment” button to send them to the workbench, which creates the desired circuit and performs the experiment in fractions of a second. The result is returned to the user. A timesharing scheme allows many users to experiment simultaneously i.e. the workbench is equivalent of a laboratory equipped with many traditional workbenches. The switching matrix for remote wiring of electrical circuits is shown in the upper left side of the photograph in Fig. 4. The card stack contains two types of boards, one for components and one for connecting instruments. The PCI eXtension for Instrumentation (PXI) chassi is manufactured by National Instruments.

Many virtual laboratories have been developed to help students gain understanding of new concepts by simulating physical systems. Although simulation is a useful and convenient teaching tool it is a poor replacement for real experimental work. Remote laboratories in electronics are not replacements for practical laboratories; it is a complement to traditional workbenches. They are open 24/7, and the students can carry out laboratory assignments without any risk of damaging any equipment.

When a student is familiar with the instruments and components and have done some hands-on experimental work in school they can e.g. use the online laboratory to finish an unfinished laboratory experiment that took place in school. Further investigations of different laboratory assignments or using remote laboratories for preparations before an exam are other examples of the strengths of a remote laboratory.

V. THE TEACHERS PREPARATIONS BEFORE A REMOTE LABORATORY EXPERIMENT

There are three different levels of access to the RL-system, administrator, teacher, and student. The administrator is responsible for the general management of the system; he/she is creating courses and deciding the limitations of recourses for this course. The system are built in a hierarchy, the administrator are overruling both the teacher and the students settings. As a teacher you are responsible for a course and handle all administrative tasks concerning the course such as registering students [5].

Entries for each course are: Name of the course, Start and end date, Maximum number of students and instructors, Log in id of the teacher of the course.

Figure 4. Equipment server.

The first task, for the teacher, is to produce an instruction manual for the experiment. Subsequent, the teacher checks the available components in the

RL. If the set of components in the RL is insufficient; the teacher has to contact the administrator, who equips the matrix with required components.

The second task is to upload the instruction manual, laboratory instructions and the url-link of the RL to a Learning Management System (LMS).

The third task is to upload a list of login ids equal to mail-addresses of the students attending the course to the RL. Katedralskolan has a mail system where you can find all the students E-mail-addresses and copy them to the web interface of the RL.

Students registered on a course are permitted to log on and to start any of the laboratory sessions of that course during the entire course period when no supervised session is taking place. The results of the experiments performed are reported to the LMS in the same way as in the traditional laboratory.

VI. EXAMPLE OF LABORATORY EXPERIMENTS AT KATEDRALSKOLAN

Two groups of students at Katedralskolan have carried out online laboratory experiments. These experiments have beforehand been prepared with theory lessons and real experimental work for the students.

Group 1, first year students, carried out experimental work on direct current. Many students at this level don't know that the current is the same, in the circuit, before and after a component. This is e.g. possible for them to check out. Another assignment was to find out the relationship between voltage and electric current, the Ohm's Law, for a component (resistor or conductor) that behaves according to Ohm's law over some operating range. This is a basic law within electricity. Ohm's Law is useful in all kind of electronics and electric work. The other assignment was to investigate Kirchhoff's voltage and current law and to find the magnitude of resistors in series and parallel circuits. Resistors which are in series or in parallel may be grouped together into a single "equivalent resistance" when are analyzing the circuit using Ohm's law. The students first calculated the values of the currents if a multimeter is located at the different positions, A1, A2 and A3, as shown in Fig. 6 and then they calculated the voltage $U_{A\text{-}C}$, $U_{A\text{-}B}$, $U_{B\text{-}C}$ see Fig. 7. The students then measured currents and voltages with the RL and compared with the calculated values.

Group 2, third year students, performed laboratory experiments on alternating current. The first learning objects was how to use and read the remote oscilloscope. The next task was basically to investigate the impedance at different frequencies for capacitors and coils. Relative phases between voltages for the components can be read of the remote oscilloscope screen. The latter group was divided into two halves. One half group carried out the laboratory experiments online at school with the supervision of a teacher, while the other half made the laboratory experiments as homework, with the RL, without help from the teacher.

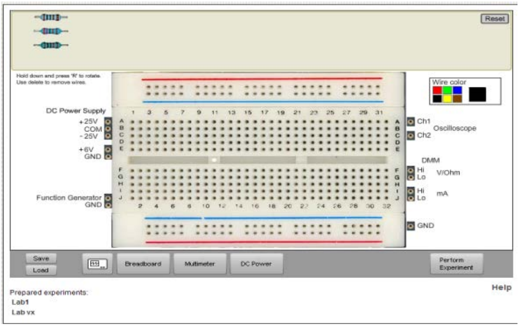

Figure 5. Virtual breadboard

VII. EVALUATION

The remote laboratory work were evaluated with a questionnaire, see Table 1. The majority of the students were satisfied. The students showed great interest in the laboratory experiments, and appreciated that it was not simulations but happened in real life. Although a few students did not realize that it was real experimental work and they wondered why they got different result from measurements, in a sequence, when they use the Perform Experiment button, see Fig. 5.

There were no significant technical problem; the students experienced no technical internet connection problems during the experiments. The online laboratory experiments were all possible to carry out according to the schedule

Answers from students; Q12, see table 1.:

Gr. 1 Remote access to the laboratory enable you to perform physical experiments with similar instrument and components at home as in school. It feels trendy using the online remote laboratory and safe to know that you cannot destroy any equipment. It is easy to use, feels like working in reality and you wire a circuit very quickly. The framework and the concept.

Gr. 2 Available. Easy to use. The devices front panels are similar to the devices front panels of school. Funny. New idea. It is pleasant wire the circuits. You can perform experimental work at home. It is a real experimental work, which is more motivating and makes the assignment funnier.

Answers from students; Q13, see table 1.

Gr. 1 A help-square where you can read about the science-theory.

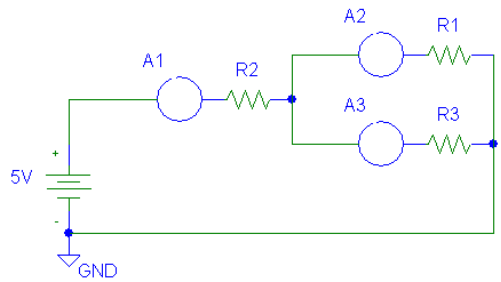

Figure 6. Circuit for an assignment for thirst year students

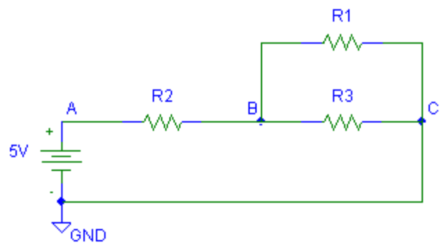

Figure 7. Circuit for an assignment for thirst year students

Gr. 2 Make it possible to see all the devices front panels at the same time. A guide available when you have trouble with the wired circuit. Make it possible for several students to perform experiments together, collaborative working. Increase the feeling of reality with a webcam. Instruction manual for the breadboard

VIII. CONCLUSIONS AND FUTURE WORK

Traditional laboratories have always played an important role in physics education and for some, not all, students it is a good learning method. In school the students have limited access to traditional laboratories. If the school offer them access to remote laboratories 24/7 there will be more students attaining the objectives of the course. Maybe we even can attract some students, who not from the beginning were interested in the subject.

Future work will be; Study the relative phase for current and voltage in a circuit with coils. Make it possible for the students to carry out experimental works on components e.g. a light bulb who do not follow Ohm's Law. A light bulb is not possible to place in the matrix, because the time of measure is too short for the bulb to warm up. However there are other components that don’t follow Ohm’s Law. Transfer the online workbench to other subject fields, for example, the mechanical or optic phenomena. Disseminate the RL to other upper secondary schools. Improve usability for the RL; Learnability: How easy is it for users to accomplish basic tasks the first time they encounter the RL, Efficiency: Once users have learned the RL, how quickly can they perform tasks? Memorability: When users return to the RL after a period of not using it, how easily can they re-establish proficiency? Satisfaction: How pleasant is it to use the RL?

Table 1. Results of the Questionnaire for VISIR-BTH in 2009-2010

	Results of the Questionnaire for VISIR-BTH in 2009-2010	Gr. 1	Gr. 2
	Surveys/Number of students in the course	15/18	14/15
Q1	I have enjoyed using the remote laboratory.	3,0	3,0
Q2	The remote laboratory helps me with my hands-on laboratory work.	3,0	3,4
Q3	I have been motivated by the Remote laboratory to learn more about the subject.	2,6	2,7
Q4	It is a good idea to extend this remote laboratory to all the students.	4,2	4,0
Q5	Using the remote laboratory, I feel it is real and not a simulation.	2,8	3,1
Q6	I would like to have a webcam to see something at the remote laboratory.	3,2	2,7
Q7	Being far from the remote laboratory, I have felt myself to be in control of it.	3,0	2,9
Q8	The remote laboratory is easy to use the first time.	3,0	2,6
Q9	The different devices are easy to use.	3,6	4,6
Q10	The devices front panels at the remote laboratory are similar to our schools real devices.	3,8	3,4
Q11	Always when I logged in to the remote laboratory I got access to it.	3,6	3,7
Q12	State two things you think are positive with the remote laboratory.		
Q13	Suggest two things that would help your teacher to improve the remote laboratory.		

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Part A

Part B

Using an online remote laboratory
for electrical experiments
in upper secondary education

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Using an Online Remote Laboratory for Electrical Experiments in Upper Secondary Education.

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Abstract—The use of remote laboratories in courses at university level has been reported in literature numerous times since the mid 90's. In this article focus is on activities carried out by teachers and students, at the Upper Secondary School Level, using the remote laboratory VISIR (Virtual Instrument Systems in Reality). The Upper Secondary School, Katedralskolan in Lund, Sweden, cooperate with Blekinge Institute of Technology, Sweden, in a project that concerns the introduction of remote laboratory environment suitable for Upper Secondary School science courses. A remote laboratory in electronics has been introduced and is used as a complement to the traditional workbench in the hands-on laboratory. Significant results from the project are; 1) the great interest shown by the students for the remote experiments, 2) the students appreciation for the fact that it was not simulations but actual real experiments, 3) the remote laboratory is easy to implement for use by both teachers and students and 4) it can be used simultaneously by many students.

Index Terms—*; e-learning, experimental work, learning assessment, remote laboratories*

I. Introduction

In January 2009 started a project at the upper secondary school, Katedralskolan Lund, Sweden, together with Blekinge Institute of Technology (BTH), Sweden. The purpose of the project is to develop and to introduce a remote laboratory, suitable for science courses in upper secondary school, based on the online remote laboratory workbench, VISIR laboratory, created at the BTH. The VISIR laboratory is a remote laboratory (RL) created in a project called VISIR (Virtual Instrument Systems in Reality). VISIR aims at forming a group of cooperating universities and other organizations, a VISIR Consortium, creating software modules using open source technologies for online remote laboratories and/or setting up online remote laboratories. At present, the department of Electrical Engineering, BTH, has four different remote laboratories, in different areas, such as antenna theory, electronics, security and vibration analysis. It is the RL dedicated to experiments on electrical and electronic circuits that is currently used in the project between Katedralskolan and BTH. Its architecture and characteristics are well described in several books and articles [1-5]. Apart from BTH, five universities in Europe have set up VISIR online laboratories for electrical experiments, 1) University of Deusto, Bilbao, Spain, 2) The National University of Distance Education, Madrid, Spain, 3) Carinthia University of Applied Sciences, Austria, 4) FH Campus WIEN, Wien, Austria and 5) Instituto Politécnico do Porto, Portugal [6-8]. The Indian Institute of Technology Madras in India will set up one soon. A VISIR community has also been established.

VISIR is a client-server architecture, where measurements are carried out on a server and the instrument front panels are displayed on the client computer screen [5]. A significant difference for a remote student compared with a student in a hands-on laboratory is how to wire circuits and how to connect instruments. A remote student uses a suitable telemanipulator instead of a solderless breadboard to perform such actions [3]. VISIR specifies a relay switching matrix and a virtual breadboard combination [3]. 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 matrix by controlling relays to setup appropriate electrical connections. Only Internet access and a web browser with a Flash player are required to access the remote experimental resources [5]. The client software is automatically downloaded from a web server.

The client software is written using Adobe Flash. It is responsible for displaying and handling 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 and behave identical, as far as possible, as the actual instrument. Position 2 in fig. 1 illustrates what is displayed on the client´s computer display when the DC Power is turned on, which contains an interactive image of the DC Voltage level. Users are then able to interact with these instrument images, which includes 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 GUI presents the instruments with a sense of realism and functionality that matches the physical instruments. Front panels possible to select another.

When a measurement is carried out, all the 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 to validate 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 safely be 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 instruments front panels. [5]

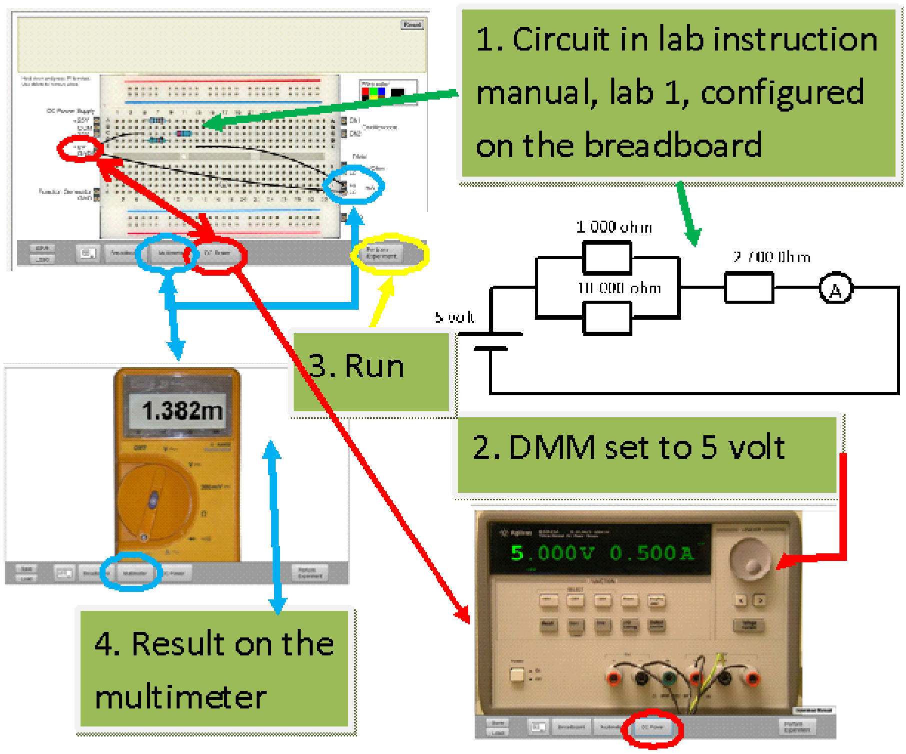


Figure 1. Practical session using VISIR with four steps. Position 2 shows what is displayed on the client´s computer display when when the DC Power is turned on.

In a typical classroom for physics at Katedralskolan there are ten workbenches allowing a number of students to perform experiments simultaneously supervised by one teacher. Also, in all science-classrooms it is possible to have hands-on laboratory work. These classrooms are all equipped with a SMART Board i.e. an interactive, electronic whiteboard which can enhance instruction and learning and a camera connected to TV that can enlarge components and screens of instruments. Why introducing RL when the school has fully equipped science-classrooms? The concept of a remote laboratory provides basically new possibilities for students to do laboratory work and become experimenters. Adding a remote operation option to traditional hands on laboratories make them more accessible for students, regardless of whether they are at school or at home. Remote laboratories in electronics are not replacements for hands on labs; they provide a complement to the traditional workbenches. Remote laboratories are open 24/7, and the students can carry out laboratory assignments without any risks of damaging any equipment.

Many virtual laboratories have been developed to help students gain understanding of new concepts by simulating physical systems. Although simulation is a useful and convenient teaching tool it is a poor replacement for real experimental work. Physical experiments provide a great way for students to learn more about nature and its possibilities as well as limitations. The advantages of these RL and comparative studies between: hands-on, simulated, and remote laboratories have been analyzed many times. [9-11]

The continuation of this article is organized as follows: Section II describes the activities carried out by teachers and students at Katedralskolan in Lund using the remote laboratory VISIR, located at BTH, with the emphasis on teaching methods. In our study during 2009-2011 two teachers and 94 students at Katedralskolan were participating in the project between Katedralskolan and BTH. In section III examples of students remote laboratory work is be presented. Section IV report the result of the questionnaire passed to the students, to acquire their opinion about the VISIR lab. Finally section V concludes the paper.

II. TEACHING METHODS WITH REMOTE LABORATORY

A. *Upper Secondary school system in Sweden.*

Upper secondary schools, in Sweden, are divided into 17 different national programmes with centrally defined programmes curricula that have between two and four centrally defined orientations. The programmes are divided into two general categories, preparatory and vocational programmes. All programmes provide basic qualification's to attend university, while the preparatory programmes typically satisfy a broader range of different special qualifications that may be required to attend some university courses and programmes.

The students at Katedralskolan are distributed amongst three different programmes of study according to [12]:

3-year National Programmes;

- Natural Programme
- Social Sciences Programme

3-year International Programme;

- International Baccalaureate.

The courses that the students attend depend on programme and orientation. The students at the science programme, a preparatory programme, study two courses in Physics, Physics A and Physics B. These two courses add up to ten percent of the Natural Sciences Programme courses.

The 1st, 2nd and 3rd semesters the students study mechanics, thermal physics, optics, electric currents and potential difference in the physics A course. For the duration of approximately seven weeks they study electrical and electronic circuits in this course. Reminding time, the 4th, 5th and 6th semesters, they attend the course Physics B. The content of the latter course is electric and magnetic fields, electromagnetic induction, alternating current, oscillations and waves, wave phenomena, atomic and nuclear physics, momentum, motion in circles, two dimensional motions. Eight weeks of the semesters of the Physic B course concerns electric fields and alternating current in electrical circuits with components like resistors, capacitors and coils.

Physics A and B have weekly classes of 3 hrs and the teacher decides when to have laboratory work, problem solving or theoretical classes. Students are assessed by two evaluation components: by their lab work performance and by approximately five theoretical examinations during the course. Four grades in the examination are currently used in upper secondary school: Did Not Pass (Icke Godkänd (IG)), Pass (Godkänd (G)), Pass with distinction (Väl Godkänd (VG)) and Pass with special distinction (Mycket Väl Godkänd (MVG)). One and the same teacher usually give both courses, physic A and B, in a class with a size of approx. twenty students.

B. The Learning Management system and Portals of Katedralskolan.

Fig. 2 illustrates the four main components used at Katedralskolan;

1) INTRANET; to store and manage internal data, 2) PORTAL; to store and manage external data, 3) LMS, the Learning Management System, itslearning, with pedagogic contents, and 4) VISIR, the remote laboratory used for experiments on electrical and electronic circuits, located at BTH. All these components have an administrator that may not be the same for all of them.

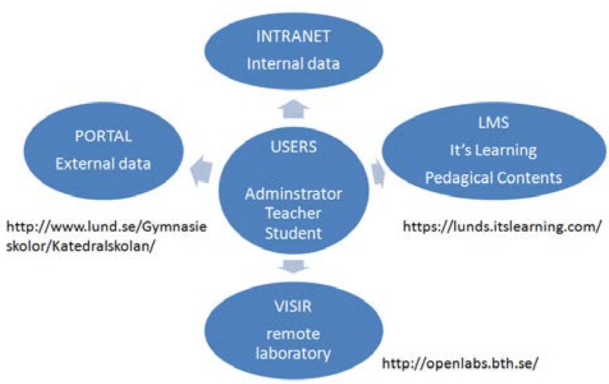


Figure 2. Sites used for institutional and teaching and learning purposes at Katedralskolan in Lund

When starting a new semester, the teachers have access to structured information on the intranet of Katedralskolan and the LMS itslearning, i.e. they will have access to the courses they will be lecturing. All the students enrolled in those courses will have access to teaching & learning materials made available by their teacher. The intranet of Katedralskolan is only accessible within the school area.

To access the intranet and itslearning the teacher have the same user identity but with different password. The portal for external data is on the internet and is a public website. Here the physics institute of Katedralskolan can be accessed at http://www.katte.se/fysik/. How to manage the access to VISIR laboratory will be described in next paragraph.

C. The VISIR laboratory

There are three different levels of access to the VISIR laboratory: 1) administrator, 2) teacher, and 3) student. The administrator is responsible for the general management of the system and he/she is creating courses and deciding the limitations of the recourses for a course. The system is built with a hierarchy; the administrator is overruling both the teacher’s and the student’s settings. As a teacher you are responsible for a course and handle all administrative tasks concerning the course such as registering students. [5]

To start a course in VISIR requested by a teacher, the Administrator starts by creating the course in VISIR and subsequently adds the responsible teacher for the course. As a support for teaches using the VISIR laboratory there is a comprehensive teacher manual available [13]. The teacher then adds his/her students into this course, see fig 3. This action simply implies copying & pasting the list of e-mails of the students enrolled in the teacher’s course from itslearning into the VISIR laboratory. The student then uses this e-mail to activate his /her account on VISIR. In the list of users, the column encircled in fig. 3, the teacher can see if a student has activated his/her account. Next step for the teacher is to create and add new prepared experiments for students according to the course, see fig. 4. Here the teacher needs to be aware of the components physically available in the matrix, see fig. 5 [14]. The switching matrix is a USB controlled circuit wiring robot, where the student's requested circuit can be realized and measured on. It is built as a stack of cards (PCBs), with a shared bus that passes through them all. Components are connected through relays on what is 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 e.g. be added to the stack, when e.g. more flexibility or new component types are needed.

Available components are;

- resistances from 50 to 220 000 ohm
- two potentiometers, 10 000 and 100000 ohm
- capacitors from 6.8 nanofarad to 10 microfarad
- one coil, 82 millihenry
- diodes
- operational amplifiers

Available instruments are;

- multi-meter
- oscilloscope
- power supply
- function generator

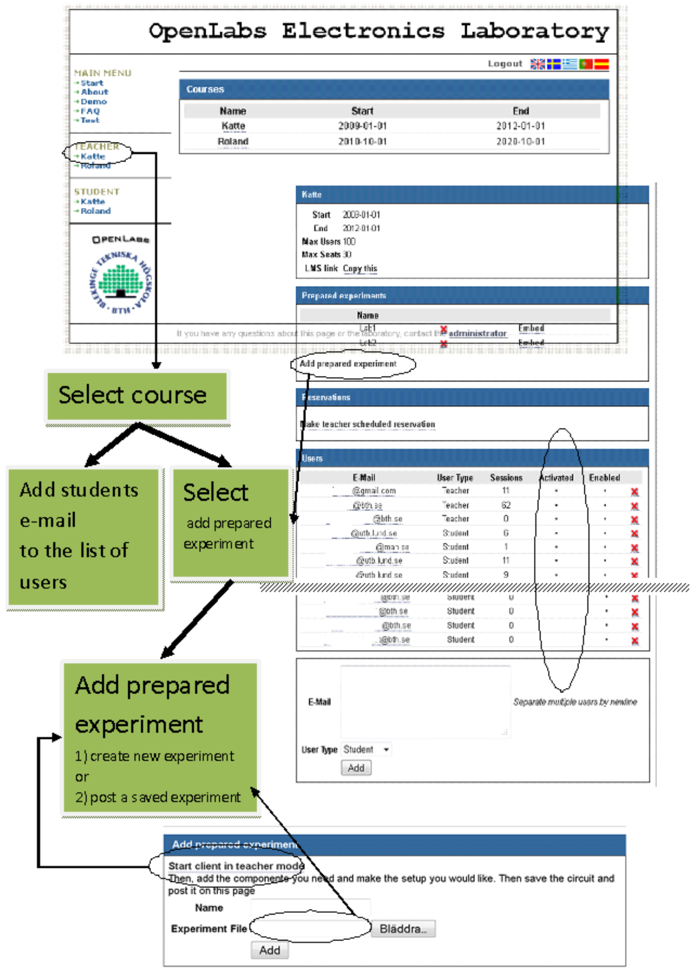


Figure 3. How to add a list of users to a particular course in VISIR to prepared experiments.

To add a prepared experiment i.e. a set of components and instruments, click "Add prepared experiment" in the course view, see fig. 3. You must first start the client in teacher mode by clicking the link, “name of the course”, below the headline “teacher”. In this mode, it is possible to select instruments displayed on the instrument shelf and components from the Component Library, which contains a photo and a description of every component defined for the VISIR platform. However, the component Library defines more components than are available in the online component store. The Component Library is a part of the VISIR open source distribution. You can display the component library by pressing the plus (+) sign in the lower right corner of the box for components in

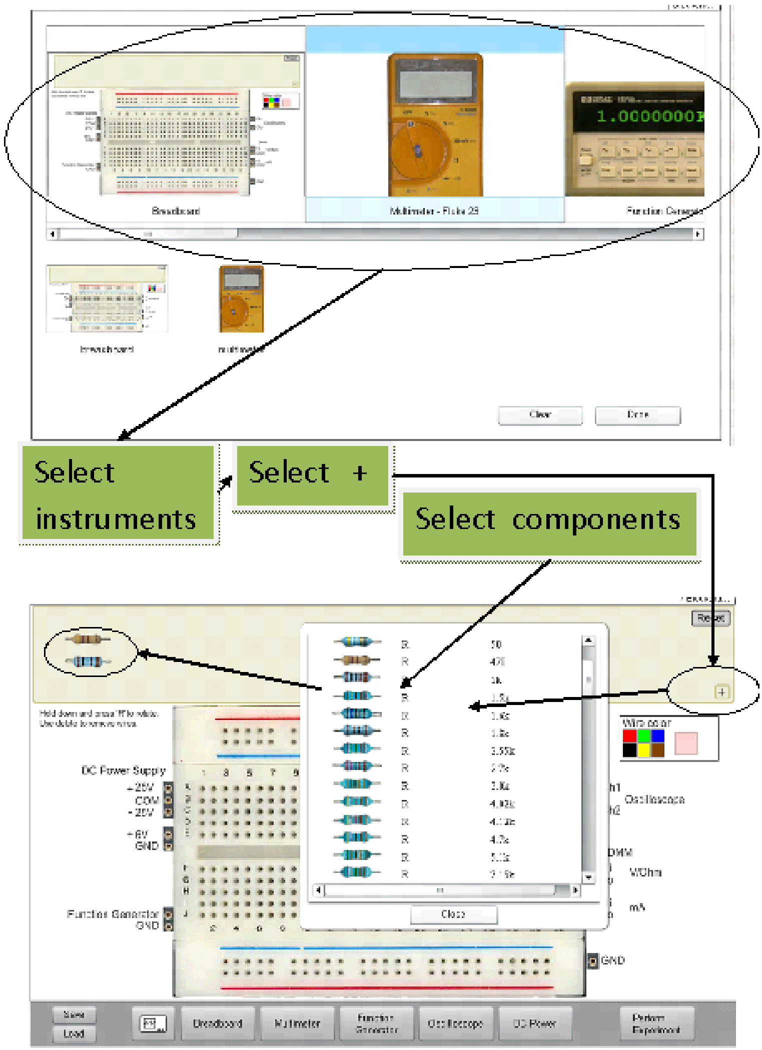


Figure 4. Top; the virtual instrument shelf and bottom; the component list.

fig. 4. By clicking on a component in the component library, it will appear in the component box. If you cannot find a particular component, ask the administrator to include it. Add all the components given in the list of materials of your laboratory instruction manual. Close the component library by pressing the close button. After the setup is complete, press the save button to save your setup. Then, return to the webpage displayed lower in fig. 3. Choose a name of your prepared experiment and pick the file you have just saved. Finally, press the "Add" button to upload and add the prepared experiment to the system.

You must verify that all the circuits to be wired by the students in your session are permitted to be created. Ask the laboratory staff for a list of the current virtual instructor rules i.e. the Max Lists. Most likely, at least some of your circuits will not be supported and a number of your components may not be present in the online component store. Ask the staff to include them. Now you must define new Max Lists in collaboration with the staff. These lists should not only support your experiments but also support all safe circuits possible to create using components of the online component store extended with your components.

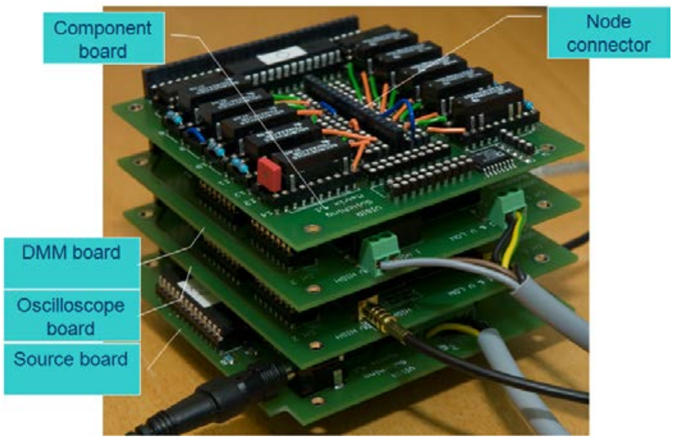


Figure 5. The switching matrix in VISIR [13].

Examples of teaching & learning materials produced by a teacher are; an instruction manual for the students that provides them with information on how to get access to VISIR laboratory and how to use the RL for experimental work [15]. For the laboratory sessions the teacher writes lab instruction manuals, describing the experiments to be performed during the sessions [16-18]. All the teaching & learning materials will be stored in itslearning, the lab instruction manual as an assignment for the students. An assignment in itslearning indicates for the student that it is requested to submit a lab report.

Another option with the RL for a teacher is to integrate experimental work in a theory lecture by login on to the website VISIR laboratory and carry out remote experimental work in real time during the lecture. Thus, the theory for electronic circuits may be confirmed with experiments from the RL in theoretical lecture. The teacher may also have exams with exercises of experimental work using VISIR laboratory.

III. EXAMPLES OF LABORATORY WORK

In a study carried out during the period 2009-2011 two teachers and 94 students at Katedralskolan were participating in a project where Katedralskolan and BTH collaborate. They were divided into five groups, group A to group E, regarding physics course and teacher (see Table 1).

Fig. 1 shows a typical practical session in VISIR. It has four steps; configure the circuit, configure the instrument (DMM), run the experiment, and analyze the results.

Lab1 deals with direct current [16]. The assignments were:

- Investigate the relationship between voltage and electric current, the Ohm's Law, for a component (resistor or conductor) that behaves according to Ohm's law over some operating range. A result from a student's lab report is shown in fig. 6.
- Investigate if the current was the same before a component as after in a circuit with two resistors in series.
- Check Kirchhoff's voltage and current law.

The students can only use 1K, 2,7K and 10K resistors in different positions. All the experimental assignments have been prepared in advance with theory lessons for students and real experimental work. Before the students started to use the VISIR laboratory it was introduced by the teacher of the class, starting with a small presentation of the VISIR laboratory interface and a explanation on how to use the RL. Further, help for the Student is provided by manuals on itslearning [15]. Most of the students manage to carry out the laboratory assignment in school during two lab-session in physics the rest completed the assignment at home. Between two and fourteen accesses per student, in the course Katte on VISIR indicates the students' usage of the VISIR laboratory during their spare time. It was compulsory for each student to write a lab report, where they had to include theoretical calculations, VISIR laboratory measurements and screen dumps of the circuits.

TABLE I.
STUDENT GROUPS A-E.

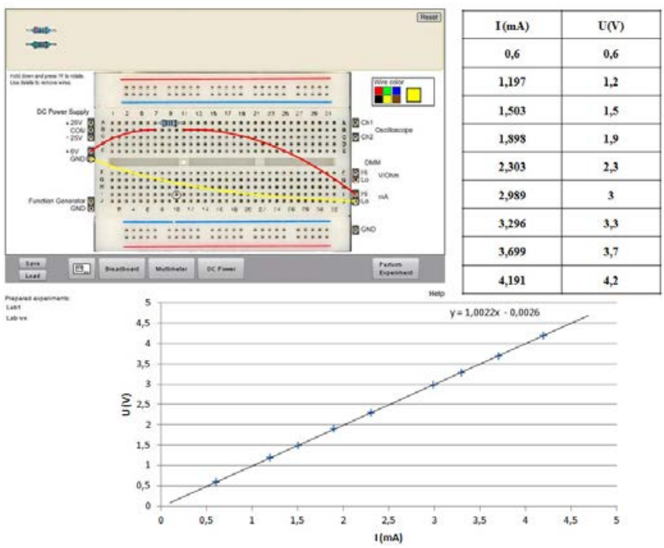
Group	A	B	C	D	E
Number of students	18	20	18	20	18
Teacher	1	1	1	2	1
Physics course	A	A	B	B	B
Performed experiment	Lab1	Lab1	Lab2	Lab2	Lab3
Time	May 2009	Dec 2010	May 2009	Jan 2011	May 2011

In lab 2 the students performed labs on the RL with alternating current [17]. The tasks were about:

- Compare the impedance of the components in DC-circuits with AC-circuits.
- Investigate the components impedance at different frequencies for capacitors and coils.
- Relative phases between various voltages for the components, assessed on the remote oscilloscope.

The available components were; 1K, 2,7K, 10K resistors, 82 millihenry coil and 56 nanofarad capacitor in different positions.

Lab 3 Group E, the same students as in Group A, but now third year students that have exams with exercises of experimental work using the VISIR laboratory. Lab3 was an exam with experimental assignments on the RL, based on the tasks in Lab2 [18]. They were not required to explanation how to use the RL in the exam. Within 75 minutes they had to do the experimental assignments. Every student downloaded a lab instruction guide from itslearning describing the three experimental assignments in the exam, one assignment for a DC circuit and two assignments for an AC circuit. They had to document the measurements from VISIR laboratory and a screen dump of the circuits into the lab instruction guide and then upload it to itslearning.



I(mA)	U(V)
0,6	0,6
1,197	1,2
1,503	1,5
1,898	1,9
2,303	2,3
2,989	3
3,296	3,3
3,699	3,7
4,191	4,2

Figure 6. Result produced by a student performing Lab1, assigment1 in the Physics A course.

IV. EVALUATION

After the sessions a questionnaire was passed to the students to acquire their opinion about the VISIR lab. The questionnaire has 13 items and covers four characteristics of a RL; 1) usability (Q2-Q4), 2) sense of reality (Q5-Q7), 3) usefulness (Q1, Q8-Q10) and 4) quality of the service (Q11). Q12 and Q13 are open ended question. The questions in questionnaire are presented in Table 2. For each item in the questionnaire a mark was calculated as the arithmetic mean of the marks given by the students for that particular item, see Table 2. The majority of the students were satisfied with VISIR. The students showed a great interest in the laboratory experiments, and appreciated that it was not simulations but happened in real life.

Based on the results of the questionnaire in Table 2 some conclusions can be remarked:

- VISIR is accepted by the students as a good learning tool. Usefulness and usability get high marks considering not all students at this age have developed an interest on electrical and electronic circuits.

- The opinion of the students of the group B is more positive as compared to the opinion of the students of group A. The VISIR-laboratory is the same, but during 2010 a special effort was made for creating a better manual and materials in order to provide a better explanation of VISIR: architecture, design, researchers, etc. If the students know the tool they will “trust” it. The fact that teacher1 had more experience of teaching with the RL is also likely be an argument for the more positive result in group B. Also, Katedralskolan supplied all the students in group B with a personal laptop computer during their time of study.

- The opinion of the students of the group D is more negative as compared to the other groups. The teacher of this group had a fairly limit experience of the RL. The fact that the students only used the RL ones, are maybe another explanation of the low marks. The fact that they used the RL in January and did the questionnaire in May the same year was probably not good either.

- Q11 got low marks from three groups. Group B probably because the VISIR was upgraded with new software during their usage of VISIR in December 2010. Some students had problem with remembering their password.

Table 2.
Results of the Questionnaire for VISIR-BTH in 2009-2011

		Results of the Questionnaire for usage of OpenLabs Scale: 1 (I not agree) – 5 (I agree)	Group A	Group B	Group C	Group D	Group E
		Surveys/Number of students in the course	15/18	16/20	14/15	19/20	14/18
usability	Q2	The remote laboratory helps me with my hands-on laboratory work.	3,0	4,3	3,4	2,4	3,9
	Q3	I have been motivated by the Remote laboratory to learn more about the subject.	2,6	3,4	2,7	2,1	2,8
	Q4	It is a good idea to extend this remote laboratory to all the students.	4,2	4,0	4,0	2,4	3,6
sense of reality	Q5	Using the remote laboratory, I feel it is real and not a simulation.	2,8	3,6	3,1	2,3	3,2
	Q6	I would like to have a webcam to see something at the remote laboratory.	3,2	3,1	2,7	1,8	3,1
	Q7	Being far from the remote laboratory, I have felt myself to be in control of it.	3,0	4,0	2,9	2,9	2,9
usefulnes	Q1	I have enjoyed using the remote laboratory.	3,0	3,8	3,0	2,1	3,2
	Q8	The remote laboratory is easy to use the first time.	3,0	3,0	2,6	2,1	3,1
	Q9	The different devices are easy to use.	3,6	3,9	4,6	2,7	3,4
	Q10	The devices front panels at the remote laboratory are similar to our schools real devices.	3,8	3,8	3,4	2,8	3,5
quality of service	Q11	Always when I logged in to the remote laboratory I got access to it.	3,6	1,8	3,7	1,8	1,6
	Q12	State two things you think are positive with the remote laboratory.					
	Q13	Suggest two things that would help your teacher to improve the remote laboratory.					

The open ended questions answers from students were;

Q12: Remote access to the laboratory enable you to perform physical experiments with similar instrument and components at home as in school. It feels trendy using the online remote laboratory and safe to know that you cannot destroy any equipment. It is easy to use, feels like working in reality and you wire a circuit very quickly. The framework and the concept. Available. The devices front panels are similar to the devices front panels of school. Funny. New idea. It is pleasant to wire the circuits. You can perform experimental work at home. It is real experimental work, which is more motivating and makes the assignment funnier. Instructive. Innovative. Easily accessible. You do not have to take out components and instruments.

Q13: A guide available when you have trouble with the wired circuit. Make it possible for several students to perform experiments together, collaborative working. Increase the feeling of reality with a webcam. Instruction manual for the breadboard. A help-square where you can read about the science-theory. Make it possible to see all the devices front panels at the same time. Use it more frequently. Make it more user-friendly. Make it look more real

V. Conclusion

The implications from this project are that the remote laboratory is easy to implement for use by both by teachers and students. 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 students' satisfaction with the RL and perception of the RL resulted in a proposal of improvements in the RL's user interface. The majority of the students were satisfied. The students showed great interest in the labs, and appreciated that it was not simulations but real life experiments.

Future work in VISIR is to integrating another DMM that will provide more potential to assemble circuits. Enable the possibility to see all the devices front panels at the same time to enhance the RL. Make improvements in user interface to fit students at upper secondary schools better.

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Part C

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

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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 or/and explaining the theory taught in class. Moreover, the experiments provides students training and experience of experimenting as well as enabling them to develop competences that concerns: the handling of instruments and components, the evaluation and determination of physical parameters of objects, the design and use of tables, calculations, plan and implement experiments.

Hands on laboratories are the most common forms of laboratory environments, offering students opportunities of experimentation 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 as well as 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 lab where students can work and conduct experiments that can be performed on a solderless breadboard remotely 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. Katedralskolan can be accessed through via Internet at the address [3]. The number of students at Katedralskolan is approximately 1200 and they are distributed between the Natural Science Programme, the Social Science Programme and the International Baccalaureate. In a study carried out during the period 2009-2011 concerning develop strategies and methods for implementation of remotely controlled laboratory experiments two teachers and 94 students at Katedralskolan participated. Result 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 a great interest in the laboratory experiments, and appreciated that it was not simulations, i.e. real experiments carried out with real physical instruments and electrical circuits. Figure 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 of improvements in the RL’s user interface. After the improvements of the VISIR electronic lab at BTH for use in upper secondary schools were implemented it has been used during the period 2012-2013 for electrical experiments in the courses Physic1 [5] and Physic2 [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 advantages and disadvantages using the VISIR lab to enhance and supplement the hands-on laboratory in physics courses at the upper secondary school, Katedralskolan in Lund. Examples of laboratory work carried out on 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. Section 4 and 5 provides examples of students remote laboratory work. Finally section 6 concludes the chapter.

Figure 1 shows the 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 instructional hands-on laboratory, which are common 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 to 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 includes experiments on mechanical vibrations [8] and on acoustics [9]. It is the VISIR laboratories dedicated to experiments on electronic circuits and acoustics that is currently used in the project between Katedralskolan and BTH. BTH offers RLs based on other principles than the VISIR platform as well, one remote lab that concerns antenna theory [10] and one remote lab that concerns security [11]. All RLs at BTH can be accessed via the internet at the address [12].

2.1. VISIR electronic lab

2.1.1. 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 how to 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 setup 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 on. It is built as a stack of cards (PCBs), with a shared bus that passes through them all, the switching matrix is shown in figure 2. Components are connected through relays on what is 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 e.g. be added to the stack, when e.g. more flexibility or new component types are needed.

Available components are;

- resistances from 50 to 220 000 Ohm
- two potentiometers, 10 000 and 100 000 Ohm
- capacitors from 6.8 nano Farad to 10 micro Farad
- one coil, 82 milli Henry
- diodes
- operational amplifiers

Available instruments are;

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

2.1.2. Software

The client software is written using Adobe Flash that is now being replaced successively by HTML5. It is responsible for displaying and handling 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 and behave identical, as far as possible, as the real-life instrument.

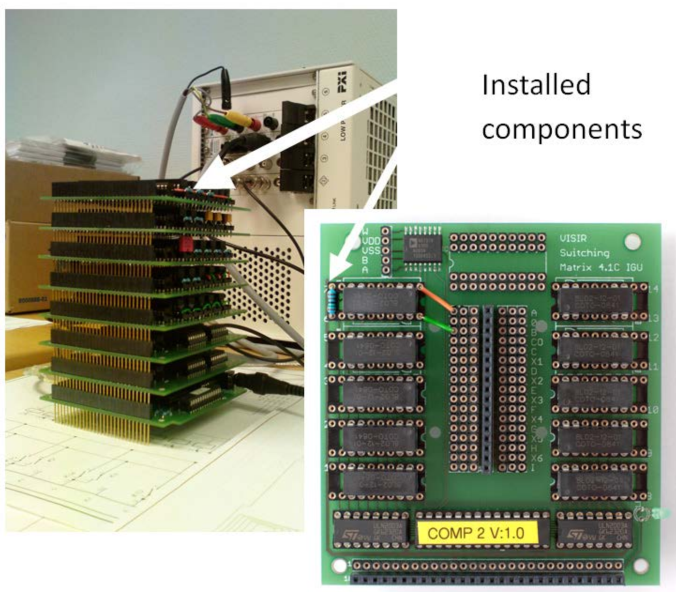

Figure 2. The switching matrix.

Figure 3 illustrates what is displayed on the client´s computer screen when the DC Power Supply is in focus, which is an interactive image where it, for example is possible to change the DC Voltage level. Users are then able to interact with these instrument front panels, which includes 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 another.

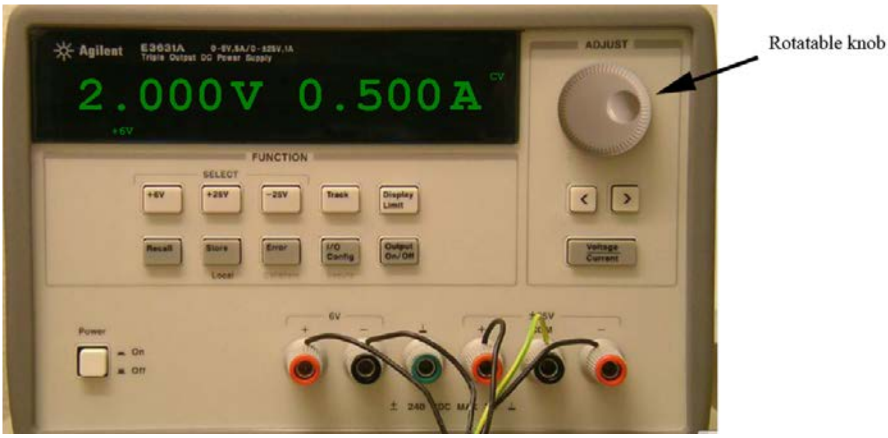

Figure 3 shows the interactive image of the DC Power Supply.

When a measurement is carried out, all the 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 to validate 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 safely be 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 instruments front panels.

2.1.3. VISIR electronic lab accounts

The user interface is the frontal web page of VISIR electronic lab that handles all the 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 VISIR electronic lab in the physic 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 responsible teacher for the course
  4) modify or remove user account
  5) switch to "teacher view"
- Teacher account (created by the administrator) can
  1) add or remove experiments ,
  2) add, remove and modify students account
  3) make a teacher 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 student scheduled reservation

2.1.4. Enhancement of the VISIR electronic lab at BTH.

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

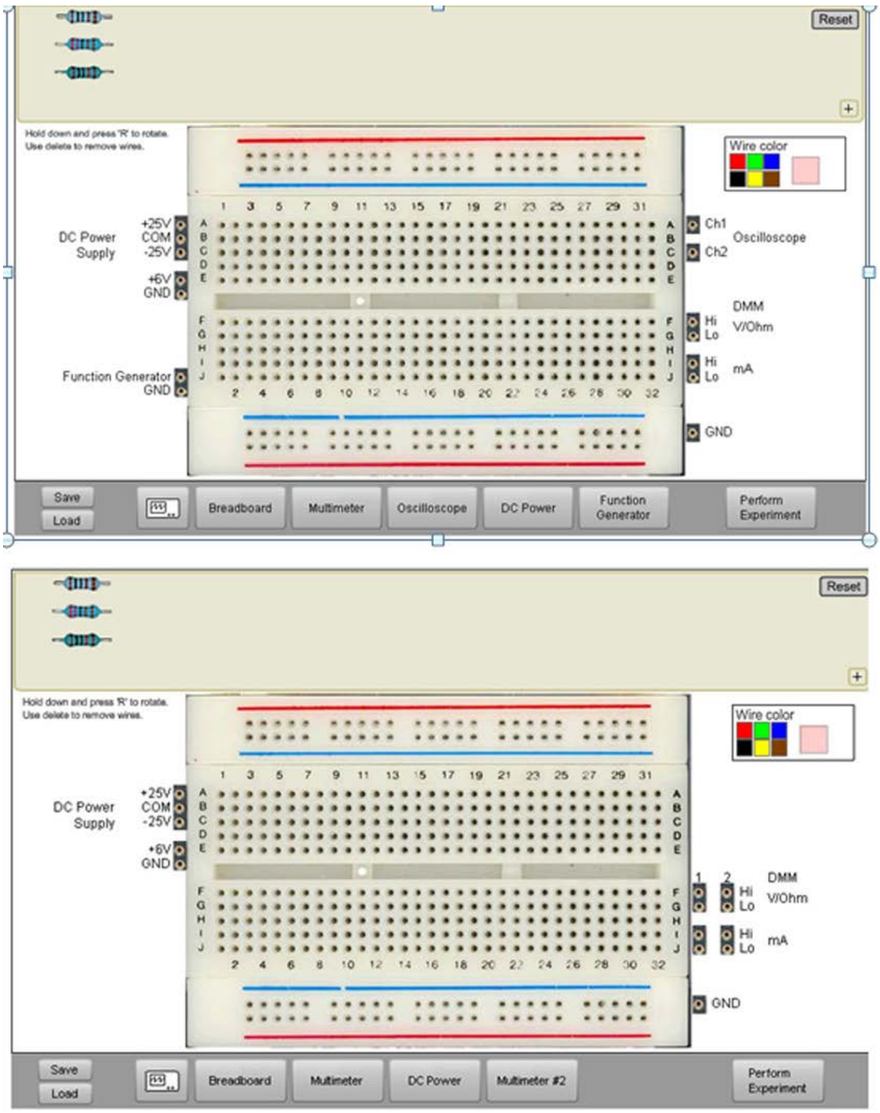

Figure 4. Top: user interface with all instrument connections to the left and right of the breadboard and the instrument selection buttons at the bottom of it. Bottom: user interface with instruments and components prepared for experiment Ohm's Law only.

In the enhanced version of the VISIR electronic lab you can choose to use flash or html5. Html 5 is working on handhold devices e.g. iPad and smart phones. Another advantage with not using flash is that the providers of RL don't need buying 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 figure 5. The use of handheld devices with touch screen also makes it possible to investigate the interaction with your fingers.

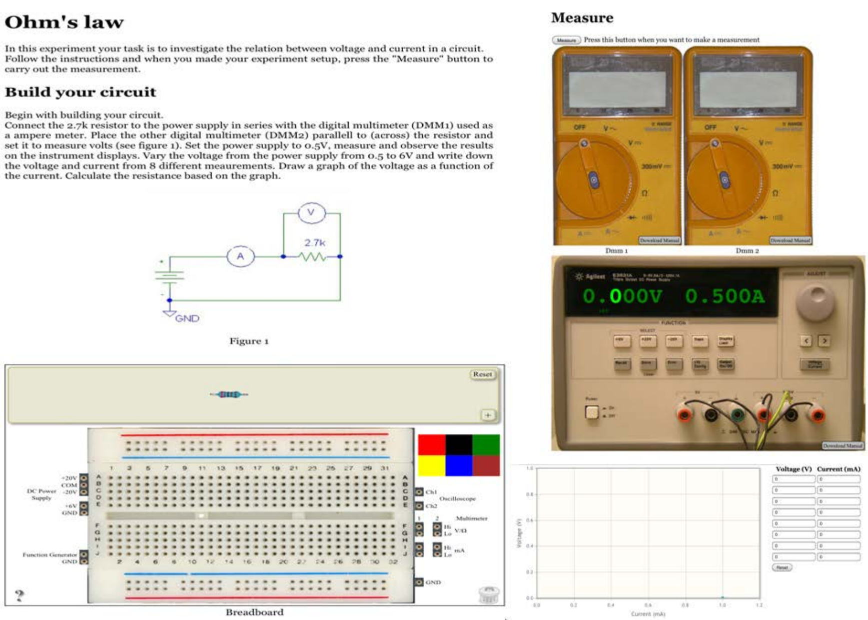

Figure 5. VISIR electronic lab Web site based on html5.

2.2. 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 Acoustics and Digital Signal Processing as well. 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 review some ANC concepts briefly.

2.2.1. Active noise control

Active noise control is a method 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 super position of the primary and secondary noise resulting in a residual noise. Figure 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 to be implemented. For example in heating ventilation and air conditioning (HVAC) systems low frequency noise is controlled actively, as passive methods such as mufflers and absorbers becomes large, bulky and unfeasible at low frequencies [14], [15].

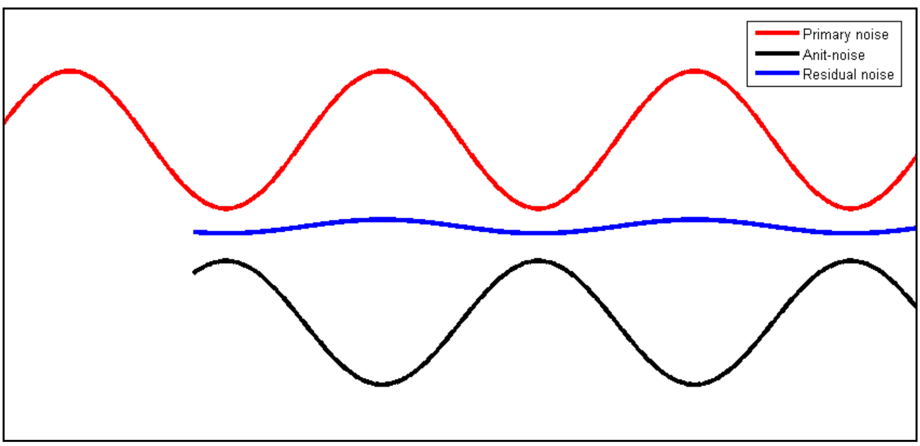

Figure 6. Illustration of the ANC concept using superposition.

The idea of ANC is simple but in practical application the primary noise and the surrounding environment is 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 is the feed forward adaptive controllers. These controller comprises of a Finite Impulse Response (FIR) or Infinite Impulse Response (IIR) digital filter and an adaptive algorithm e.g. the least mean square (LMS) algorithm which steers the coefficients of the filter to minimize a cost function e.g. the instantaneous residual noise power [15]. The term feed forward means that the controller is supplied by some prior information of the primary noise, known as reference signal. Figure 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 known as the desired signal, the primary noise at the point where the superposition of the noises take place. The physical equipment e.g. microphone and loud speaker etc. between the electrical signals y(n) and e(n) introduces 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, as an FIR filter using adaptive system identification techniques.

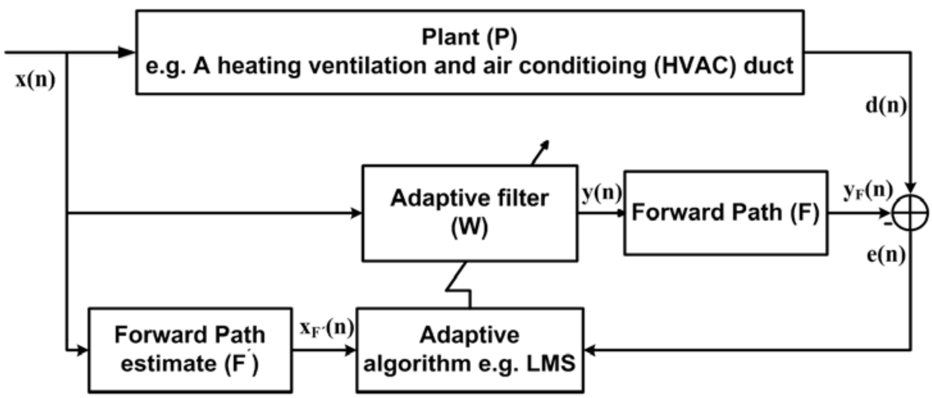

Figure 7. A simple feed forward active noise control system for a heating ventilation and air conditioning duct.

2.2.2. The VISIR acoustic lab setup.

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

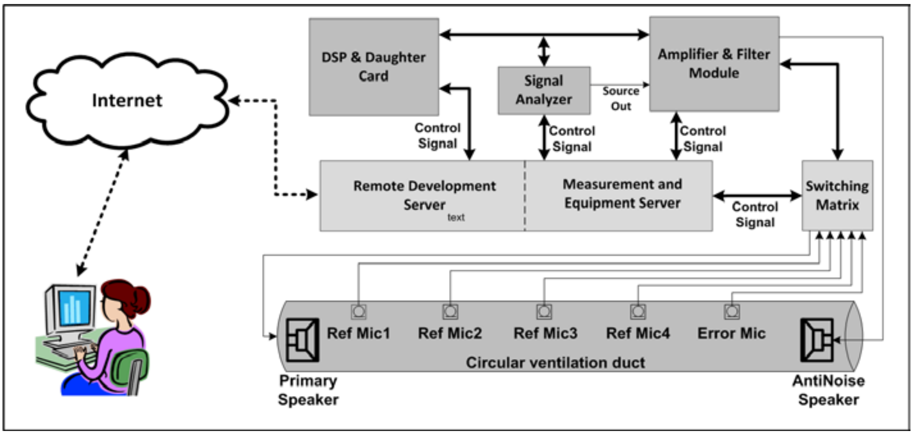

Figure 8. Block diagram of the remote VISIR acoustic lab, showing the interconnection of the equipment.

Laboratory equipment: The 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) the reference and error signals. It may be noted that being a single channel controller only one reference microphone is sufficient. The uses of four reference microphones provide flexibility in positioning the microphones for the control of the acoustic field in the duct. For 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 to the primary noise speaker and for analysis of the control and other microphone signals as well as.

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 doing 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, 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 named as Measurement and Configuration Client and Web-Based Development Environment respectively. The former developed using Hyper Text Markup Language (HTML) and JavaScript is shown in figure 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 figure 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.

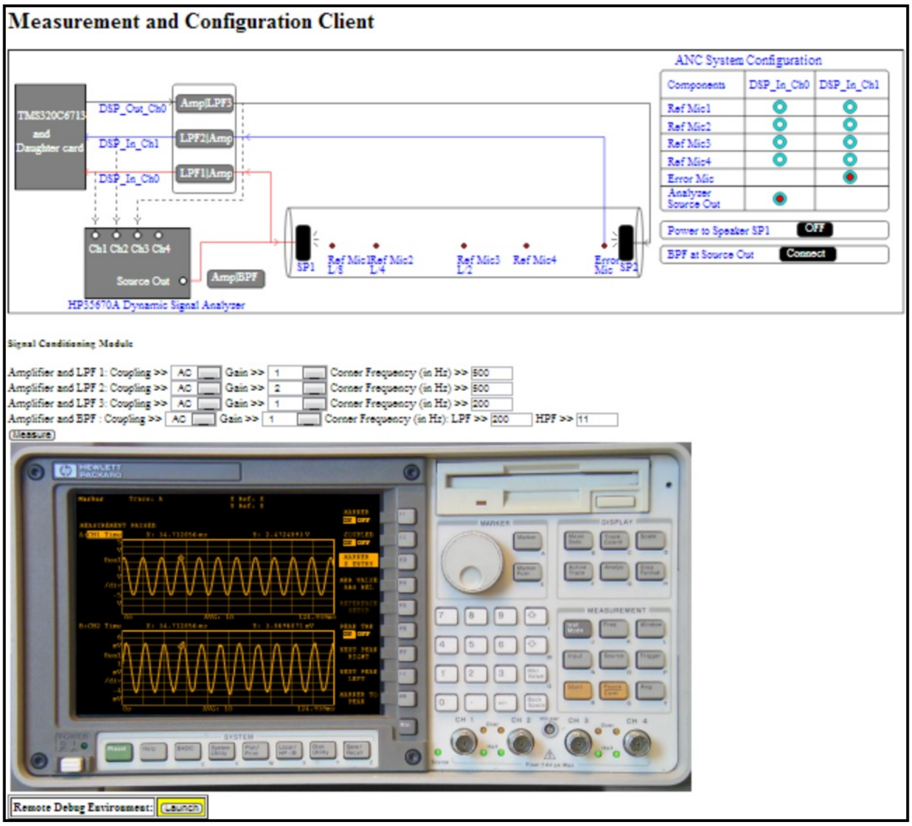

Figure 9. A snap shot of the Measurement and Configuration Client used during a basic acoustic experiment.

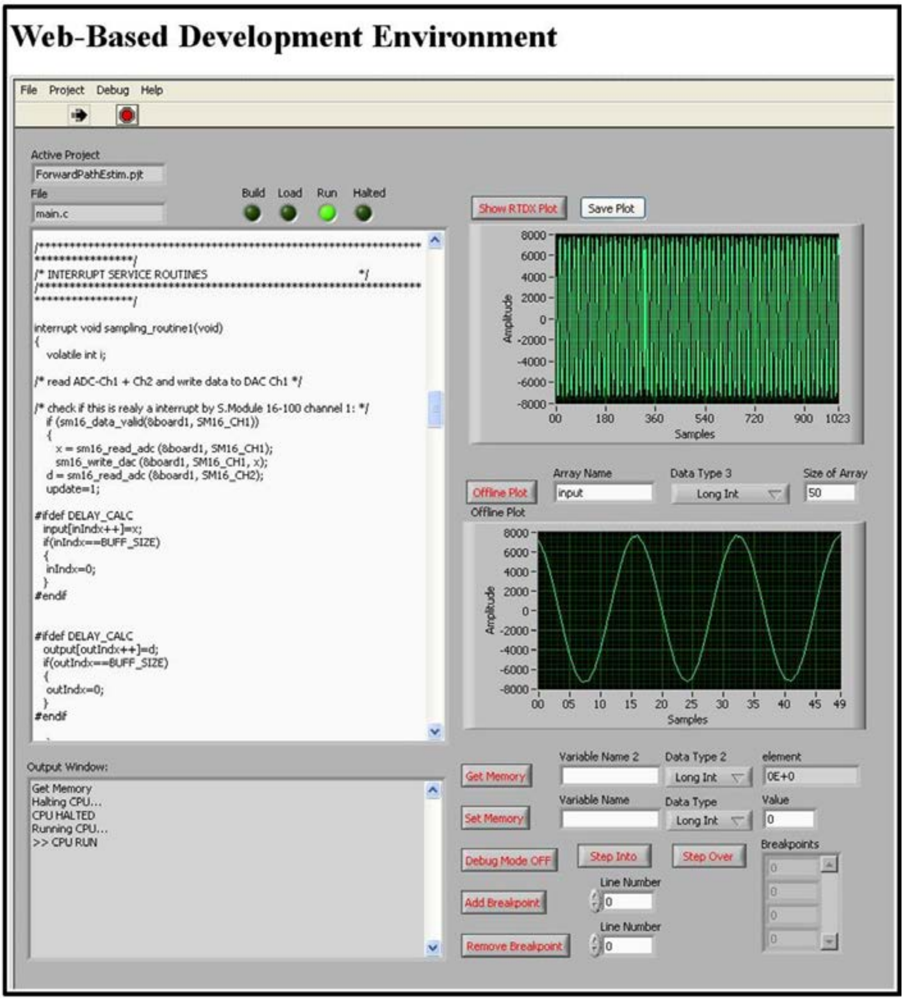

Figure 10. A snap shot of the Web-Based Development Environment used during an ANC controller implementation.

3. Teacher’s tasks in the VISIR lab.

3.1. 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 with differing needs and abilities [16]. All youth 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, and for personal development and active participation in the life of society. The upper secondary school consists of three different types of programmes:

1) 18 national programmes each lasting three years. They are divided into upper secondary foundation subjects, subjects common to a programme, orientations, programme specializations and a diploma project, 2) Five introductory programmes for pupils who are not eligible for a national programme and 3) Education that deviates from the national programme structures; special variants, programmes based on national recruitment and nationally approved sports programmes (NIU).

The 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. The teacher awarding the grade should also be able to inform the student of the reasons for the grade assessment.

3.2. The courses Physic1 and Physic 2

The national programme Natural science programme is intended for students who wish to work with the natural sciences. The programme 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 programme 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 physics1 are 1) Mechanics, Kinematics and Dynamics 2) Electricity 3) Thermodynamics and 4) Nuclear Structure. The core contents of physics2 are 1) Mechanics, Kinematics and Dynamics 2) Electricity and Magnetism 3) Optics and Waves and 4) Atomic Structure.

Why do 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 aim of the subject it is written: the teaching in the subject of physics should give the students the opportunities to e.g. 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 knowledge from universities and possibly in future employment.[5]

In physics1 the students have weekly classes of three hours spread over one and a half year, in total 150 hours and in physics 2 the students have weekly classes of three hours spread over one year, in total 100 hours. One and the same teacher usually gives all the lessons in a course. The number of students is approx. twenty. The teacher decides when to have laboratory work, problem solving or theoretical classes. Students are assessed by two evaluation components: by their lab work performance and by theoretical examinations during the course.

3.3. 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 system (LMS)) are a software system designed to support teaching and learning. A LMS is especially useful when teaching Science in general and Physics in particular because it allow implementing objects of many kinds such as links to remote laboratories which can be used for laboratory work and animations which can be used to show dynamically many physical situations and concepts that are often difficult to apprehend by the students.

The LMS, Itslearning, is in use at Katedralskolan since 2009 and provides tools e.g. for assessment, communication, uploading of content, return of students' work, administration of student groups, questionnaires, tracking tools, chats and forums over internet. Itslearning allow 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 at the Katedralskolan they have computers at their own disposal.

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

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

Itslearning:

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

- link to the VISIR lab
- an instruction manual and/or video clip for the students that provides them with information on how to get 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
- discussion forum
- a folder, of type assignment, where the students can return their result from the experiment

The teacher's tasks in VISIR electronic lab:

The course in the VISIR electronic lab is started by the administrator by requested from the teacher. The administrator adds the responsible teacher 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 into this course, see arrow C in figure 11. This action simply implies copying & 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 on VISIR electronic lab. In the list of users, arrow B in figure 11, the teacher can see if a student has activated his/her account.

Next step for the teacher is to create and add new prepared experiments experiment (arrow A in figure 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 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 are permitted to be created. The teacher may ask the laboratory staff for a list of the current virtual instructor rules i.e. the Max Lists. Most likely, 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 of 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.

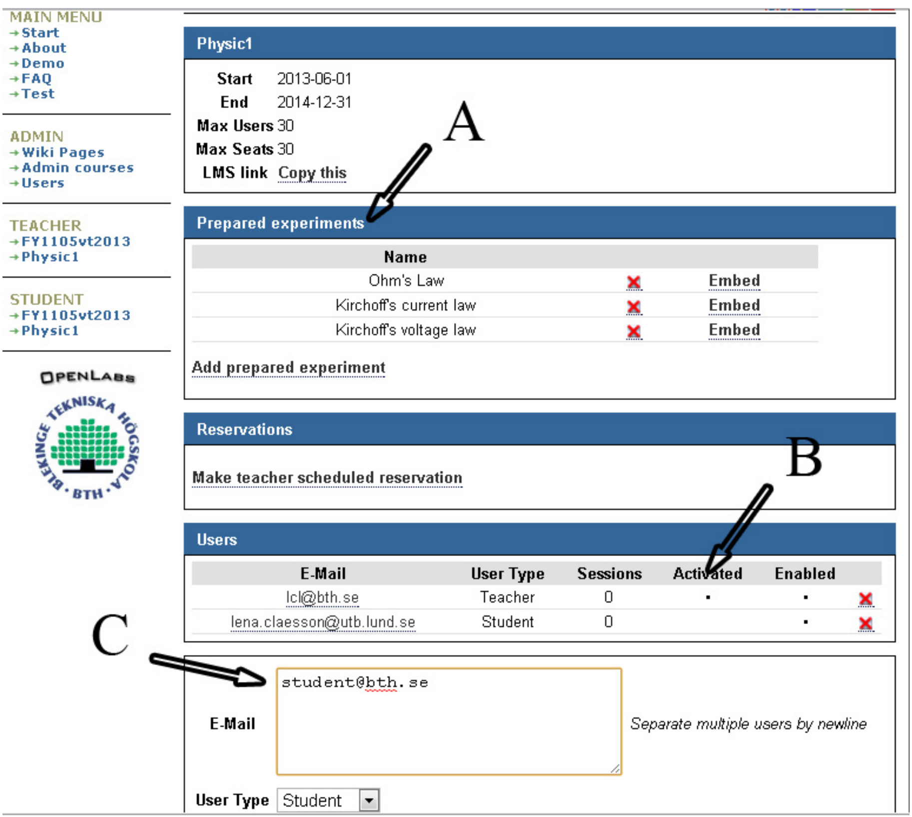

Figure 11. Teacher view of course physic 1 in VISIR electronic lab for electrical experiments.

3.5. The students' steps using VISIR electronic lab.

The student starts with login at website VISIR electronic lab at [18], choose his/hers course and then click 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 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 2009-2011 two teachers and 94 students at Katedralskolan were participating in a project where Katedralskolan and BTH collaborate. The students were divided into five groups regarding physics course and teacher. Very interesting experience from remote experiments are reported in [4]. The majority of the students were satisfied with VISIR electronic lab. The students showed a great interest in the laboratory experiments, and appreciated that it was not simulations but happened in real life.

After some improvement of the VISIR electronic lab at BTH for use in upper secondary schools it now has been used for electrical experiments in courses Physic1 and Physic2 at Katedralskolan in Lund, Sweden. So far VISIR electronic lab had more than 150 registered users from Katedralskolan. The courses have been offered by the first author and one other physic teacher at Katedralskolan. The tasks to be carried out by the students in VISIR electronic lab were compulsory in the physic courses. The experiments have beforehand been prepared with theory lessons and real experimental work for the students. In Physic1 the experiments deals with direct current and in physic2 alternating current.

A typical hands on experiment to start with in the course physic1 is when a student investigates the relation between voltage and current in a circuit with a nonlinear component, a light bulb. In VISIR electronic lab component library there isn't a nonlinear component. A light bulb is not possible to place in the matrix, because the time of measure is too short for the bulb to warm up. However there are other components that don't follow Ohm's Law that can be placed in VISIR electronic lab.

4.1 Ohm's Law experiment.

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

The experiment instruction for the student:

Begin with the building of your circuit, see figure 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 resistance based on the graph.

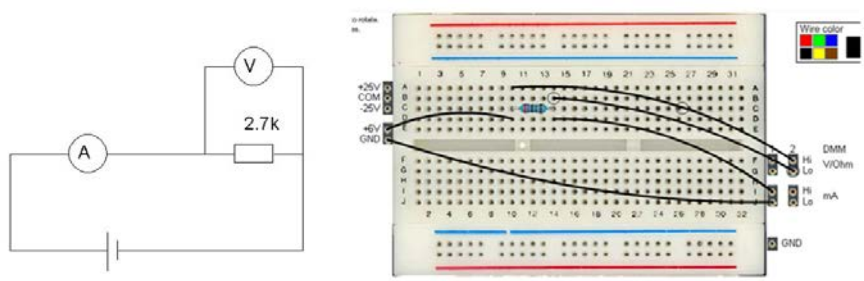

Figure 12. Left: The circuit for experiment Ohm's Law. Right: The circuit in VISIR electronic lab.

4.2. Electric current experiment.

Frequently students at upper secondary level don't know that the current is the same, in the circuit, before and after a component. This is e.g. possible for them to check out in this experiment.

The experiment instruction:

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 in this circuit you insert the ammeter. Do you get the same current reading whether you insert the ammeter before, between or after the resistors?

Method: Connect the 1.0k-resistor and the 2.7k-resistor to the power supply in series with the digital multimeter (DMM1) used as an ammeter, see figure 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 figure 13.

Conclusions? Calculate theoretical the current with Ohm's Law and compare the result with the measured data.

4.3. 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 figure 14, the students can investigate if this is true. In the same figure 14 you can see the result of the circuit configurated by two individual students measuring the current going through the 1000 Ohm resistor.

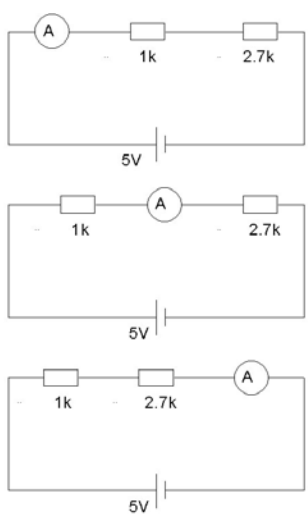

Figure 13. Circuits for experiment: measuring current in different positions.

4.4. 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, in top of figure 14, the students can measure voltage case over resistors and investigate if Kirchoff's voltage law is true.

4.5. Alternating current experiments.

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

1) If impedance is voltage over current, why is it different from resistance? Let the students investigate impedance at different frequencies for capacitors and coils.
2) What is 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 to add the voltage over a resistor and a capacitor in series? 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; 1kOhm, 2,7kOhm, 10kOhm resistors, 82 milli Henry coil and 56 nano Farad capacitor.

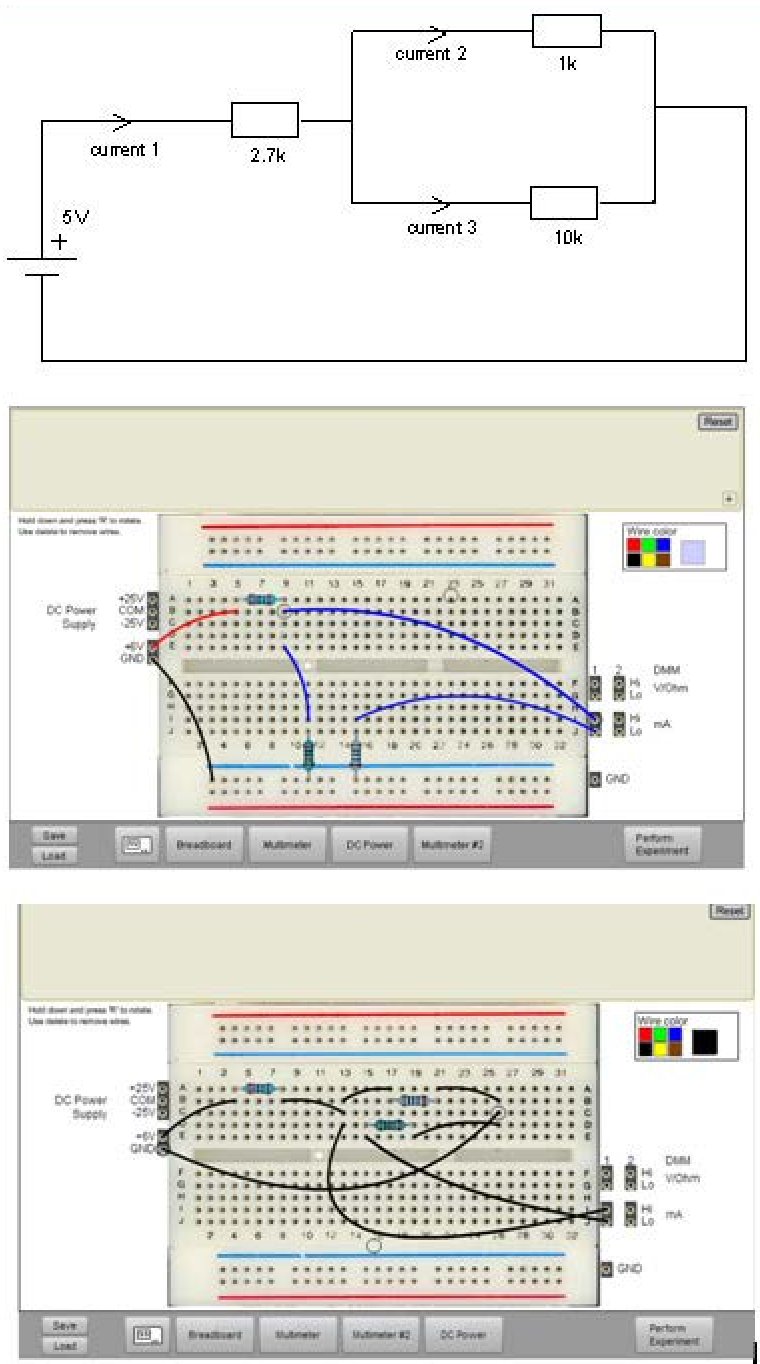

Figure 14.Top: Circuits for experiment measuring current flowing into and out of a nod. Middle and bottom: Student circuit configurations.

4.6 Experimental examination.

Experimental examinations using the VISIR electronic lab have advantages over hands on laboratories. You can have 20 students experimenting at the same time. The time consumed in preparing hands on laboratories do not exists for VISIR electronic lab if you have used the lab beforehand with the students. You do not have to examine the students' circuits instantaneous if you demand that the students 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 problem the students have, for example 1) incorrect setting of measurement range on the instruments, 2) 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 level 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 figure 15. For acoustic experiments only the Measurement and Configuration Client shown in figure 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 signal, to be input to the primary speaker and the measured signal of the error microphone can be analyzed simultaneously for comparison etc.

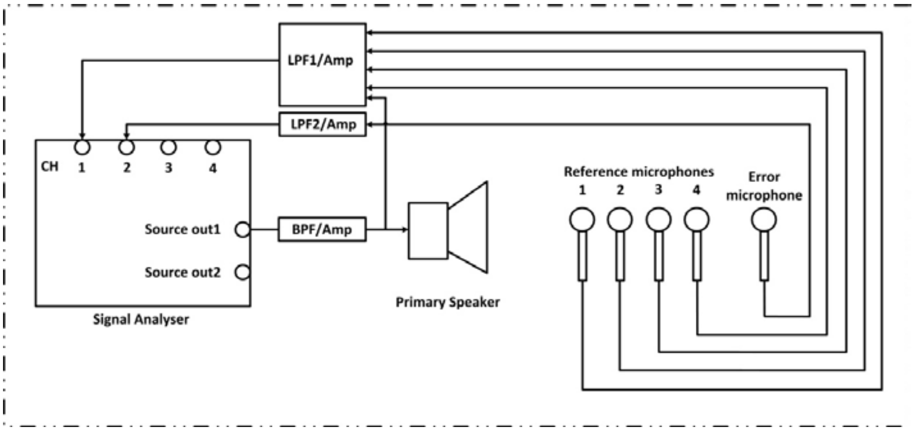

Figure 15. The acoustic setup of the VISIR acoustic lab. The connection of the microphones to the Signal Analyzer via the Filter/Amplifier modules are also shown.

The Signal Analyzer is power full 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 given.

5.1 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 acquainted in the class room.

5.2. Study of the 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 seen on their computer screens and they can listen to them via the computer loudspeaker this may prove to be very exciting and informative for the students.

5.3. 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 relation 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 thus, improve his 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 figure 16.

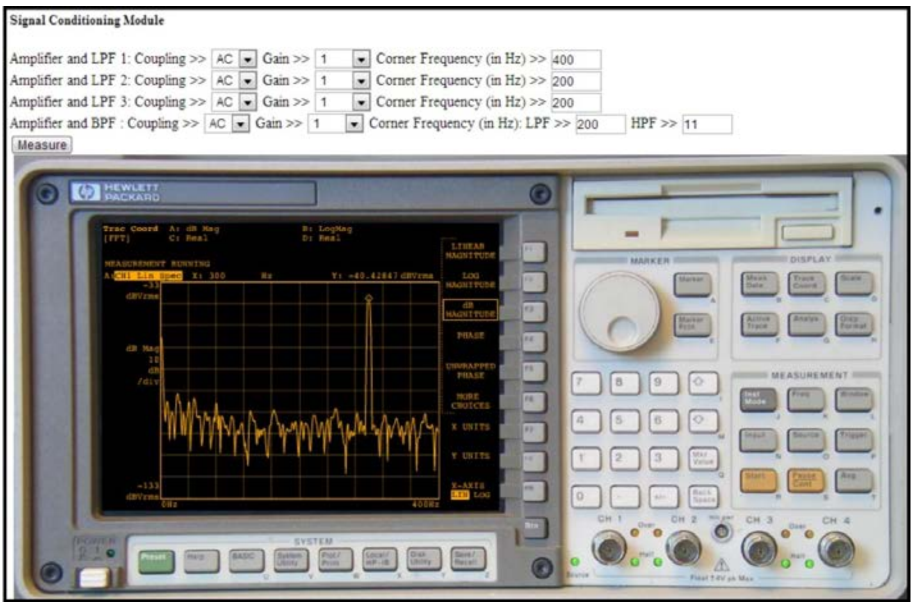

Figure 16. Use of the Measurement and Configuration Client during measurement of sinusoidal sound signal in dB.

5.4 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 on the VISIR acoustic lab is shown in figure 17.

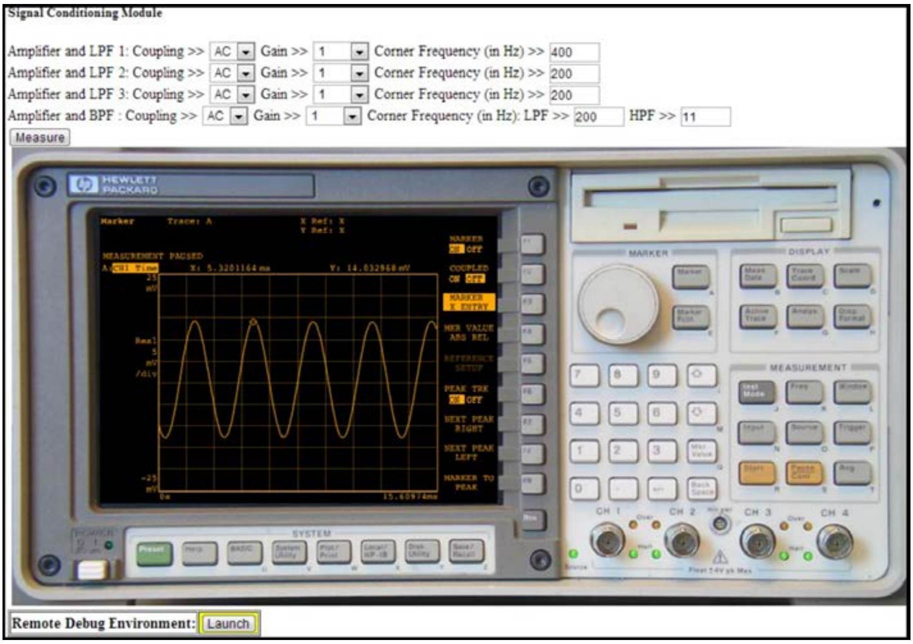

Figure 17. Illustration of a sinusoid sound signal in remote Lab experiment, to understand the wavelength and frequency relationship.

5.5. Sound pressure measurements:

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

5.6. Plane wave propagation:

Although this cannot be treated as an experiment but 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.

5.7. 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 figure 18.

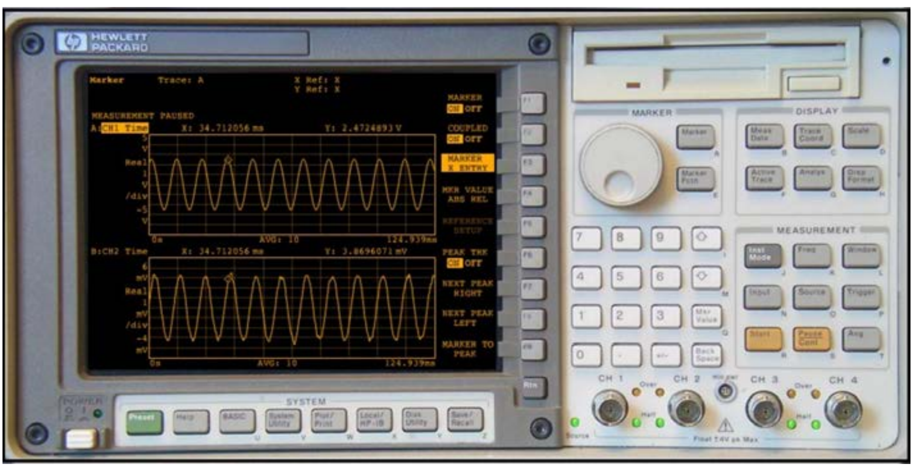

Figure 18. Illustration of determining the speed of sound in an acoustic experiment performed remotely.

5.8. 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 needed. 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 advance level acoustic experiments can be expanded.

5.8.1 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 waves 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 duct have certain Eigen frequencies. The student may first estimate the resonance frequencies fr for the duct of length L, open at both ends using the formula;

$$fr=nc/L \qquad (2)$$

Where c= 320 m/s, is the speed of sound in the air and n=0,1,2…is a integer number. Using the formula, the Eigen frequencies of the duct used are 79, 158 and 234 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 figure 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 plane wave region if desired, by limiting the frequency range of the signal analyzer. The number of resonance frequencies can be limited to plane wave region if desired. The students can further validate his/hers findings by generating a periodic signal having the same frequency as one of the duct resonance frequencies and slightly vary its frequency while keeping its amplitude constant.

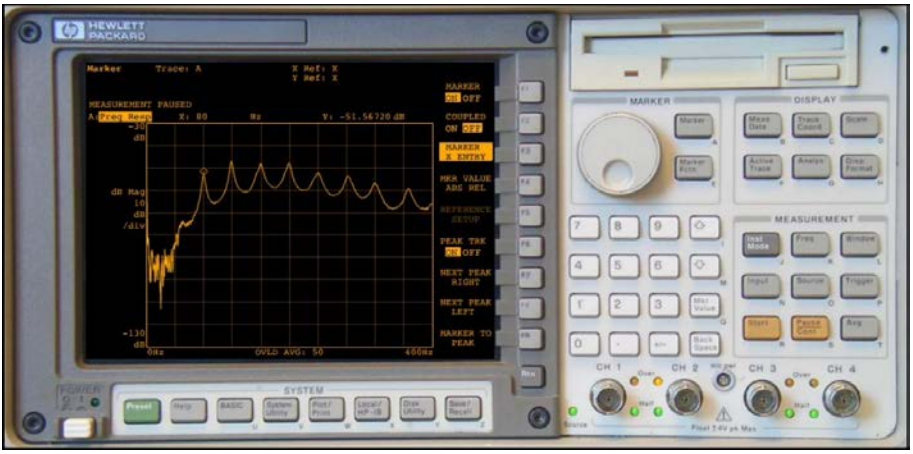

Figure 19. The measurement of the FRF for determining the Eigen frequencies of the duct. The first Eigen frequency at 80 Hz is shown by the marker.

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 the microphones can measure the maximum of a standing wave or a mode shape as shown in figure 20. The student can verify the existence of a standing wave by selecting e.g. an 80 Hz sinusoid signal and measure it with reference microphone3. Without changing any other parameters except the measurement microphone, he/she should get maximum amplitude on reference microphone 3 as compared to microphones 1, and 2. Which 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 may be difficult to achieve, so this experiment should be performed with care.

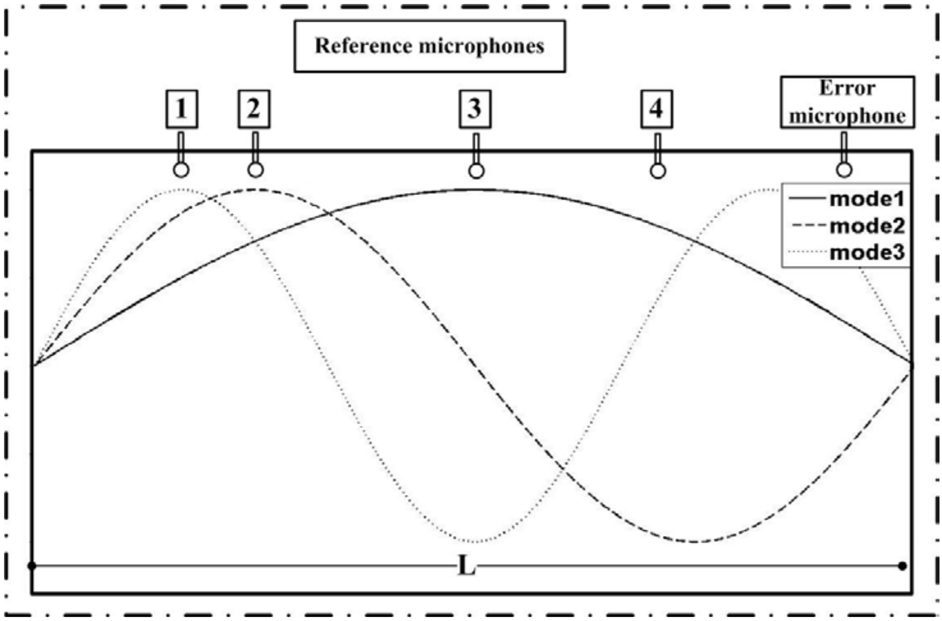

Figure 20. Illustration of the acoustic modes inside the duct and the positioning of the reference microphones inside the duct.

5.8.2. 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 figure 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 from this project are that the VISIR laboratories are easy to implement for use by both teachers and students. 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 setup is used by a teacher, the more new possibilities for experiments will emerge.

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

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Part C