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.

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.

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.

Figure 2 Workbench prepared for electronic labs.

Figure 3. Classroom at Katedralskolan, Lund, Sweden.

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.

Figure 4. Equipment server.

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.

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 not sufficient; 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 to the RL on a Learning Management System (LMS).

The third task is to upload a list of login ids and 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.

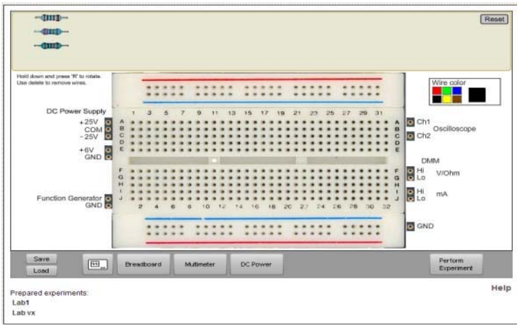

Figure 5. Virtual breadboard

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 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.

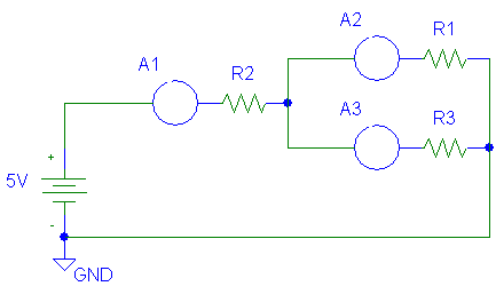

Figure 6. Circuit for an assignment for thirst year students

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.

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

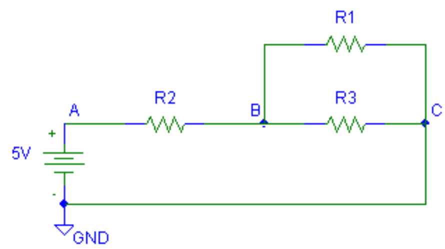

Figure 7. Circuit for an assignment for thirst year students

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.		

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?

References

[1] I. Gustavsson et al., "An Instructional Electronics Laboratory Opened for Remote Operation and Control", *Proceedings of the ICEE Conference*, San Juan, Puerto Rico, July 23-28, 2006.

[2] I. Gustavsson et al., "Remote Operation and Control of Traditional Laboratory Equipment", *International Journal of Online Engineering*, Vol. 2, No. 1, (2006).

[3] http://www.skolverket.se/content/1/c4/28/69/nv.pdf

[4] http://www.skolverket.se/sb/d/726/a/13845/func/kursplan/id/3053/titleId/FY1201%20-%20Fysik%20A

[5] K. Nilsson, J. Zackrisson, M.I. Pettersson, "Remote Access of Computer Controlled Experiments", *International Journal of Online Engineering*, Vol. 4, Issue 4, nov. 2008

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