Remote Experiments in Secondary School Education

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***Abstract*—This paper describes the current influence of the remote laboratory on practical learning aspects of secondary sector of education. The key challenges faced by the teaching of science include insufficient hands-on laboratory usage in classrooms. The main objective of the paper is to present learning approach of adaptation and usage of remote experiments of WebLab-Deusto in curriculum of secondary school. The activity was organized in collaboration with secondary school teachers of P. Andrés Urdaneta School. Educators can benefit from different teaching methods (collaborative, inquiry-, and project-based learning) integrated in WebLab-Deusto.**

The teaching of Ohm´s Law in Physics curriculum of secondary school was one of the topics executed during this research. The remote laboratory assignment for students was developed on Virtual Instrument Systems in Reality (VISIR) Open Lab Platform. The existing remote laboratories are more or less copies of hands-on ones. VISIR is a remote laboratory created by Blekinge Institute of technology (BTH) for designing, wiring and measurement of electric circuits. This main feature of VISIR allows one building a scenario of performing basic DC and low frequency AC circuits experiments related to Ohm's and Kirchhoff's laws. Moreover, the students will become familiar with instruments, components, manuals, data sheets, circuit wiring, and other laboratory work.

In the paper the main principle of VISIR will be presented; the remote experiments executed by students will be shown. Finally, the result of integrating of remote experiments for study in Urdaneta School will be discussed.

Keywords—remote laboratory, remote experiment, STEM, secondary education, Ohm's law, VISIR

I. INTRODUCTION

In order to successfully compete in a global economy, Europe aims to be amongst the most highly skilled regions in the world. Recent study shows that the occupational structure of EU employment of the engineering sector tends to shift towards knowledge- and skills-intensive jobs from 27.3% in 2007 to 32.4% in 2020 [1]. Industry requires well educated science, technology, engineering and mathematics (STEM) graduates. At the same time the percentage of drop off students in STEM is high - almost 30% for the science education and 50% for the engineering. Indeed the first encouragement students get in the school through the class instructions, practical assignments, laboratory work, and extra curriculum activity. A teacher is a source of knowledge and inspiration for the students in the education. Because of that teachers should have access to high quality and real-life-based resources to support student´s curiosity using up-to-date research and developments in STEM, multimedia interactive instruments including an experimental laboratory.

The OLAREX (Open Learning Approach with Remote Experiments) project consortium realized that the new strategies in the STEM educational field are needed; the knowledge and skills requirements exchange between school and industry through the university expertise should be established. For these purposes the consortium has been granted by Lifelong Learning Programme of the European Union [2].

The OLAREX started at November 2011 [3]. The institutions from different EU countries (Spain, Lithuania, Austria, Bulgaria, Hungary, and Poland) are involved in the project. For now the secondary schools teachers from all partner institutions already benefited from the first piloting session participating in the courses and modules designed during the project.

The aim of this paper is presenting the results of the implementation of the OLAREX module "Ohm´s law: How does the current flow?" and to discuss how OLAREX facilitates integration of remote experiments in teacher professional practice.

II. OLAREX PROJECT ACTIVITY

The main project purpose is to innovatively implement ICT-based (Information and Communications Technology) learning materials, remote experiments, and e-didactic methods into formal and non-formal lifelong learning settings. It will enhance and modernize STEM curricula, foster student creativity and motivation, and develop professional skills and insights about the impact of evolving technologies.

The organized training for teachers will build the e-didactic competences in the STEM by providing remote lab work explanations, offering practically-oriented approaches for strengthening educational programs and technical practices.

This work was supported by Lifelong Learning Programme of the European Union within Key Activity 3 - ICT (OLAREX project 518987-LLP-1-2011-1-ES -KA3-KA3MP). However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the European Commission.

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During the training, teachers integrate at least one learning module into their curriculum, test them in their classrooms, and encourage their students to apply what they learned in a final project. The six comprehensive learning modules with remote experiments – in English and the national languages of the partners – have been prepared based on the target groups' requirements. Learning and teaching materials have been incorporated into an e-platform - personalized learning environment.

III. NEEDS ASSESSMENT SURVEY, SPAIN, 2012

The presented survey was performed in Spain, in March-April, 2012, to analyze the knowledge and skills requested from secondary school students; a demand on teacher ICT competence development; a role of administration staff in ICT integration in school curriculum; e-learning materials and remote experiments needs as well as education methods.

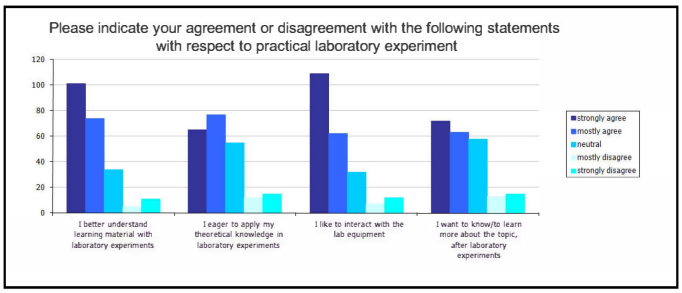
Most secondary schools in Spain show interest in remote experiments. More than 62% of the participated in survey teachers informed that they had an interest to test remote experiments in their curriculum. They also are interested to get more information about the Open Courseware and free online lectures, and how to use it in their curriculum.

At the same time, it was indicated that obstacles influencing the ICT integration in curriculum are lack of knowledge in using ICT instruments for education purposes, insufficient number of software/applications copies for educational use, and lack of knowledge on hardware and software characteristics. Usually students execute experiments in the frame of traditional hands-on laboratories. However, the laboratory equipment is expensive and its maintenance is complicated. The remote laboratory reduces the costs significantly, makes lab experiments available almost at any time and everywhere, personalizing the learning pathways [4], [5]. When the project started, the secondary schools of Basque Country, Spain, do not use remote experiments in the curriculum.

All target audiences of the survey stated a high interest in the remote laboratory and experiments believing that this tool can enhance STEM curriculum and teaching methods in class instruction and at the same time can develop a student competence which are required by industry.

242 students out of 464 participated in survey (52,4%) pointed out that they use hands-on laboratory activities and experiments laboratories in the class. Students, who had or have laboratory experiments, evaluated their experience with the words "strongly agree", "mostly agree", "neutral", "mostly disagree", "strongly disagree"- by answering on the questions :

- I better understand learning material using laboratory experiments
- I am eager for application of my theoretical knowledge in laboratory experiments
- I like to interact on the lab equipment
- I want to know/to learn more about the topic, after laboratory experiments



The results are presented on Fig. 1.

Fig. 1. Evaluation of the expirience to hands-on laboratory

The 44% of all survey participants like to interact using the laboratory equipment. 46% strongly agree and mostly agree that they better understand learning material. 37% of responders strongly agree and mostly agree that they are eager for application of their theoretical knowledge in laboratory experiments.

173 students out of 462 (37%) have heard of remotely accessible laboratories before, while 283 students (almost 63%) never have heard about it. However, despite on the huge number of those who never have heard about the remote experiments, after a brief presentation of the remote laboratory, more than 67% of all responders would be interested testing and applying remotely accessible experiments. It shows us the willingness of students to use new tools to support their practical assignments.

Teachers were another respondent group in the survey. In Spain, more than 100 teachers filled in the online questionnaire and responded that: 56% of responders do not use a practical laboratory component currently in their curriculum; while 44% apply the laboratory experiments in the class. Usually teachers apply laboratory activity in Mathematics, Biology and Technologies.

If remote experiments are available in the school, 50% responds that they are interested, 7% are very interested and 6% are completely interested applying them in class instruction (Fig.2).

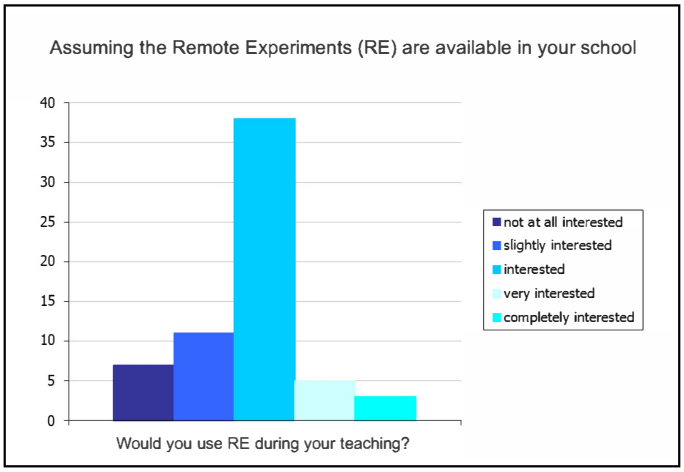


Fig. 2. Teachers´ interest to implement the remote experiment in class instruction

The main purpose of the study was to understand in the participated countries the ICT knowledge gap, necessity and willingness to apply the remote labs for learning and teaching. Based on the reports' conclusions the partners identified the methods, instruments and content approach, and expected ICT competence demands for the primary target groups: secondary school teachers and their students. The profiles of teachers, students, administrative representatives and companies responding the survey is available on the project website.

IV. Remote Experiment in Secondary School Instruction

Based on the survey, five courses on e-didactical competences for secondary school teachers were developed. One of them is "Transforming curriculum with remote experimentation: how to integrate it in secondary school classroom". This course aims to develop the competences such as the use of different types of remote and online labs, and to present them to students. During this online course the teacher activity is focused on an implementation in class instruction one of the six STEM modules:

- Black body radiation of common light sources (simulation activity)
- Farm Experiment: from an egg to a baby chick, step by step (remote experiment activity)
- Working as a computer – Logic gates (remote experiment activity)
- Analogue circuits measurements (remote experiment activity)
- How does the current flow? (remote experiment activity)
- Easy Java Simulation for Phys&Sports (simulation tool)

In this paper we will present the module "Ohm´s Law: How does the current flow?" tested in collaboration with secondary school teachers of P. Andrés Urdaneta School. The provided module is a didactic support module for implementing the remote experiments in a classroom. Teachers can use its structure as a whole element without any changes. They can apply some parts such as exercises, experiments, problems, or only ideas of topics for student´s final projects. Average learning time for the module is around 20 hours: 10 hours of theory, 5 hours of execution of exercises, tests, experiments, and one final small project (5 hours of work) are included in the module. The learning module covers following topics: electrical current, Ohm's law for direct and alternative current, electrical resistance, capacitors, signal generators, digital circuits and measurements within the VISIR. Each module unit provides both theoretical and practical approaches including a problem solving by simulations and using remote experiments.

The main learning outcomes of this activity are: (1) the skills to design experiments confirming the hypotheses; (2) the practice to work with laboratory materials and equipment, including the VISIR; (3) the knowledge of digital circuits of direct and alternating currents.

V. VISIR Open Lab Platform

Electrical experiments are common at schools and universities. Usually students execute experiments in the frame of traditional hands-on laboratories. The existing remote laboratories are more or less replicas of hands-on ones. Virtual Instrument Systems in Reality (VISIR) Open Lab Platform is a remote laboratory created by Blekinge Institute of technology (BTH) for designing, wiring and measurement of electronic circuits. A student designs circuits using virtual instruments and wires on the interface of the devices-gadgets such as: Smartphone, tablet, iPad, and PC. Then, VISIR Open Lab Platform converts the student's design into a real wired circuit and sends the measurement results to the interface of the student device. Thus, VISIR Open Lab Platform is a real electronic lab environment which can be accessed at any time and from anywhere over the Internet [6].

There are three main scenarios for practical learning using VISIR Open Lab Platform [7]. However we will only present the usage of the VISIR by secondary school students. They can use VISIR Open Lab Platform for performing basic DC and low frequency AC circuit experiments related to Ohm's and Kirchhoff's laws. Moreover, the students will become familiar with instruments, components, manuals, data sheets, circuit wiring, and other laboratory work [8].

The main part of VISIR Open Lab Platform architecture is online workbench (Fig.3) that is similar to hands-on laboratories at any school. Workbench for electrical experiments contains power sources, measuring instruments and a solderless breadboard (Fig.3). A virtual instructor protects the online workbench from student's harmful errors and damages during experiments.

The VISIR Open Lab Platform provides a virtual component box and virtual breadboard for controlling the switching matrix and for "wiring" circuits remotely using the mouse pointer. Users select components using the button "+" from the library of components and put them into the component box.

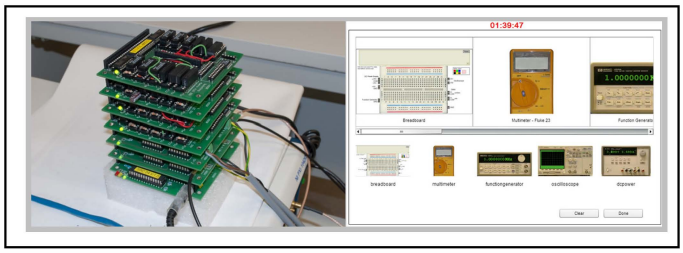


Fig. 3. The online VISIR workbench at WebLab - Deusto, University of Deusto

The VISIR Open Lab Platform offers virtual front panels of the desktop instruments and the multimeter in image format

(Fig.3). Adobe Flash animations enable students to turn the knobs and buttons, and make settings using the mouse pointer. In order to avoid misunderstanding and provide immersion of the remote experiment, the virtual panel is an exact virtual copy of devices which students use at hands-on laboratories. In order to build holistic immersion of the experiment sessions of the remote activity should be organized as a hands-on laboratory - one workbench per student or student´s team [9]. Each remote student or student´s team creates the experiment using laboratory interface and sends a message containing a description of the desired circuit and the instrument settings to the VISIR workbench (server). The experiment result or an error message is returned to the requesting client computer after performing the procedure. The student should wait in queue to execute the experiment in case of server occupation.

VI. Results of Implementation in School

The laboratory practice on remote experiments was taking place during two weeks in March 2013. Forty eight students of 2nd year of Baccalaureate (grade 11) of Urdaneta high school (Loiu, Bizkaia, Spain) [10] participated in it. A group of Urdaneta high school teachers in STEM areas have volunteered time within their busy schedules, to design and implement one curriculum topic – Ohm´s Law, which requires the laboratory practice, learning, and understanding of the technology [11].

The activity is divided into three parts. In the first part a teacher presents WebLab-Deusto remote laboratory: how to login in the remote laboratory, how does library of components work, how wire the digital equipment such as multimeter, DC power, function generator, etc. In this first part, students experiment at home in order to become comfortable with the remote experiment approach. The second part includes the work on the design of electrical circuit connected in series. The students get an exercises list including ten different series circuits that they execute using simulation tool- Falstad Analog Circuit Simulator Applet [12] and WebLab-Deusto remote laboratory, and compare the results accomplished with two different tools. This assignment allows one to study the Ohm´s law using inquiry-based learning approach as well as to analyze the difference between a simulation and a remote experiment. The next activity provides a set of experiments for parallel circuits. The students use the same instruments and report template as for the series experiments. The final project includes creating by student circuit´s schemes based on proposed requirements, designing "invented" circuits in WebLab-Deusto (Fig.4), using the components library of the WebLab-Deusto; analyzing obtained results, writing a report and a conclusion how his/her hypothesis fits the results obtained during experiments.

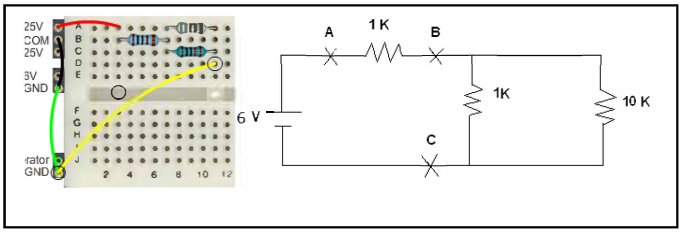


Fig. 4. Presented by Urdaneta school student circuit schema and circuits built in WebLab-Deusto environment

During the practice teacher can control an execution of an assignment by students. They can check how often students work in laboratory, how much time they spend, what errors occurred during the activity, the source of the errors - system failure or student´s mistake (Fig.5)

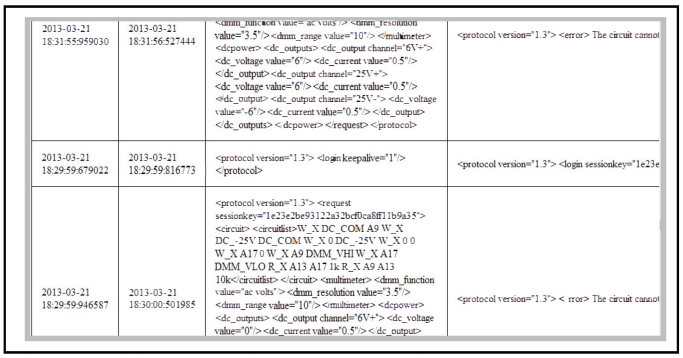


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Fig. 5. Statistics of execution of remote experiments by student

Although the practice in environment of remote laboratory was organized for the first time, 72% of students show successfully performed exercises and laboratory work. The preliminary analysis of implementation of Remote Laboratory in class instruction in Urdaneta School shows positive feedback on presented trial: due to flexible connection to the laboratory, student´s access was massive during several days before the deadline of the final project. Most connections were done after 6pm. Such open schedule will be not possible with hands-on laboratory. Students can design circuits several times and experiment safely; discover functioning, components and equipment the remote laboratory before the actual activity will start; share and discuss their final project during lessons; obtain understanding of research cycle from hypothesis statement until analysis of the results, discussion, conclusion and report writing. However the remote laboratory needs holistic understanding of the difference between computer simulation and real experiments provided with Internet. Several sessions were needed in order students can recognize that it needs time (just several seconds) to send signals to server, complete the experiment and get it back on the screen of their computer, tablet or Smartphone. Namely, this misunderstanding was a reason of student´s disappointment on the first stage of VISIR execution at high school level. We decided in the next semester to improve the strategy of introduction of remote laboratory in secondary school classroom.

VII. Conclusions

OLAREX project contributed to teacher training on how to use remote laboratories and to improve practice at secondary schools considerably. Teachers showed great interests in using remote labs at their classes. Considerable effort was made by project consortium, and great appreciation was received by the teachers, to have both, training on application of remote labs, and having the context of ICT courses, training on integration of remote labs and facilitating teachers to do so.

In this paper we discussed the aspect of integration of remote laboratories into the secondary school curriculum using WebLab-Deusto. Thanks to modern communication instruments, common resources including remote experiments are available for students anyplace and anytime.

Our future work can be conducted in three directions: (1) provide this teaching approach to several EU countries (by providing teachers online technical and content supports); (2) improve introductory and visionary activity for remote laboratories in secondary school to allow a holistic immersion to the topic; (3) personalize the web interface of the remote laboratories and experiments. This year we have got the first results of using the remote experiment in the secondary school physics instruction. The 72% of successfully performed exercises and laboratory work students show that this tool is valuable supplementary instrument in the education of school sector. Next phase requires teacher´s individual effort and motivation. The future will reveal how these efforts will be met in local and national contexts.

ACKNOWLEDGMENT

We thank Olatz Alzola Colinas from Urdaneta Secondary school, Spain for her help implementing the module in her class instruction.

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