Abstract—Remote labs that enable students to conduct real-world experiments at a distance using a computer and Web-based tools can be the only realistic method of performing practical experiments in the context of distance learning.

eScience Tempus project "Maghreb Network of remote labs" offers an innovative pedagogical approach which integrates eLearning and is complementary to classroom learning. The main objective of this project is to create an efficient remote labs network in the Maghreb region for the modernization of higher education in technological sciences.

The current paper summarizes the work carried out on a heat exchanger bench to be fully accessed and controlled remotely. Through this new device a student of Mechanical Engineering is introduced to many fundamental aspects of heat transfer.

Keywords—eScience project; Maghreb; remote lab; heat exchanger

I. INTRODUCTION

The Web has spurred our imagination as to how education can be radically transformed and enhanced through the adoption of ICT. While the use of Web-based education to date has seen significant innovation, it has not had the revolutionary impact originally envisaged, and has certainly not displaced the traditional settings of classrooms, schools, colleges and universities [1], especially in educational laboratories. Those practical educational aspects need more and more development.

As we know, the use of laboratory experiments is a critically important aspect of education. Experience in teaching has shown that a complementary approach combining theoretical and practical exercises is vital for effective learning [2]. According to Hansen (1990) [3], students retain 25% of what they listen to, 45% of what they listen to and see, and 70% when they manipulate, control and modify experiments, putting into practice what they are learning.

In the context of distance learning, remote access to distance laboratories can be the only realistic method of performing practical experiments [2]. These remote labs enable students to conduct real-world experiments at a distance using a computer and Web-based tools [4].

Increasingly, teaching institutions are offering remote access to distant laboratories as part of an overall e-learning strategy. Remote experimentation provided as part of a Web-based learning approach affords a number of critical benefits, allowing flexible access to on-campus resources free of time or geographical constraints. However adapting and redeveloping existing experimental resources to this purpose is a very hard task.

In the Maghreb region, the strong demand for top technicians and engineers needs increase of training capacity. Enrollment growth and quality of courses are often incompatible.

In order to avoid typical constraints of traditional laboratories, such as scheduling, cost of equipment and location, remote operation of real plants can be incorporated into engineering courses [5].

eScience Tempus project "Maghreb Network of remote labs" [6] offers an innovative pedagogical approach which integrates eLearning and is complementary to classroom learning. The main objective of this project is to create an efficient remote labs network in the Maghreb region for the modernization of higher education in technological sciences.

As a partner of this project, we have to adapt and develop distant access solutions for two remote labs allowing students to perform practical experiments on heat transfer and mechanical vibration. These two remote labs will be a part of the Maghreb Network of remote labs.

In this paper, a heat exchanger experiment remote lab is presented, through which a student of Mechanical Engineering is introduced in both a theoretical and practical way, to many fundamental aspects of heat transfer. We present the work carried out to adapt and redesign this device to be fully accessed from the Internet.

II. THE ESIENCE PROJECT

The eScience Tempus project "Maghreb Network of remote labs (2012-2015)" offers an innovative pedagogical approach which integrates eLearning and is complementary to classroom learning. The main objectives of this project were:

- to build a network of remote labs in Maghreb region,
- to implement of a state-of-the-art solution,
- to establish a best practice,

for the modernization of higher education in technological sciences. This remote labs network will enable students to conduct real-world experiments at a distance, and to assess the educational potential of such a system.
The specific objectives of this project are:

- The adaptation of content to the technological changes sciences taking into account the expectations of the market needs,
- The setting of three remote measurements platforms in the Maghreb and their networking,
- The implementation of remote practical activities,
- The development of e-learning modules and courses,
- The evaluation of the course developed,
- The accreditation of the learning units in accordance with the Bologna process,
- The use of resources,
- The dissemination of the project at national level in partner countries and at international level,
- The sustainability through enrollment in university courses in partner countries.

At this time, the eSience project is well advanced and the majority of remote labs are under test and evaluation.

At the Gabes Higher Institute of Industrial Systems (ISSIG), as a partner of the eSience Tempus project, we adapted and developed distant access solutions for two remote labs allowing students to perform practical experiments on heat transfer and mechanical vibration. These two remote labs will be directly connected to the e-Lab server of Ene’com-Sfax, Tunisia.

The current paper summarizes the work carried out on a heat exchanger bench to be fully accessed and controlled remotely. Through this new device a student of Mechanical Engineering is introduced, in both a theoretical and practical way, to many fundamental aspects of heat transfer.

III. THE HEAT EXCHANGER BENCH

Engineers learning about thermodynamics and heat transfer need to know how well different heat exchangers work. They can use this information to decide the correct heat exchanger for their own designs. TD360 Heat Exchanger bench [7] shows students how different small-scale heat exchangers work. They mimic the most common heat exchangers used in industry and compare how well they work for different flow rates and temperatures.

TD360 module (Fig. 1) is a compact frame with two water circuits (hot and cold) and instruments to measure and display water flow and temperature. This module can work with various types of heat exchangers (Concentric Tube Heat Exchanger, Plate Heat Exchanger, Shell and Tube Heat Exchanger and Jacketed Vessel with Coil and Stirrer). Students test each of the optional heat exchangers and record the flow and temperature changes to see how well the heat exchanger works. If they have one or more of the heat exchangers, students can compare them to see which is best for any application.

In the present experiment we use only the Concentric Tube Heat Exchanger (Fig. 2). This heat exchanger is a simple shell and tube heat exchanger. It has two tubes, one inside the other. The outer tube is the shell. The inner tube carries the water from the hot circuit; the other tube carries the water from the cold circuit. Heat transfers between the two tubes. You may connect the water circuits to give contra-flow (counter-flow) or parallel flow experiments. This heat exchanger is in two equal parts with extra thermocouples at the mid-point.

These experiments help students to understand more clearly how the temperature changes along the heat exchanger. Fig. 3 shows an example of results of the effect of varying cold flow rate on the performance of the heat exchanger in both parallel flow and counter flow connection. In this case hot flow rate and heater temperature are fixed.

![Fig. 1. TD360 Heat Exchanger bench](image1)

![Fig. 2. Concentric Tube Heat Exchanger (TD360-a)](image2)

![Fig. 3. Example of heat exchanger experiment results](image3)
IV. THE REMOTE CONTROLLED HEAT EXCHANGER BENCH

The architecture of ISSIG remote lab is presented in Fig. 4.

Fig. 4. ISSIG remote lab architecture.

The heat exchanger bench was adapted for remote operation. The adaptations included control of the hot water supply pump, the heater and the cold and hot water supply flows (Fig. 5). To provide students with an overview of the whole heat exchanger bench an IP camera was located in the laboratory.

Fig. 5. Heat exchanger remote Lab.

The user interface (UI) application which was developed to enable students to control the heat exchanger remotely is shown in Fig. 6. The UI included buttons for controlling the different parts of the heat exchanger bench, and displayed the feeds from water supply flowmeters, thermocouples and the IP video camera.

Fig. 6. Screenshot of the user interface developed at ISSIG to control the heat exchanger remote lab.

V. PEDAGOGICAL EVALUATION

The evaluation of our remote labs will be in the framework of the whole evaluation strategy adopted by all eScience project partners [8]. The evaluation strategy of the project will focus on five different but interrelated directions (a) usability of remote labs; (b) learners’ attitude towards remote labs; (c) technical evaluation of remote labs operation; (d) evaluation of the e-learning content namely the teaching units previously described; and (e) learning outcome.

The evaluation will be conducted in two sequential phases:

- phase I : pilot evaluation
- phase II : large scale evaluation

The first phase will be the pilot evaluation of all remote labs in small scale usage. During this phase we plan to assess the remote labs’ usability and proper functioning as well as learners’ attitude towards remote labs.

The first evaluation phase of the ISSIG remote labs will be conducted on December 2014. A population of 30 students will perform their experiments on every remote lab.

According to the results of the first stage evaluation of the remote labs, operation and user interface will be improved and they will be deployed in a large scale usage. After that period of usage the large scale evaluation will be accomplished. The large scale evaluation will focus on usability of remote labs; learners’ attitude towards remote labs; evaluation of the e-learning content; and assessment learning outcome. [8]

VI. CONCLUSION

The main objective of eScience Tempus project was to create an efficient remote labs network in the Maghreb region. As a partner of this project, ISSIG have to adapt and develop distant access solutions for two remote labs allowing students to perform practical experiments on heat transfer and mechanical vibration.
The current paper presented the work carried out on a heat exchanger bench to be fully accessed and controlled remotely. This includes control of the water supply pump, the heater and the cold and hot water supply flows. Also, an IP camera was located in the laboratory to provide students with an overview of the whole device.

In addition, a user interface application was developed to enable students to control the heat exchanger remotely. It incorporated buttons for controlling the different parts of the heat exchanger bench, and displayed feedbacks from sensors (flowmeters and thermocouples) and the IP camera.

To test and validate this remote lab an evaluation phase will be conducted. It will be in the framework of the whole evaluation strategy adopted by all eSience project partners.

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