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Remote Control Experiments in Chemical Engineering Education

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Computing and communication technology has had a significant impact on the engineering education system. It improves the students' learning experiences and helps them face the new challenges regarding environmental constraints and sustainable development. A special feature of chemical engineering education is the development of experimental related skills. Environmental monitoring requires specialised laboratories for air, soil, and water analyses. This is a costly enterprise in terms of equipment, maintenance, and reagents consumption. One of the advantages of remote laboratories is a direct cost saving because little loss of equipment through misuse, a comparatively small number of apparatus and equipment sets that can be more efficiently shared by the students (due to the queuing, and scheduling used by the on-line access management system), lower maintenance costs, and dramatically reduced floor space requirements.
We report the development stage for the remote control experiments oriented towards training and e-learning in Environmental Monitoring Analyses in our faculty. The implementation of this laboratory is an example of the integration of open source software tools: running the experiment on the student's computer requires only a Java-enabled Web browser. Consequently, the feedback received from users is extendedly commented to provide future development strategies.

1. Introduction

Higher education has submitted great change over the past decade and further change is yet to come. The student population has increased massively and the sheer numbers alone are creating pressure on space, teaching time and facilities. The student population is not only increasing but is also becoming more diverse. We are moving away from a short sharp burst of education early in one's career towards "lifelong learning". There

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are increasing numbers of part-time, distance taught and work-based students taking an increasingly diverse range of courses.

Computers are being looked to as a flexible delivery mechanism. They have been used in teaching for more than thirty years. During the last decade the exponential expansion of the Internet has had an enormous impact on the education sector. The new technology has brought a significant improvement in communication within the academic community and has improved students' learning experiences.

One of the most important factors in forming the engineering graduate qualities is the practical component of the engineering curriculum. The professional engineering community expects engineering graduates to develop practical skills during their educational experience. Work in the engineering laboratory environment provides students with opportunities, as testing conceptual knowledge, working collaboratively, interacting with the equipment and performing analysis on experimental data.

Work in a real laboratory imposes time and physical boundaries both for students and academic staff. It requires significant scheduling effort and financial investments.

Without doubt the experimentation in a real laboratory is irreplaceable, but there are certainly aspects that make this option difficult to implement and in some cases, like distance education, impossible to support. On the other hand one can ask how much does an average student benefit from working in a real laboratory under the pressure of limited time, without enough knowledge to troubleshoot the equipment and the opportunity to repeat the measurements at the later stage.

Remote Laboratories are a relatively new development concept but their numbers are exponentially increasing due to recent technological progress and availability of tools for their design. They certainly represent the best alternative to working in a real laboratory because, if properly designed, they can offer students a tele-presence in the laboratory where they can perform experiments on real equipment, the possibility to collaborate, to perform analysis on real experimental data but, also, flexibility in choosing time and place for performing experiments.

2. E-learning Portal as Support for Remote Control Laboratories

The Faculty of Applied Chemistry and Material Science has implemented a portal for assisted education and, in the frame of this portal, a remote laboratory for environment quality monitoring was developed. Engineering students of our faculty are thus offered, through the duration of their programs, a balanced mixture of real and remote labs.

The portal developed and tested in the University 'Politehnica' of Bucharest offers the users (students and academics) five different spaces: personal homepage, teaching/learning, workspace, collaboration, and administration (Josceanu 2008). Common document, drawing board, agenda, meeting notes, instant messaging, private discussion, Web tour, slide presentation, audio and/or video conferencing represent the tools currently available in the workspace. They were highly appreciated by those who used them for training purposes in the chemical engineering undergraduate curricula. The next stage in development is represented by the integration of a module for remote controlling equipment in the environmental monitoring laboratory of the faculty.

Current Internet-based technologies allow traditional control laboratories to be supplemented with remote or simulated experimentation sessions, which hold much promise for distance learning institutions (Sivakumar et al. 2005, Dormido et al., 2005, Helander et al, 2008). The remote control experiments allow students to acquire good laboratory practice skills, and experience related to real equipments in an intuitive and cost-effective way. Another attractive advantage is represented by the chance of freely and flexibly training in contrast to a fixed and regular class schedule.

UPB and Siveco Romania have started a pilot innovated e-learning project and for testing of new specialized education ways. In this view we developed a complete solution, named **LV1**, to perform the lab tests and data processing with personal computer assistance. The main advantage is that the experiments and the lab tests can be made from distance through internet. With the help of this pilot device it is possible to make 4 simultaneous experiments for each sample among the 8 tested.

3. Remote Laboratory 1.0

Remote Laboratory vers. 1.0 (LV1) propose to sustain education process through high level of innovation and through newest technology used. This is made by two components: *software component* and *hardware component or automatic machine.*

3.1 *Software component*

The software component consists of a software application which is a friendly user interface developed in Microsoft Visual Studio.net integrated with the AEL portal. The integration with the AEL Portal is made using two of the five spaces available: workspace and teaching/learning. In workspace the academic will create a learning object, which represents the theoretical part of the experiment.

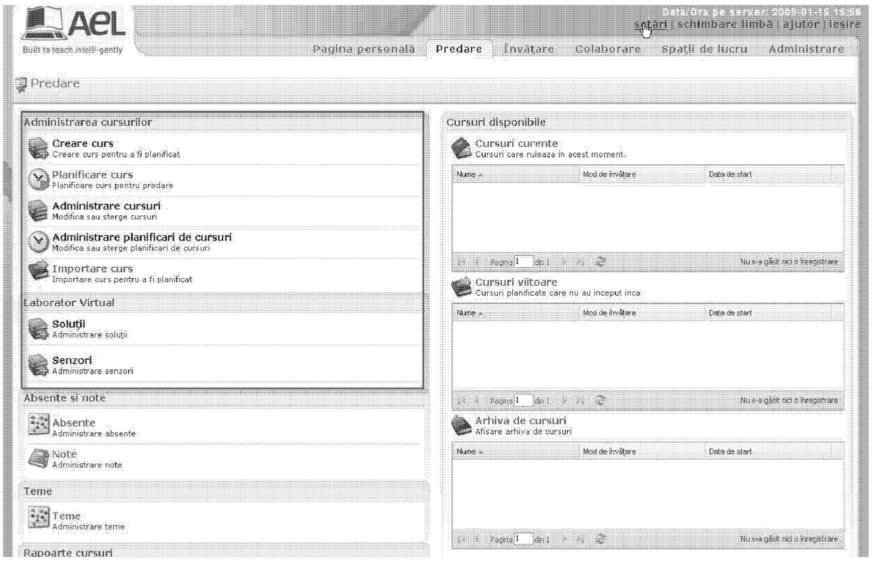

Figure 1 Teaching space with the described actions highlighted

In the teaching space **the academic** will have the following actions available:

- Create a course in which the learning object containing the theoretical parts of the experiment will be embedded.
- This course is then scheduled and participants are added. These students will be able to access the remote laboratory in order to make the experiments.
- Also in this space the academic will prepare the laboratory. There is a special section where the academic will see a list of sensors and a list of the available solutions. In the solutions list items can be added, edited or deleted.

The application provides the **student** with the possibility of conducting an experiment. In the learning space the student can open the course assigned by the teaching staff. From the course's main page he can browse the materials of the experiment and then launch the remote laboratory. If, at that particular moment, the laboratory will be locked by another student a message will appear. When the laboratory is free the student can launch it. A window will appear from which the student can control the experiment: choose the sensor or sensors involved, choose the solution and start the experiment. After the experiment is completed a confirmation message will be prompted and certain graphics about both the theoretical result and the actual ones can be viewed. The other students will watch the experiment and they will be able to interpret the data obtained.

The information regarding an experiment, such as those about students, solutions used, sensors and results will be stored and automatically archived in the database.

3.2 Hardware Component

The *Hardware component* is represented by the hardware interface for the laboratory equipment and PC communication. This hardware component is made by interface *firmware* – developed in code machine / Assembly Language and C++, that configures the device.

The device is made out of a stable frame, a revolving disc and 4 sensors. On the first one, there are the mechanisms which unleash the 4 sensors, as well as the one unleashing the disc. In order to generate different movements there have been used miniature engines of small steams, a step-by-step engine and several serrated racks, all of them being dictated by the hardware component.

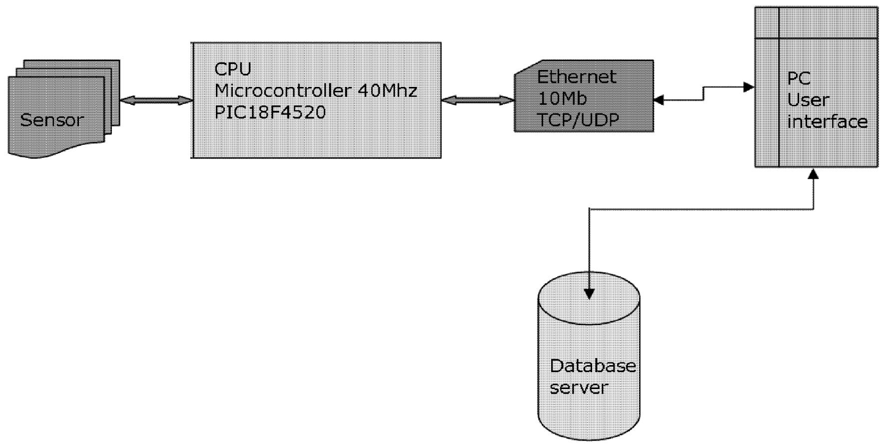

Figure 2. Hardware schematic representation

The remote laboratory allows the academic to configure and prepare the device for each single experiment. The trainer has to set this automate so that it can recognize each substance used for the experiment and each sensor involved in the experiment for the good functioning of the works conducted in the laboratory. The laboratory substances are poured into 8 Berzelius glasses, placed around in circle and for the measurements there are used maximum 4 sensors, each with different functions. This configuration allows the user to do 4 experiments at the same time.
From obvious reasons, the device can be used for measurements only by one user at a given time. The others can observe the experiments and do the analysis of the data that are obtained. This way, the laboratory is blocked for the time measurements are made, being available to the user that controls it.
For the student type of user, the application allows this one to choose the experiment he would like to make. To this purpose, the student chooses the substance prone to the experiment and the sensors that will be used. Also, depending on the work, the student has to make the standardization of the sensors. The other participants view the experiment and analyze the data obtained consequently.
The information related to the experiment, such as the details on the students, the substances used and the results are stocked and archived in the data base, being available at any time.

4. User's feedback

Studies documenting the impact of these more sophisticated technology systems showed increased teacher-student interaction, cooperative learning, and, most important interacting with the equipment, and performing analysis on experimental data. Our test group is formed of undergraduate students in the first, second, third and fourth year.

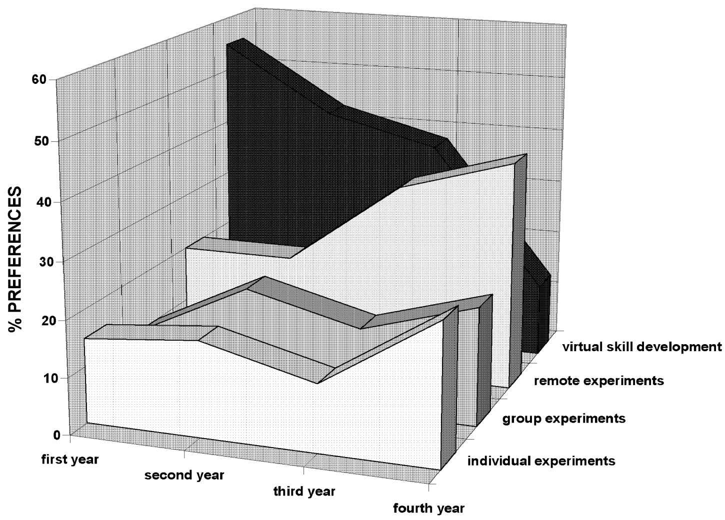

Figure 3 Students' preferences regarding laboratory activities

The total number of interviewed students was 78, divided in groups varying between 20 and 30. Sophomores are attracted by the virtual laboratories, in which they can develop simple laboratory skills in an environment similar to computer games (to which they are very familiar and very attracted). As they gain more experience in the chemical engineering training they discover that real and valuable laboratory skills are developed by real life experiences collected individually or as a member of a group with an assigned learning objective. The interest for remote controlled experiments becomes evident for the students in the third and fourth year of study, and this fact seems to corroborate with the increased complexity of the problems to be solved in the laboratory. In their case, data collected in dynamic regime require advanced processing using dedicated tools that can be found in the common space module of the e-learning portal. These tendencies are numerically illustrated in Figure 3.

5. Conclusions

The design and delivery mechanism for the new module of the e-learning portal are tailored as recommended in the literature (Sivakumar 2004) to: i) provide a constructivist pedagogical approach; ii) model a collaborative learning environment for group interaction; iii) match the characteristics of the delivery media to specific learning processes (media-synchronicity theory) including the provision of unambiguous feedback and guidance; iv) assign appropriate instructional roles, and v) determine desirable student competency outcomes, all in a remote learning context. A multi-tier role architecture consisting of faculty, facilitators at both local, and remote sites, and students, has been used and adapted to maintain academic integrity and offer the same quality of interaction as the on-site laboratory activity. The interface between the user and the automatic machine is developed in Visual Studio .net and PHP. The automatic machine is split into an interface firmware component developed in assembly language and a hardware module, composed by microcontrollers from PIC family. The communication is established as Ethernet 10 MB and uses standard protocols like TCP and UDP.

Students, the main beneficiaries of this module have shown a great deal of interest towards the possibility of carrying out experiments remotely. Academic staff showed less enthusiasm toward the present version of the application, demanding more flexibility in the data acquisition and working parameters optimization stage, as well as visualization of the whole experiment.

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