Remote Electroanalytical Laboratory

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***Abstract*—Remote Laboratories are web based distance learning laboratories that have immense potential to disseminate technology in the area of practical science. These laboratories can be accessed through internet.**

In the present paper, we will be discussing our experiences in setting up a remote analytical laboratory at our centre. Further, we will discuss remote experiments in the area of electroanalytical chemistry & colorimetry and their role in strengthening the system of science education.

***Index Terms*—Remote Laboratory, Windows Server 2008 Remote Applications, Analytical Electrochemistry.**

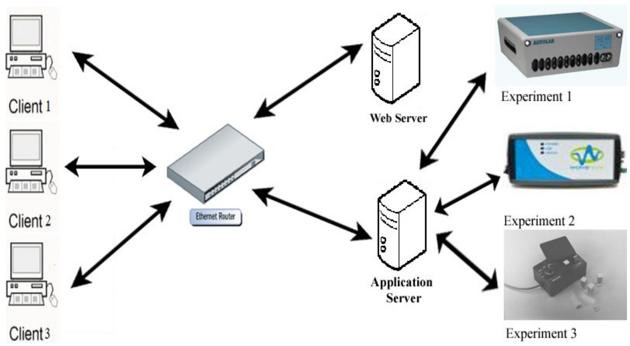

Figure 1. Remote Instrumentation Setup

I. INTRODUCTION

Practical courses are an essential part of a chemistry curriculum. In case of chemistry courses via distance mode, conducting the laboratory component at the convenience of the learner becomes a difficult task. In the last few years, there has been a tremendous effort in integrating real experiments into online material for providing wider access [1, 6, 7]. There are two chief approaches of including experiments into the online material:

a. Simulation of an experiment
b. Implementation of remote access into real laboratory equipment and real experiment.

The first approach, i.e., simulation is a more economical method of introducing the learners to new experiments. However, simulation of an experiment makes use of a mathematical model and hence is more hypothetical rather than real, whereas, the second approach provides access to real experiments and is more challenging and interesting for the learners [2].

Some of the applications of remote controlled experiments being practiced successfully are:

a. Microelectronic Device Characterization in the iLab project at MIT, USA [3].
b. Remote control to research equipment-MALDI-TOF at University of Delaware, USA [4].
c. Remotely controlled laboratories for physics students (for example, wind tunnel experiment developed by Jodl and co-workers) [5].

The above laboratories have provided ample evidence of success and utility of the virtual laboratory setup for providing universal access to quality practicals in science courses.

The Ministry of Human Resource Development (MHRD) under the National Mission on Education through ICT (NMEICT) has launched a network of virtual laboratories. The design and development of the Virtual Labs has been jointly taken up by the IITs (Delhi, Kanpur, Bombay, Madras, Kharagpur, Guwahati, Roorkee), IIIT Hyderabad, Amrita University, Dayalbagh Educational Institute, NITK Surathkal and College of Engineering, Pune. These Virtual Labs are effective both as instructional tools as well as self-learning tools, and provide a laboratory experience on the net. The web site for virtual labs is http://vlab.co.in. The above virtual laboratories follow UG, PG and research curriculum of Indian higher education in Science and Engineering.

As part of the NMEICT Virtual Labs Project, we have developed a remote analytical laboratory (Analytical Virtual Instrumentation Applications Laboratory-AVIAL) at Dayalbagh Educational Institute, Agra, India. The distance learning material for the practical course consists of several learning units with experiments in analytical chemistry. The experiments are remote experiments with simulation component at the front end so that the students can experience a real experiment environment. The experiments reported in this paper are in the area of electroanalytical chemistry.

II. DESIGN OF REMOTE LABORATORY

Access to remote experiment is based on client/server architecture. The software we have used for remote connections is Windows Server 2008 with capability of remote applications. Figure 1 above explains the setup of the real laboratory. The lab comprises of web server and an application server connected to the instrument. The web server and the application server are on the Local Area Network (LAN).

A router is placed as the interface between LAN and the clients who are on the internet. The router port forwarding technique has been applied for securing connectivity between the virtual laboratory and the client. For example, the web server runs on port 80 (default port for web servers). When the client connects to the virtual lab through the website a request is made by the client at port 80 to the router and the router is programmed to forward the request to web server which is connected to the local network.

The server controlling the laboratory is one of the main components and the application software resides in the server. The client is a Windows XP computer connected to the internet running a standard browser and has a remote desktop client 6.1 installed for remote connections. The client on remote connection to the server enters user ID and password and after authentication is logged on to an application running under terminal services (TS) program.

III. COURSE LESSON DESIGN

Practical course lessons have been designed similar to the real laboratory course. In the left panel of the screen shown in Figure 2, the structure of a course lesson is displayed. The objective of the experiment is described under *Introduction* section. The *Introduction* section also describes the theoretical background of the experiment.

This section is followed by *Setup* which describes the equipment used for the experiment. In the *Materials and Sample Preparation* section students get to know about the material used in the experiment. The *Procedure* section gives details for controlling the real-time experiment in a sequential manner. Students can run the animation of the equipment as a demonstration before accessing it in real time under the *Animate Instrument* section.

Experimental data, video and audio are stored under the *Virtual Experiment* section. The student can review the recorded data here. In the *Online Experiment* section a student is able to remotely access the instrument and do the real time measurements. The *Data Analysis* section details what the student needs to do with the data obtained.

IV. PERFORMING AN ONLINE/REAL TIME EXPERIMENT

A web site, http://220.227.100.58 was created for virtual analytical laboratory at Dayalbagh Educational Institute. The site has study material with related experimental procedures, simulations for the students to prepare for a real laboratory environment, quiz, feedback, etc. A student can interact remotely with an instrument, a potentiostat in our case for electrochemical measurements and a colorimeter. Three such experiments are reported in this paper.

V. A CYCLIC VOLTAMMETRY EXPERIMENT

Discussed below is a basic experiment in cyclic voltammetry, viz., determination of ascorbic acid in lemon. Initially, the student does a simulation exercise to reinforce his concepts about cyclic voltammetry. The student then remotely connects to a potentiostat, WaveNow, of M/s Pine Research Instrument, USA [8] and the measurement is done through manufacturers' application software, AfterMath. Either full control of the potentiostat is given to the authorized client or viewing of the experiment is allowed in case he is not authorized to control the experiment. In Figure 3 the electrochemical instrument setup and the front panel of the cyclic voltammetric measurements are displayed in Figure 4. The student can then calculate redox potential, peak current and other parameters like diffusion coefficient (for example, in the case of Ferricyanide /Ferrocyanide couple) by plotting a graph of current vs (scanrate)$^{1/2}$.

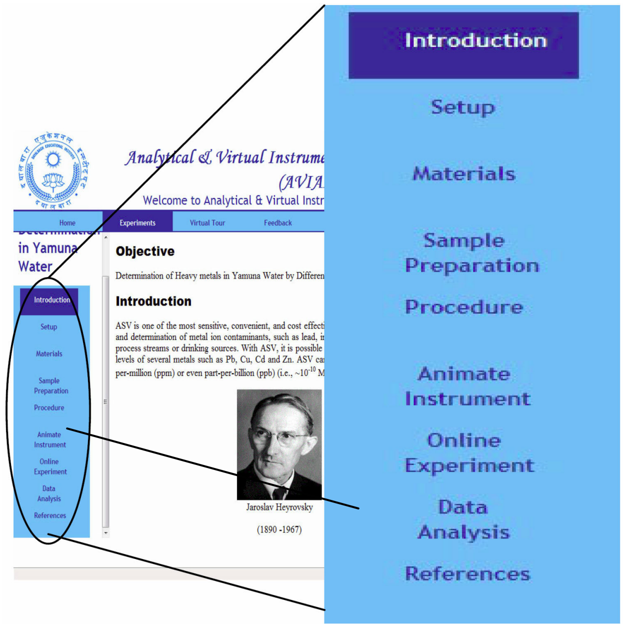

Figure 2. Structure of practical lesson

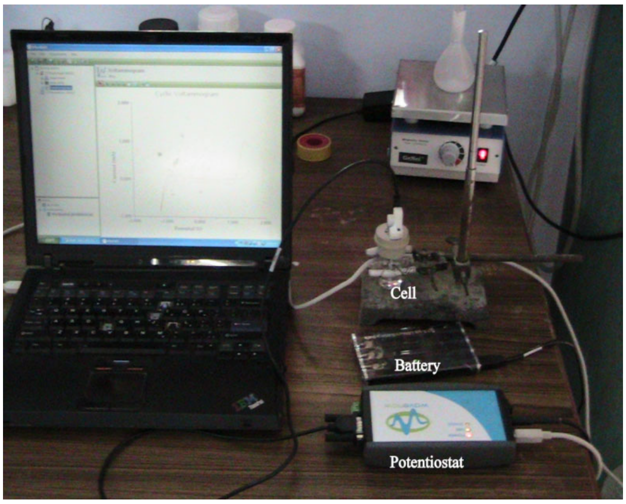

Figure 3. Electrochemical Instrument Setup

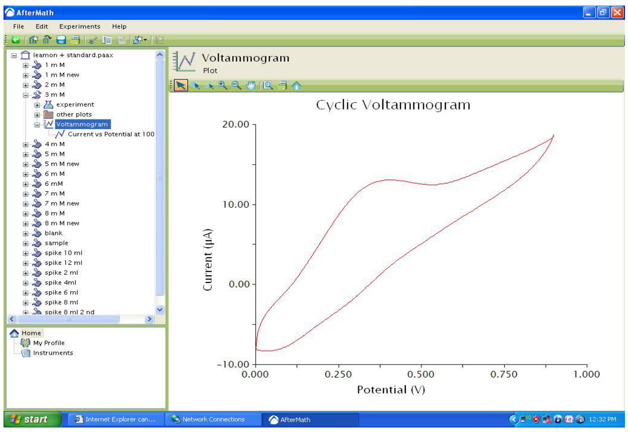

Figure 4. Voltammogram of Ascorbic Acid

VI. A DPASV EXPERIMENT- DETERMINATION OF METAL IONS IN GROUND WATER

In this experiment a student logs on remotely to NOVA 1.5 software application which gives access to Ecochemie Potentiostat, PGSTAT302N [9]. Differential Pulse Anodic Stripping Voltammetry (DPASV) technique is used for determination of metal ion in ground water sample. Figure 5 shows images from Web Cameras which allow the real time viewing of the experiment.

Figure 6 shows a DPASV voltammogram of ground water sample. The voltammogram can be viewed on the desktop of the client using VNC. Concentrations of metal ions present can be calculated by running their standards.

VII. COLORIMETERIC EXPERIMENT

In another experiment, we could remotely control a colorimeter. An experiment for measurement of glucose in a solution using DNS (di-nitro salicylic acid) reagent was conducted. The experimental setup consists of a Vernier colorimeter sensor [10] and EMANT300 USB DAQ card [11].

The colorimeter software is designed in .Net Framework 3.5 using C#. The front panel shown in Figures 7 & 8 consists of four subpanels :-

i. **Initialize** – Gives the reading of dark current, blank & difference between both. According to the experimental protocol one first has to initialize the sample, which is done by clicking on the initialize button.

ii. **Calibrate** – In this panel first the student has to give concentrations of the standard solutions. Then the student has to click on the calibrate button to calibrate the standard samples.

iii. **Unknown** - This panel contains the button labeled ‘Unknown’, after clicking this button the software automatically plots the calibration curve and gives the reading of the unknown sample.

iv. **Graph** – A graph is plotted between concentration and ln((I-Ib)/Io) (volt absorbance relation) where I is the volt for unknown concentration, Ib is the volt for blank and Io is the difference between blank and dark current.

This method can be extended for measurement of glucose levels in blood. The results we have obtained initially are quite encouraging and an attempt is being made to standardize the experiment.

VIII. FURTHER RESEARCH

The present virtual analytical laboratory is to be further expanded in scope by addition of more experiments in areas of analytical electrochemistry, bioanalytical electrochemistry, etc.

Work on customized software development for electrochemical instrument control is in progress. Also, in future, analytical instruments like FTIR, UV-VIS spectrometer, HPLC will be connected to LAN so that they can be accessed remotely.

It is hoped that in future with addition of new experiments and the reduction of human intensive inputs, the virtual laboratory will provide a wide base for teaching and learning analytical chemistry at the university level.

Figure 5. Web Camera Images of electrochemical Cell and potentiostat front panel

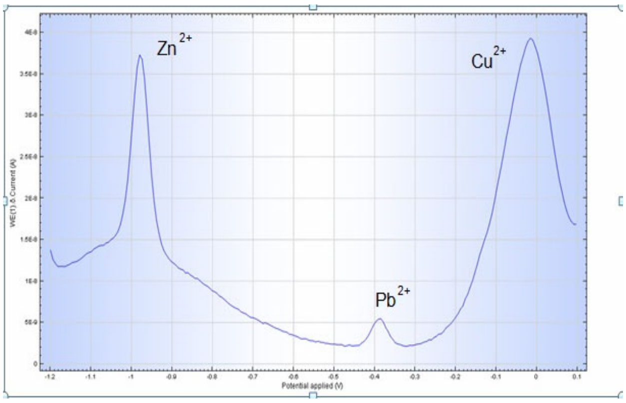

Figure 6. DPSAV of Ground Water Sample

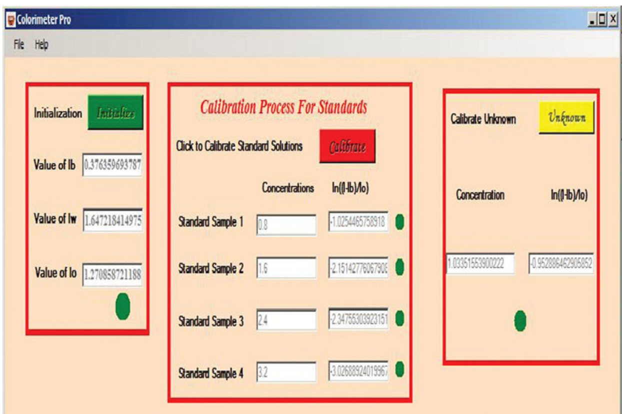

Figure 7. Front Panel of Colorimeter (Numeral Data)

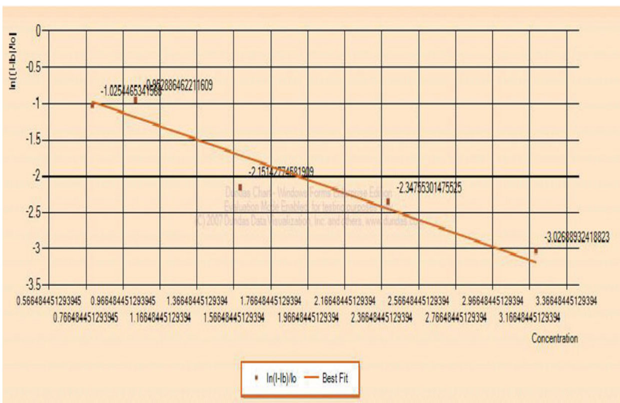

Figure 8. Front Panel of Colorimeter (Data Graph)

IX. CONCLUSIONS

The use of Virtual Laboratory in scientific experimentation has immense potential. Expensive instruments at well equipped universities can be accessed online and easily shared when they are not in use by the host university/department. However, sharing requires collaboration and teamwork and there are related issues which need to be addressed.

In brief, virtual laboratories can bring about tremendous improvement in quality of research & teaching work, economy of resources and expansion of sophisticated laboratory services with equalization of educational opportunities for remote and backward areas.

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