Implementing a Remote-Triggered Light Microscope: Enabling Lab Access via VALUE Virtual labs

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ABSTRACT
Biotechnology and biology education has been known to show declining student interest due to classroom environments and instructor teaching styles, hence we introduced virtual labs as an interactive self-learning material in a blended environment. With ICT-based education becoming ubiquitous, virtual and remote triggered labs have become a novel platform that helps users to engage in a proactive learning process. A promisingly new trend in virtual labs-based education is the development of remote laboratories that are available over the internet and can be accessed by students and teachers. We implemented and deployed a low-cost light microscope using a simple front-end to enable users to have anytime-anywhere access. This paper reports the implementation, deployment and user-case studies on the learning and usage based on the remote-triggered virtual lab. This study also focuses on the analysis of using remote-triggered experiments as supplementary laboratory resources for overcoming the problems faced in a traditional lab environment. The study used online feedback surveys for evaluating the learning outcome and the flexibility of user-interactions with the remote labs and reports the status of usage of remote triggered techniques in biology courses. The statistical analysis suggests that remote labs are an easy learning and interactive platform for users from different places.

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Categories and Subject Descriptors
D.3.3 [**Programming Languages**]: PHP

K.8. **IBM PC**

K.2. **IEEE**

General Terms
Management, Design, Experimentation, Security, Theory

Keywords
Remote triggered lab, Light Microscopy, Experimentation.

1. INTRODUCTION
Biotechnology and biology education has evolved in the past years and more recently studies in science suggest evolving trend of learners losing interest in such mainstream disciplines. The reasons has been mainly trends in career choices and job market scenes although key references point to instructor teaching styles, classroom environment, amongst others [23]. To complement this, we used an Internet and Communication Technology (ICT) tools in learning environments, namely virtual laboratories[3, 16] as an interactive self-learning tool accessible to teachers and students. Online education has taken away some of the major limitations of classroom-based education like accessibility, location and cost [22]. It has been suggested that student's confidence on the use of laboratory equipment improves the learning experience [8]. Students may often need access to this equipment for extended periods beyond the normal time-tabled class hours. Physical experimentation process is mostly expensive and hard to maintain. It also involves expertise in handling and trained operational skillset.

Hands-on experience has pivotal role in understanding and communicating the essential aspects of science and technology [8,

10]. Hands-on laboratories have been an essential part of biotechnology education and research [2]. In this paper, we look into the implementation of a simple light microscope and analysis of user behaviour on such pervasive equipment as an exploration of a novel applied computer science pedagogy technique due to the inter-dependence of server technology, data handling and learning technologies. We highlight the implementation and role of such labs in enhancing education in a blended learning environment.

1.1 Virtual Labs: Simulations and Remote Experiments

Simulation-type experiments lack ability to generate real data when compared to remote triggered experiments. Simulation experiments do not provide access to real laboratory equipment[6].

1.2 Laboratories and issues with remote experiments

Extending the traditional hands-on laboratory settings over the internet is a significant challenge faced in developing a remote triggered experiment[10]. Practical knowledge obtained from doing hands-on experiments is relevant for tuning theoretical knowledge. Remote lab can be a complementary educational resource to hands-on labs. One of the main challenges faced by the remote triggered experiment over real experiment is the occurrence of delays. Another drawback in remote triggered experimentation is the lack of touch-and-feel experience. In a remote triggered microscope experiment, button or sliders were used in the GUI to control the knobs of microscope. The user was also not allowed to change the specimen. The objective of setting up a remote lab was to take advantage of accessibility, flexibility of self-organized learning, security of environment, anytime experience and cost-effectiveness.

VL- Remote Triggered lab is part of the "VALUE @ Amrita" project. VALUE project [1] aims to provide laboratory based practical learning experiences to students across India who may not have access to adequate laboratory facilities or equipment. This paper focuses on the implementation strategies and impacts of a remotely triggered simple light microscope. The experimental set up consists of a server, a light microscope, a web-camera to provide a live streaming to the user and an electronic circuitry including a micro-controller, servo-motors and software (web-streaming, database and apache servers and DAQ interface environment). The implementation was setup to allow any internet user having a valid email id to access the light microscope and to control the set-up via an internet browser. This experiment can be accessed at http://amrita.vlab.co.in/.

2. METHODS

Our main objective was to develop a remote learning environment for undergraduates and other learners by allowing users to access, control, and manipulate a microscopy device.

2.1 Architecture of VALUE Remote Labs

2.1.1 Overview

A remote lab is a blend of both physical and virtual aspects of laboratory experimentation[14]. The architecture (see Figure 1) involves live web-streaming, concurrent access management, interface control between equipment, data acquisition system and the server. The concurrent access system was managed by the CAPVL platform[18]. Remote laboratories were enabled at the user-end through a simple XML-based form to a web-based front-end. Remote laboratories involved real signals [12] that were either analogue or digital. A scheduling scheme for all users was selected based on the type of the experiment. A user-friendly interface was designed to access the equipment. A live media server was set-up for the streaming videos. Remote labs were designed and developed with objectives namely, user-friendliness, ease of deployment and good maintenance.

2.1.2 Remote lab setup

The core of the architecture was the lab server, capable of handling several concurrent users and their requests. The experimental setups were connected to the server. The server communicated with the client through the service-broker. At completion of an experiment the server notifies the user through a service broker when the results became available. Remote laboratory was developed using NI LabVIEW software and NI hardware [24]. Remote-triggered setup essentially needed a web-server to communicate with a data acquisition module, as an interactive platform and the experimental device which is to be remotely triggered[19]. Here, an apache server was used for handling data requests. Data traffic and connection to the clients were handled by the server. Client access was delimited to pre-selected controls necessary to perform the experiment [25]. Access to those features which required expert supervision and specialist training was restricted. Most experiments were designed to allow a single user access at any time. A slot booking system was employed for user-management.

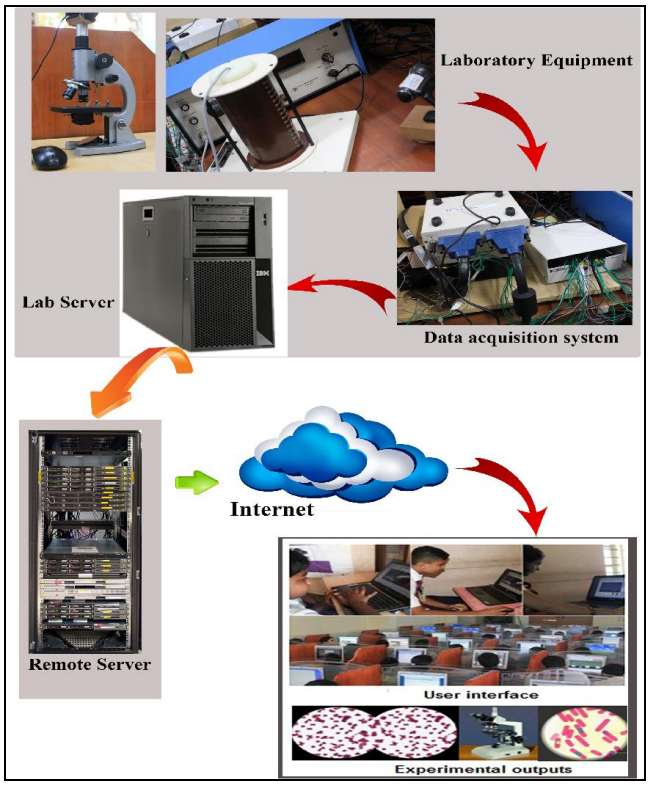


Figure 1. Architecture of remote-triggered virtual lab.

2.1.3 Client side requirement

Any user with a valid email id can access the experiment at anytime from anywhere around the world [20]. A computer with

an internet connection and an Adobe flash-enabled browser could use the remote experiment. Remote labs were maintained such that no other software was needed. Graphical User Interface (GUI) developed for the user to access the experiment was web browser-based[11] and allowed controlling the configured control elements in the DAQ-interfaced equipment. User sends data and access information to the remote server while triggering the experiment remotely [9]. The control signals from the client machine were transmitted to the remote server in XML format and the processed output was sent back to user in the same format. User GUI interpreted the output in forms of graphs, numerical values or images as defined in the experiment design. A real-time video was streamed to the user in order to monitor the remote process.

2.1.4 Web interfaces and dialogues

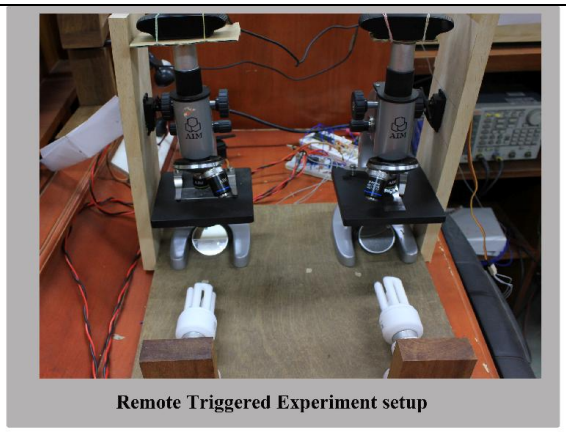
Traditional web applications used standards such as HTML, XHTML, CSS [15]. Virtual lab experiments are generally content rich [5]. Many experiment required audio and video interactions are mandatory for remote triggered experiments. The GUI allowed to record experimental screenshots and data traces when needed in addition to proving control and access panels.

2.1.5 Content Management

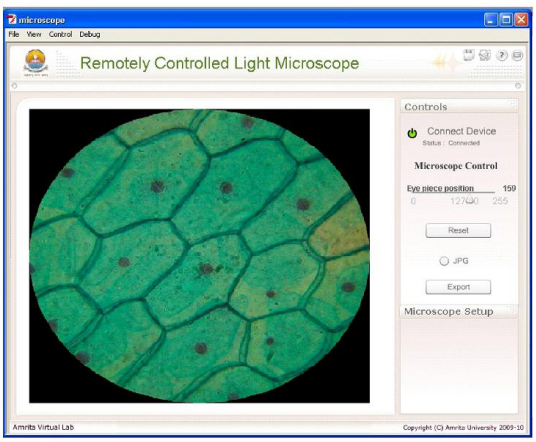
CAP-VL platform[18] already included a feature-rich content management platform for editing and delivering course and addition material. All virtual lab experiments included individual tabs on theory, procedure, quiz, assignments and feedback in addition to simulation and remote-panels [4].

2.2 Design of Experiments: A Case Study of Remote Triggering a Light Microscope

Light microscope is used as an instrument in most biology laboratories. The objective of remote-triggering a light microscopy device was to educate and test observational skills of undergraduate students with focus on using the stage and objective. In our Remote triggered light microscope experiment, the experimental setup consisted of a server, a modified light microscope and an electronic circuitry including a microcontroller and servo motors. The specimen was fixed in this experiment. Changing the specimen by the users was not included in this case study. A user could operate the remote microscope using an internet-enabled computer. User could control the microscope's fine and coarse adjustments by moving a virtual slider in the graphical user interface. Controls signals initiated by the change in the slider were transferred to the server via the internet. Server communicated with a PIC microcontroller circuit through a serial port on the server. The output of the PIC microcontroller was transferred to a servo motor attached to the microscope stage, which, in turn, moves the stage of the microscope. A webcam was attached to the eyepiece of the microscope. Video was streamed over the internet using standard protocols on the web interface. This allowed the user to observe the cell and cellular components through the microscope was controlled remotely, adding to the feeling of controlling real equipment (See Figure 2). Security for the equipment setup was implemented by offering the students a control over the features of microscope.



Remote Triggered Experiment setup



GUI for the remote user

Figure 2. Remote-triggered light microscope setup.

2.3 Data Collection

2.3.1 Analyzing the role of remote triggered labs as a flexible learning platform

The flexibility of remote triggered experiment was analysed based on usage information and statistics recorded in the virtual lab server and by performing various surveys and collecting online feedbacks from different users. A set of questionnaire-based feedback was collected after performing the Microscopy experiment remotely (see http://amrita.vlab.co.in/?sub=3&brch=258&sim=1449&cnt=1). The feedback survey included the following questions (with Likert-scale ratings 1-Very poor, 2-Poor, 3- Average, 4- Good, 5– Excellent).

1. How do you rate the online performance of the experiment?
2. To what extent do you control the equipment interactions?
3. Were the results of the experiment easily interpreted?
4. Can you easily compare your results with the given typical results?
5. Can you easily run the remote experiments (ex. without interruptions)?

The individual points given for each question by the users were calculated and analysed.

2.3.2 Analyzing the role of remote triggered labs as an effective teaching tool.

In order to study the role of remote triggered lab as an effective teaching tool, a general survey was conducted among 600 teachers who participated in workshops for teaching fraternity in different Indian schools and universities. The main objective of the survey was to understand whether remote triggered experiments can complement a real hands-on laboratory experiment in their institutions.

2.3.3 Analyzing the scope of remote triggered microscope experiment

As a part of the study, teachers asked the students to perform remote-triggered microscope experiment as their pre-lab exercise. Students were allowed to access the microscope experiment during this assignment and feed was collected. The feedback questionnaire included the following questions.

1. How well could you control the microscope?
2. How would you compare a remote-triggered experiment to a real lab microscope experiment?
3. How do you rate the experiment?

3. RESULT

3.1 Remote Microscope as a data flow process

The user accessed the experiment and controlled the parameters through a computer with an internet connection[17]. HTTP service was used as the communication protocol. When the user made changes to control elements, an HTTP request was sent. Web services forwarded the user's request to the remote server. XML-RPC protocol was used for this purpose. XML-RPC works by sending a HTTP request to a server. The remote server processed the request. The request was transferred to the LabVIEW server and then to the associated devices. Response of the request was then sent back to the user. Raw data was in XML format. The GUI processed the XML-formatted data and displays in a human readable format such as graph or image or plots.

In the remote microscopy experiment, users were allowed to change the coarse-adjustment knob. For this purpose, a virtual slider was provided in the GUI. When a user tries to access the microscope experiment, the authentication was also performed by CAP-VL platform[18]. The server granted permission to access the experiment for authenticated user. A connection to the remote server would then be established. The user could change the slider to control the coarse adjustment on the microscope. User sent controls caused the PIC microcontroller to generate a pulse width modulation (PWM) signal that was provided to the servo motor attached to the knob of the coarse-adjustment setting in the microscope. RTMP protocols were used in the live streaming of video information.

3.2 Increase in remote lab users

Data showed students used remote labs on holidays. Number of users increased since deployment (See Figure 3). Nearly 190639 users visited the virtual laboratories during 04-May-14 to 01-Jun-14, with an increase of 75% new users from the previous month. Trend suggests remote lab tools such as the light microscope experiment were preferred than simulations by most student users (data not shown).

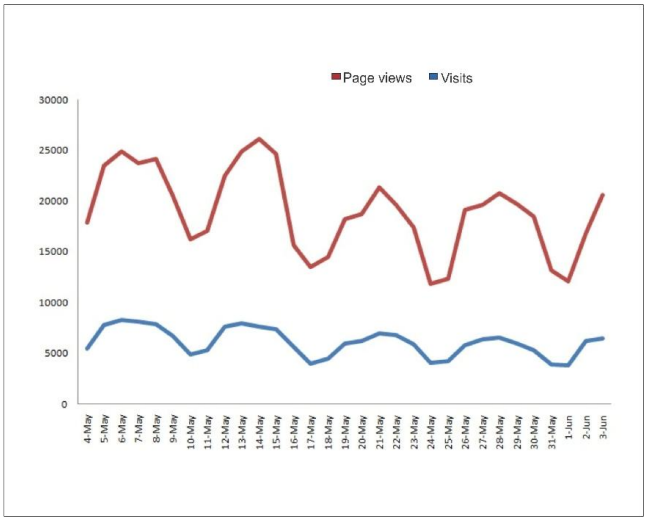


Figure 3. Traffic Overview from 04-May-2014 to 03-Jun-2014

3.3 Remote labs are an effective teaching tool

Workshops were conducted for teachers to train the usage and access of remote triggered experiments. Among 600 teachers, 84 % of them suggested that advanced technologies like remote triggering were helpful in classroom education scenario, whereas 10 % did not favour use if such tools in blended learning. 6% of the teachers did not answer this question (see Figure 4).

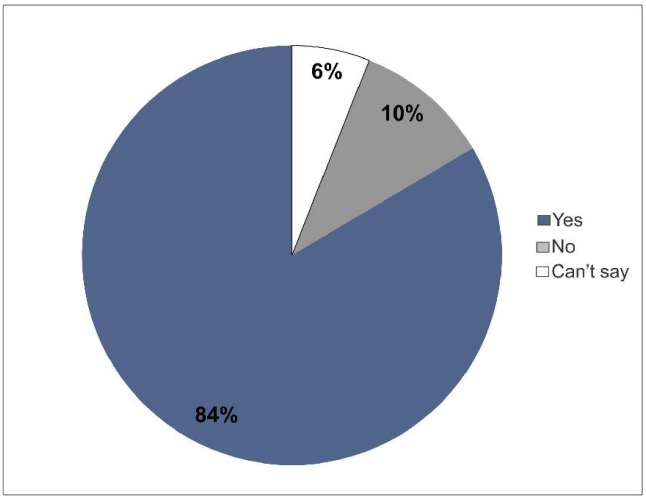


Figure 4.Teachers response about role of Remote triggered experimentations in laboratory education.

3.4 Remote triggered microscope experiment: Feedback-based analysis of user acceptability

User interaction and learner satisfaction were primary challenges while constructing remote triggered laboratories. After deploying the remote triggered microscope experiment, we conducted surveys and collected feedback from the 100 students (see Figure 5).

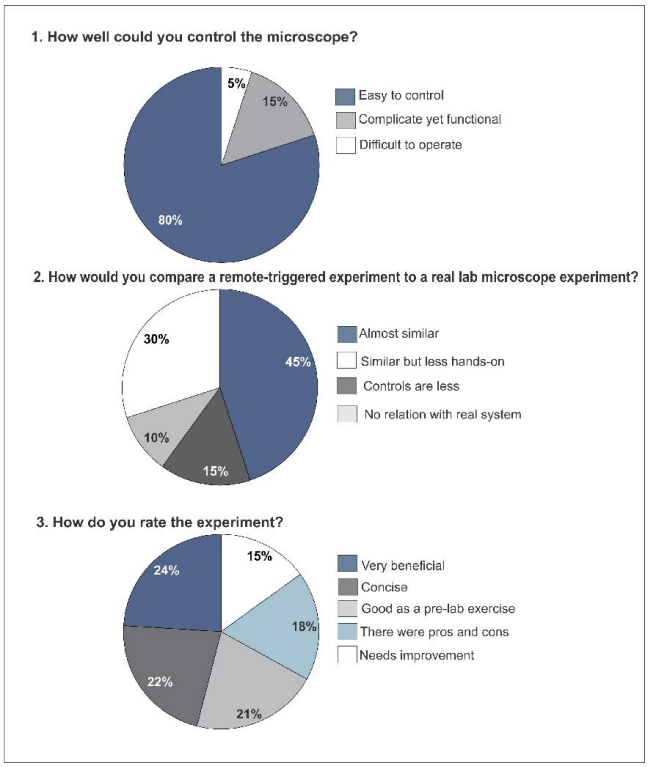


Figure 5. Student acceptability for remote triggered labs. A very high percentage of student users suggest remote virtual labs as complementary education tools for enhancing classroom performance[16]**.**

4. DISCUSSION

In this paper we have implemented and discussed a remote-triggered light microscope to facilitate biology and biotechnology students with equipment access. Remote laboratories enhance laboratory experience and classroom quality in a blended learning process[16][7].

Results suggested remote labs achieved their primary objectives namely; most student users agree they have more control over the experiment while providing complementary solution to real labs. A large number teachers (84% of 600) strongly agreed on the use of virtual labs in classroom education would be viable with remote-triggered experiments such as this microscopy lab. A growing trend in student users is also observed. Perhaps this will help overcome loss of student interest in disciplines like biotechnology where instructor style was known as one of the reasons[23] behind lack of motivation. Concurrent usage of microscopes by online users will reveal the trend of VL-based teaching styles in Universities. Future enhancements include triggering an advanced biotechnology devices including multiple microscopes to enhance remote exploration.

5. CONCLUSION

Virtual and remote triggered labs were introduced to improve education system by effectively using technology and thus by engaging the student in the learning process [13]. Remote labs such as this light microscopy lab have been becoming popular with student users than mathematical simulation-based lab experiments [21]. More tests may be needed to predict the futuristic role of remote labs as interactive textbooks.

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