

The VALUE @ Amrita Virtual Labs Project

Using Web Technology to Provide Virtual Laboratory Access to Students

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Abstract—In response to the Indian Ministry of Human Resource Development (MHRD) National Mission on Education through Information and Communication Technology (NME-ICT) Initiative, the Virtual and Accessible Laboratories Universalizing Education (VALUE @ Amrita) Virtual Labs Project was initiated to provide laboratory-learning experiences to college and university students across India who may not have access to adequate laboratory facilities or equipment. These virtual laboratories require only a broadband Internet connection and standard web browser. Amrita Vishwa Vidyapeetham University (Amrita University) is part of a consortium of twelve institutions building over two hundred virtual labs covering nine key disciplines in science and engineering. This National Mission project hopes to reach out to India's millions of engineering and science students at both undergraduate and postgraduate levels. The Virtual Labs Project is providing virtual laboratory experiments that directly support the All India Council for Technical Education (AICTE) and the University Grants Commission (UGC) model curricula for engineering and sciences undergraduate and postgraduate programs.

Keywords—virtual labs; remote labs; e-learning; distance-learning; chemistry laboratories; physics laboratories; higher education; tertiary education

I. INTRODUCTION

India's Ministry of Human Resource Development (MHRD), the government organization responsible for the development of India's greatest resource — her people, since its establishment in 1985, has been continuously working to provide improved educational opportunities for all of India. From programs to ensure nutritious mid-day meals, the launching of the EduSAT educational satellite, and the amendment of the Indian Constitution to make free and compulsory education a fundamental right, the Ministry has worked tirelessly to achieve its goal that *no talent of the country should be allowed to go waste* [1].

Early in 2009 MHRD received approval from the Cabinet Committee on Economic Affairs for a comprehensive scheme utilizing information and communication technology for education titled, the *National Mission on Education through Information and Communication Technology* (NME-ICT). A key component of the NME-ICT is the creation, implementation, and widespread use of virtual laboratories in

colleges and universities as an educational tool to support, undergraduate, postgraduate, engineering, and science curricula; enhancing, supplementing, and in some cases replacing real-world laboratory experiments.

From Section 3.14.1 of the Mission Document [2], the objectives of the Virtual Labs Project are:

- To crystallize the concept of a Virtual Lab, which will essentially comprise of a user-friendly graphical front-end, working in synchronization with a backend, possibly consisting of a simulation-engine running on a server or actual measurement data or a real experiment.
- To identify the suitable topics, where Virtual Labs will provide maximum benefit to the students using them.
- To develop these Virtual Labs so that they work in a complementary fashion to NPTEL¹ in the sense that they teach the student the basic concepts, as well as trigger their imagination and inquisitiveness.

In 2009 a consortium of twelve institutions met to determine the academic areas in which virtual labs would be developed, a common look and feel for virtual labs interfaces, and which institutions would develop which virtual labs. The academic areas chosen for implementation were:

- Electronics & Communications
- Computer Science & Engineering
- Electrical Engineering
- Mechanical Engineering
- Chemical Engineering
- Biotechnology Engineering
- Civil Engineering
- Physical Sciences
- Chemical Sciences

¹ NPTEL (National Programme on Technology Enhanced Learning) is a complementary NME-ICT component responsible for developing video and web-based courses.

The VALUE @Amrita Virtual Labs Project is sponsored by the Indian Ministry of Human Resources Development (MHRD) National Mission on Education through Information and Communication Technology (NME-ICT).

The Sakshat Portal Project established the look and feel for the user interface. The Sakshat Portal (www.sakshat.ac.in) is another component of the NME-ICT and is responsible for implementing a single web portal to provide access to all MHRD e-learning initiatives (see fig. 1).

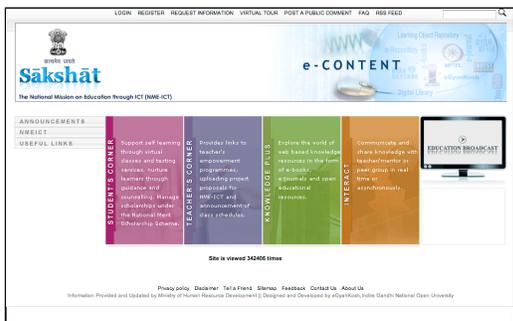


Figure 1. Sakshat Web Portal

Amrita University agreed to develop virtual labs for Biotechnology Engineering, Physical Sciences, and Chemical Sciences. Within Amrita University Biotechnology Engineering is being developed by the Amrita School of Biotechnology [3–4]. Physical and Chemical Sciences are being developed jointly by the Amrita School of Biotechnology and Amrita School of Arts & Sciences.

II. BACKGROUND

Virtual laboratories are computer-based, interactive environments that allow a user to perform a set of tasks that would normally be performed in a laboratory, through an interface that supports simulation, animation, and in some cases remote control of real laboratory hardware. The value of virtual laboratory technology as a teaching and learning tool has been repeatedly assessed and in nearly every case has been found to be an effective learning and teaching tool [5–8].

Seeking to address the country of India's vast educational needs in the most cost effective way possible, MHRD drafted the Mission Document for NME-ICT. Because of the inability of the country of India to be able to provide laboratory facilities and equipment for its millions of college students, virtual laboratories are seen as a solution to this educational and economic dilemma. The Virtual Labs Project addresses the following three main objectives from the NME-ICT Mission Document [9]:

- Extensive leveraging of the advancements in the field of ICT for taking the knowledge resources to the door steps of the learner,
- Capability to handle the user base which would ultimately be expected to cross 50 crore [500 million] in the long term.
- Use e-learning as an effort multiplier for providing access, quality and equality in the sphere of providing education to every learner in the country.

In 2009 Amrita University was funded to begin work on the Virtual and Accessible Laboratories Universalizing Education

(VALUE @ Amrita) Virtual Labs Project in support of the NME-ICT. Amrita University's goal is to provide college and university students throughout India with access to virtual laboratories, allowing them to experiment, discover, and have learning experiences similar to their colleagues who have access to real laboratories.

III. VIRTUAL LAB DEVELOPMENT AT AMRITA UNIVERSITY

Virtual labs at Amrita University have been divided into three primary areas, biotechnology, physics, and chemistry. Each primary area is subdivided further into twenty-six secondary subject areas for managing development and ease of web site navigation. Each of these secondary subject areas constitutes a virtual lab and contains experiments developed to provide students with laboratory-like experiences in those secondary subject areas. Listed below are the three primary areas and the virtual labs under each area.

- Physical Sciences
 - Mechanics Lab/Nonlinear Dynamics
 - Advanced Mechanics Lab
 - Electric Circuits
 - Optics Lab
 - Electricity & Magnetism Lab
 - Heat & Thermodynamics Lab
 - Modern Physics Lab
 - Harmonic Motion and Waves Lab
 - Physical Energy & Materials Science Lab
- Chemical Sciences
 - Physical Chemistry
 - Organic Chemistry
 - Inorganic Chemistry
 - Electrochemistry
- Biotechnology Labs
 - Neurophysiology
 - Biochemistry Virtual Lab I & II
 - Population ecology Virtual Lab I & II
 - Immunology Virtual Lab I & II
 - Microbiology Virtual Lab I & II
 - Molecular Biology Virtual Lab I & II
 - Cell biology Virtual Lab I & II

Each virtual lab contains several experiments. For example, the Physical Sciences/Optics Lab consists of the following experiments: Brewster's Angle, Diffraction Grating, Newton's Rings, Laser Beam Divergence and Spot Size, and Numerical Aperture of Optical Fibre. All of the above virtual labs and their associated virtual experiments can be accessed from the



Figure 2. VALUE @ Amrita Virtual Labs Web Site

VALUE @ Amrita web site (amrita.vlab.co.in — see fig. 2) or the National Sakshat Virtual Labs web site (vlabs.co.in — see fig. 3).

Although the virtual experiments are divided into twenty-six separate virtual labs, they have all been developed using the same coordinated processes. After selection of an experiment from either the All India Council for Technical Education (AICTE) or the University Grants Commission (UGC) model curricula, Virtual Labs research assistants (usually graduate students) reacquaint themselves with the experiment. They then work with one of the Amrita University e-learning teams to create storyboards, provide suggestions for the experiment design, and test and evaluate interim versions.

The Virtual Labs research assistants also collect reference materials and assist subject matter faculty with the development of the theory and procedure discussions, assignments, and self-evaluation quizzes.

Amrita University's learning team, the Center for Research in Advanced Technologies for Education (CREATE @ Amrita) is responsible for creating the virtual lab interactive animations and simulations. The team uses Adobe Flash for animating the virtual labs and Adobe ActionScript for the simulation engine that controls the animation.

After the experiments are completed, they undergo extensive beta testing in the hands of the Virtual Labs research assistants and by faculty review.

To date ninety-eight experiments have been completed and are available free online. Every experiment contains seven components (see fig. 4), Theory, Procedure, Self-Evaluation, Simulator, Assignment, Reference, and Feedback.

IV. VIRTUAL LABS DISSEMINATION

Regardless of the need or the benefits provided, the rate of adoption of any new technological improvement can be frustratingly slow [10]. To address this potential problem, a

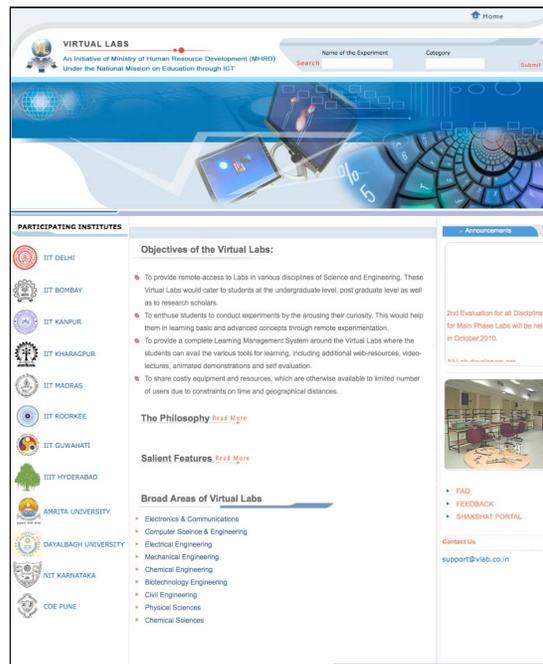


Figure 3. Sakshat National Virtual Labs Web Site

significant amount of effort has been expended to demonstrate to the higher education community the relative advantages, compatibility, and ease of use of virtual labs technology.

To this end, in January of 2011 the VALUE @ Amrita Virtual Labs Project held the first of a series of workshops at Amrita University, Amritapuri Campus located in the Indian state of Kerala. The purpose of these workshops was to provide university faculty with a comprehensive overview of Virtual Labs and provide guidance on how they might use Virtual Labs to support their engineering and sciences curricula. The following month subsequent workshops were held in Coimbatore, Tamil Nadu, and Bangalore, Karnataka.

To increase the chances of hosting successful workshops extensive preparations were done beforehand. Faculty at Amrita University were consulted to make sure that the most important topics regarding Virtual Labs were covered. In addition, several neighbouring institutions were visited and toured in order to obtain a better understanding of the learning environments at other colleges. Based on faculty recommendations, a key feature of the workshops was to have separate, parallel sessions for chemistry and physics faculty.

An extensive multi-pronged marketing campaign was also undertaken to make sure that a large variety and geographical diverse set of institutions were invited and attended the workshops. In total we had 237 attendees from 125 different educational institutions. 74 of those institutions sent faculty who attended the chemistry sessions, 80 institutions sent faculty who attended the physics sessions, and 29 institutions sent faculty to both sessions.



Figure 4. Brewster's Angle Virtual Experiment

At the end of each workshop exit surveys were given. (76% of the Workshop attendees completed the exit surveys.) The survey contained several questions regarding the perceived effectiveness of VALUE @ Amrita Virtual Labs. The survey results indicate that faculty felt virtual labs could be an effective tool with more than 94% of the responses to be either Good, Very Good, or Excellent, with over half of those respondents responding with Excellent or Very Good. There were no responses of Poor (a rating scale of Excellent, Very Good, Good, Average, and Poor was used — see fig. 5). In response to another one of the questions on the survey, “Do you feel such virtual labs sites aids/assists you in your job as a teacher?” 97% of the respondents answered yes.

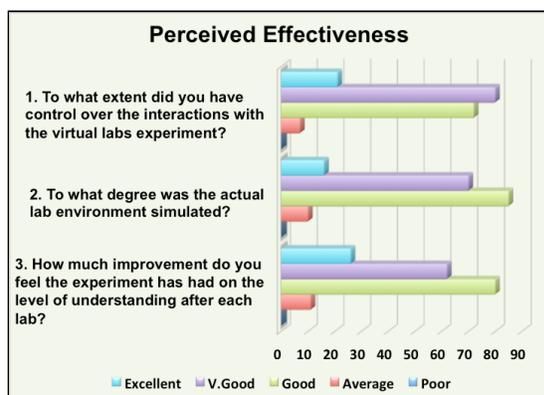


Figure 5. Exit Survey Results — Perceived Effectiveness

An important part of these workshops was that attendees were given the opportunity to become Nodal Centres or pilot program participants. The purpose of the Nodal Centres² is to encourage local colleges and universities to act as champions, using and promoting virtual labs. Institutions that meet the requirements (see below) and would like to participate as a Nodal Centre, enjoy the following benefits:

- Information on upcoming events.
- Invitation to Nodal Centre activities and forums.

² The Nodal Centre concept including purpose, benefits, and requirements was developed by IIT Delhi.

- Assistance with faculty & student VALUE @ Amrita Virtual Labs training.
- Computer infrastructure assessment.
- Updates and feedback on virtual labs development.
- Student internship opportunities.
- Networking with a vast collection of colleges and institutions.
- Encouraging the sharing of information for improving the quality of education and strengthening the skills of future students in India.

The requirements for becoming a Nodal Centre comprise of the following:

- The institute is recognized by AICTE/UGC.
- They have the necessary infrastructure (dedicated time on 5-10 personal computers with a broadband internet connection) for implementation of VALUE @ Amrita Virtual Labs.
- Students will not be charged an extra fee to use the Virtual Labs facility.
- Strict adherence to standard laid down laboratory procedures will be followed.
- A Technical Evaluation team may visit our institution on or after _____ (date) for feasibility studies.

With the success of the workshops and a significant number of institutions wishing to be Nodal Centres (Kerala — 16, Tamil Nadu — 22, Karnataka — 5), we have begun the process of inaugurating universities and colleges as Nodal Centres. Our first Nodal Centre inauguration was CMS College, Kottayam — the oldest college in South India. To date we have five Nodal Centres with more inaugurations planned when the new school year begins.

V. CONCLUSIONS AND FUTURE PLANS

VALUE @ Amrita Virtual Labs, requiring only a broadband Internet connection and standard web browser, can effectively provide laboratory-like experiences to students that may not have access to real laboratory facilities or equipment. While we are still in the very early stages of the dissemination phase of the Virtual Labs Project, a review of the workshops exit surveys as well as the comments received and enthusiasm displayed during the workshops, give every indication that the workshops have been a great success and that there is a strong willingness on the part of faculty to give virtual labs a real opportunity to succeed. Furthermore, the number of institutions expressing a strong desire to be Nodal Centres gives every indication that support for virtual labs will be substantial and widespread.

Presently Virtual Labs exist for the subjects of Chemistry, Physics, and Biotechnology. Efforts are underway to add Computer Science and Mechanical Engineering virtual labs, as well as virtual labs for vocational training that would support

the use of state-of-the-art haptic devices. In addition to these technological advancements, the VALUE @ Amrita Virtual Labs Project plans to continue its growth throughout the other states of India.



Figure 6. Students Using Virtual Labs at CMS College

In conclusion, we have been encouraged by the recognition that college and university faculty have displayed regarding the potential value virtual labs can add to the field of higher education. If these faculty are as willing as they appear to be to incorporate this technology into their curricula, then perhaps VALUE @ Amrita Virtual Labs can help MHRD get one step closer to being making their objective, *providing education to every learner in the country*, a reality.

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