

## Virtual Labs Collaborative & Accessibility Platform (VLCAP)

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### Abstract

India has embarked on a National Mission project to build over 150 Virtual Labs (VL) targeting over 1450 experiments mapped to the under graduate and postgraduate curriculum. Due to the lack of user centric tools and mechanisms for VL authors, it became crucial to architect a Virtual Labs Collaborative and Accessibility Platform (VLCAP) for use by the large scientific community building multi-disciplinary VL. With multi-tier, scalable architecture at its core, the technology platform allows VL builders to focus on particular logic of their experiments. The axiomatic design of the user interfaces built into the various modules including VL workbench, collaborative content management, repositories and so on assists in functional use of the elements while reducing the overall development time of VL by individual users. Integration of common tasks in user management, such as single sign-on, role based access control etc. enhances flexibility without compromising on security.

Using this collaborative platform not only provides cost optimality in development and deployment of VL, but also gives learners a consistent, homogeneous and rich interactive experience. VLCAP has been deployed for over 22 VL totaling 132 experiments within them. Key accomplishments of this work include application of VLCAP to simulation and remote-triggered VL while providing instructors with easy-to-use authoring tools, pre-configured templates, user management and assessment modules. VLCAP supports multiple deployment models including the local institute cloud model, the hosted model and a mixed model. It further ensures scalable, reusable and reliable deployment in a hosted environment and secure access for learners in remote locations.

## **Background**

National Mission Project on Virtual Lab under the National Mission on Education through Information and Communication Technology (NME ICT) is a multi-year, multi-institutional collaborative project that was launched in March of 2009. The overall objective of the project was to develop and deploy over 150 Virtual Labs by 2012 covering various engineering disciplines mapped to the Under Graduate curriculum.

Each lab proposer for the several virtual labs used different software technologies and hardware interfacing software for remotely accessible equipments, to explore issues in the design, implementation and usage of multi-institutional shared virtual labs at the scientific, methodological and technical levels. These virtual tools were to be made available to the end users, i.e. learners and educators of Indian universities to use these labs as part of the course work.

One of the unique aspects of the Virtual Lab was the fact that it brought together partners out of very different technological and cultural horizons: the consortium consists of twelve academic partners with a wide range of expertise in various engineering disciplines, Multimedia, Animation and Simulation, Cloud computing etc.

The project involved consortia of 12 premier institutes partnering to build over 150 VL with the mission to collaborate and involve many more institutes in the course of the project. Nine disciplines of science and engineering were chosen for the project.

## **Introduction**

The development, authoring, animation and deployment of high quality, online educational multimedia content are a joint and collaborative effort of course developers, subject matter experts, graphic designers, animation experts and software developers. Developing large consortium multi-institutional projects for various labs like; remote triggered equipment labs, simulations and animations that teach laboratory procedures, further increases the complexity as various software and hardware interfacing technologies used by multiple institutes need to be integrated into one platform.

The challenges included joint development of distributed labs that use different software and interfacing technologies and yet offering an integrated portal with a similar look and feel for all the distributed labs while reliably serving a large number of users requiring various levels of roles and offers scalability, quality of service and security. Only a few projects like Lila [1] and iLabs [2] have attempted to support, integrate and offer faculty and learners a single platform to help develop and deploy such labs.

Based on our initial survey of the consortium partners, we found that the Virtual Lab (VL) faculty deals with a number of Lab management administrative tasks: learners have to be authenticated, templates for Lab customization has to be programmed, lab resources have to be managed and allocated, learner data needs to be recorded and stored, quizzed, administered etc. But more often the VL faculty does not have the time to work on these Lab management tasks. We also found that the faculty had to maintain a separate set of learner data for each VL. Thus if the learner was registered with multiple VL, this becomes further complicated. All these suggested that there was a need for a platform that would provide services for all the commonly performed tasks of the VL.

In this paper, we present the architecture, methodology and deployment of the Virtual Labs Collaborative & Accessibility Platform which was designed to enable the complete development life cycle and the deployment of multi-site VL, while providing a similar look and feel for the diversity in the experiments. An important objective was to reduce the cost of development and deployment of multimedia by reusing and repurposing them, and by minimizing dependency on IT and programming resources.

VLCAP project is unusual in its methodology because it distributes the technology independent content of all institutes into one repository. Institute content that is dependent on various software technologies or remote equipment interfaces is isolated while maintaining the metadata and accessing it from the host institute. Thus any institute was provided the flexibility to use any technology while allowing the reuse of such content and also unifying the content developed into one integrated platform using various technologies.

It allows use of templates, pre-existing simulations and wizard based instructions, so that an educator can create his own learning objectives, assignments, step-by-step instructions for learners, worksheets, control quizzes and so on.

### **Relevant literature and previous work**

Since 1996 [3] remote labs have been increasingly popular and their development has mostly been driven to assess the technical feasibility of different approaches. As the remote laboratory platforms are getting mature, we observe that they are still built without a shared interoperable approach [4] - [5].

A popular example of distributed architecture for remote labs is iLabs [2], developed at the Massachusetts Institute of Technology. With iLabs, the equipment was managed by Lab servers, and authentication and access was moderated by a service broker. Conversely, as

recently discussed by [6] most existing Learning Management Systems (LMSs) support rich functionality, much of which is highly relevant to remote laboratories (i.e. grade tracking, collaboration tools, management of assessment tasks, etc), but as [7] Rapuano and Zoino reports, research to integrate Remote Labs into LMS has been slowed by the fact that LMSs were usually closed proprietary software systems that are often not customizable at all.

An EC-funded project, LiLa [1], initiated by University of Stuttgart, aims at developing an integrated platform for remote experiments and Virtual Laboratories. It provides learners and lecturers means to search for remote experiments and Virtual Laboratories, perform them through a 3D integrated web portal enabling their collaborative use. LiLa reuses BweLabs [8] open source framework dedicated to complex experiments (initially dedicated to nanotechnologies) and based on Web Services and Semantic Web technologies.

Research literature already shows experiences of integration between LMSs and remote labs. The research lines are several: for example in MARVEL3 pilot project, financed by the Leonardo programme of the European commission, [1] Ritcher, Boehringer, Jeschke, and [5] Ferreira and Cardoso, developed a booking system integrated with Moodle LMS. It is designed as an extension of Moodle, requiring the laboratory manager to use this LMS, even if the activity is not part of a distance learning class.

Physlets [9], also known as Physics Applets, is a collection of Java applets. It is among the only existing tools that aim at enabling faculty to create their own online virtual experiments. However, users were still required to know programming with Java Script, which limits its usage among faculty of online science courses.

### **VLCAP designs and goals**

VLCAP was constructed with several goals. We indicate some of the main design focuses below.

- Provide tools for rapid development and deployment of Virtual Labs (VL).
- Enable faculty from multiple institutions, across geographies to collaboratively develop VL.
- Provide learners with a single unified portal interface to use VL.
- Provide learners with a customized lab area that is isolated from the actions of other learners.
- Provide a scalable platform that allows 1000's of users from multiple institutions to work together.

### **Architecture**

VLCAP was developed with an N-tier architecture to support web based interactive and collaborative development of Virtual Labs (VL). It was intended to let the educators focus on the particular logic of their experiments, avoiding most of the issues related to user management, deployment, security, audit, collaboration, access control etc.

VLCAP allows VL to be deployed in a hosted environment and securely accessed by learners in remote locations. It facilitates the development, user management, deployment, sharing of VL and scalability of the platform to support hundreds of labs and thousands of users. The primary users are faculty, course developers, learners, remote lab providers and administrators.

VLCAP addresses the following:

- Lab Management – capabilities that enable institutions that are developing VL to centrally define, deploy and manage them.
- Lab Delivery – capabilities that give learners a secure, personalized, and highly interactive experience.

VLCAP has the following major components (Figure 1):

- VL Workbench.
- VL Repository.
- VL Collaborative Content Management.
- VL Management system.

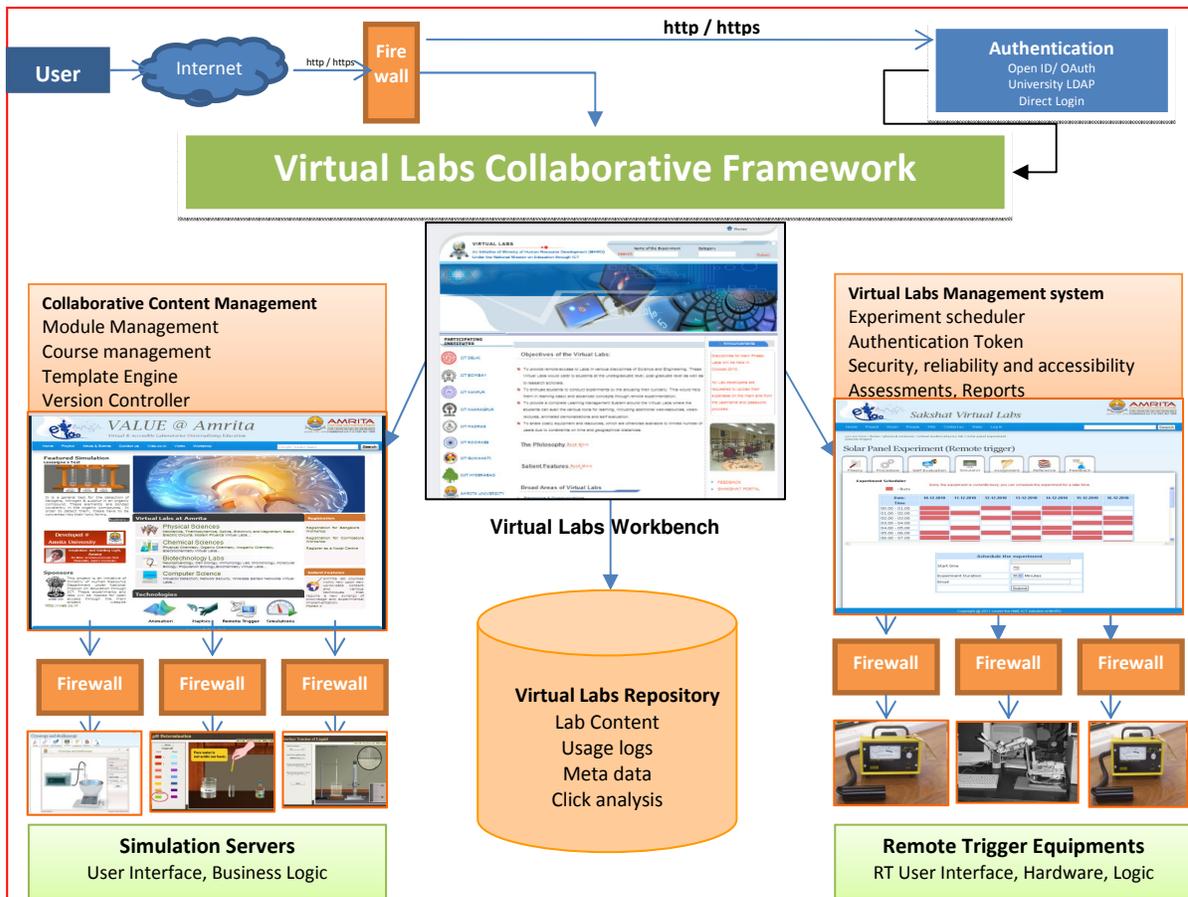


Figure 1: VLCAP Component level diagram

## VL Workbench

VLCAP allows for a unified and consistent look and feel (Figure 2) as a user navigates through experiments and labs created by various departments and institutions. This central component allows learners to perform experimentation. It communicates with all other components.

The screenshot displays the 'Sakshat Virtual Labs' web interface. At the top, there is a navigation menu with links for Home, Project, Vision, People, FAQ, Contact us, Video, and Log In. A search bar is located on the right. Below the navigation, a breadcrumb trail reads 'you are here->home->chemical sciences->physical chemistry->cryoscopy and ebullioscopy'. The main heading is 'Cryoscopy and ebullioscopy'. A row of icons provides access to Theory, Procedure, Self Evaluation, Simulator, Assignment, Reference, and Feedback. The central area features a 3D simulation of a laboratory setup. On the left, a 'TEMPERATURE CONTROLLER' shows a digital display of '37 °C'. In the center, a glass tube is submerged in a beaker of blue liquid. To the right, a control panel includes a 'POWER' switch (ON/OFF) and a 'MODE' selector (HEATING/COOLING). A 'Components' sidebar on the right allows for parameter adjustment: Solvent is set to 'Water' with a mass of '1 g', and Solute is set to 'Sodium chloride' with a mass of '0 g'. A 'RESET' button is also present. The interface includes copyright information for Amrita University (2009-10) and MHRD (2011).

Figure 2: Template for an experiment

A standard set of layouts, locations for audio, video and images are provided along with links for navigation. The faculty and course developers can create their own coursework by reusing or replacing the content without worrying about developing multimedia content.

## VL Repository

VLCAP maintains and manages a centralized Virtual Lab repository for each institute that it supports, and allows access based on authentication as defined by the lab developer and the user. The repository maintains information about;

- All VL contents, with links to experiments at various sites with metadata about the experiment (subject, experiment name, author, lab name, server etc.)
- User information.
- Usage logs.
- Measurements, Assessment results and Assignment information for learners.

## VL Collaborative Content Management

By providing both customizable but easy to use content development environment, as well as the ability to support a wide-variety of file types, the VLCAP serves to unify teams in multiple institutions to develop, assemble, re-use, manage and deploy Virtual Labs content. The whole content have been put under three levels of hierarchies (Figure 3) which consist of subject, topic and experiment. And the content may be in different forms like; theory, procedure, simulation etc.

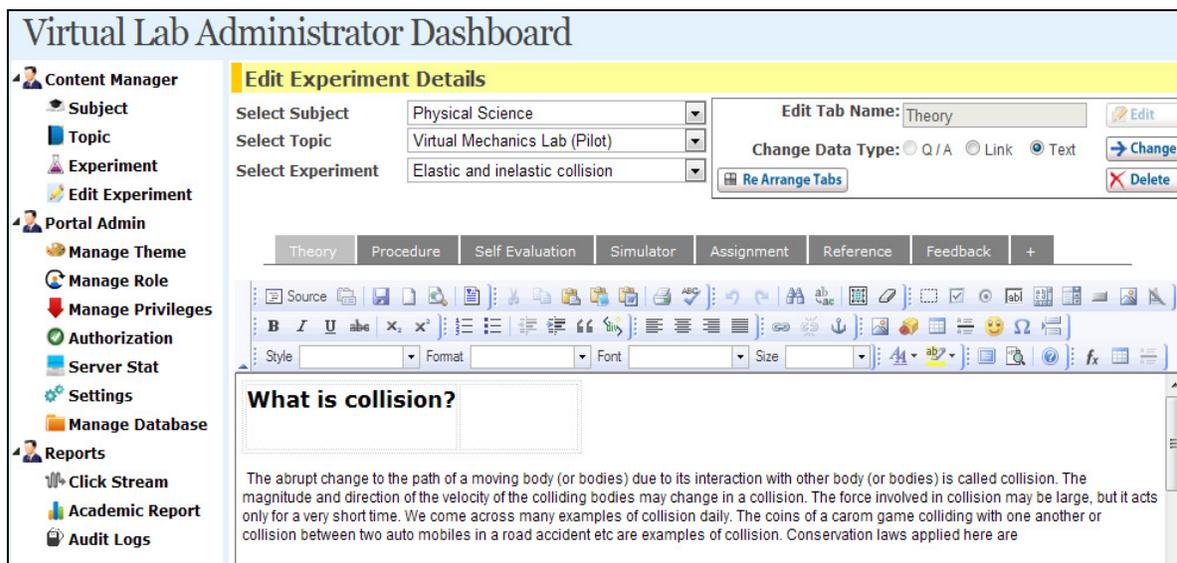


Figure 3: Content Management Interface

VLCAP maintains a library of templates in the repository. These templates allow simulations, animations and hypertext to be directly plugged in without any programming effort.

VLCAP allows creation of reusable learning objects that are accessible from the repository. The application automates content development by providing customizable templates (Figure 4) and the faculty can create an entire course by using the existing learning objects in the repository, creating new learning objects, or using a combination of old and new objects and adding multimedia content from the same or other approved repository. Existing content can be quickly and easily added to the repository or integrated with the tool.



Figure 4: Pre configured set of templates and designs

Review comments between the author and developer may be exchanged using the VLCAP. Instructors may add their knowledge to a course without programming, while providing the storyboard to the animation artist or the requirements for a simulation to the software developer.

### VL Management System (VLMS)

Management in the Virtual Lab context consists of the ability to keep track of a VL secure access with single sign on, content management, scheduler, template engine, version control, lab usage, deployment dependencies etc. Virtual Lab Management System supports the following;

#### Single sign on

Login at the main site provides access to labs from all institutions on any server. So the main site authenticates access to other sites. Kerberos based single sign on reduces the burden of having different username password combination on various Virtual Lab servers. The central

server generates a Kerberos One-Time Password (OTP) token which handles the entry/exit/access to systems without the inconvenience of re-prompting users.

### **Role-based Access Control**

This provides users with various access controls to use the VL in the system to a centralized security model. Students attending a VL course will see the experiments relevant to the course. Participating institutions are allowed to add/modify labs based on their access privileges.

Typical Roles are;

- Authors: to create contents with associated dynamic scenarios.
- Platform administrators: to manage users, schedule sessions.
- Instructors: to follow, help and evaluate their learners.
- Learners: to perform experimentation, to collaborate within teams, to report experimentation.

### **Scheduling and Work Flow**

A true Virtual Lab management system includes robust scheduling to maximize productivity and eliminate resource conflicts. The system allows reservation of remotely accessible equipment for learners, faculty, and classrooms using an online scheduler (Figure 5). It supports batched experiments where the entire instructions and variables for an experiment are specified before the experiment begins. This locks the equipment for the minimum amount of time to the particular user.

The screenshot shows the 'Sakshat Virtual Labs' interface for a 'Solar Panel Experiment (Remote trigger)'. The page includes a navigation bar with links: Home, Project, Vision, People, FAQ, Contact us, Video, Log In, and a search box. Below the navigation bar, there are icons for Theory, Procedure, Self Evaluation, Simulator, Assignment, Reference, and Feedback. The main content area is titled 'Experiment Scheduler' and displays a calendar grid for the dates 10-12-2010 to 16-12-2010. A red bar indicates that the equipment is currently busy. Below the calendar is a 'Schedule the experiment' form with fields for Start time, Experiment Duration (set to 30 minutes), and Email, along with a Submit button.

Figure 5: Online scheduler for Remote Trigger Virtual Labs

It also supports interactive experiments where the learner monitors and controls one or more aspects of the experiment during its execution. It allows only one user to access such a reserved remote trigger experiment and also updates an online calendar.

### Assessments

Faculty may create assessments setting appropriate properties for the type of questions. After submission of the questions and answer types, the system automatically generates HTML pages, with the appropriate code to make the pages interactive. A question can be reused for more than one experiment. Any instructor can add to the question bank for a specific lab.

### Feedback Loop

The Feedback module allows administrators to create and conduct surveys to collect feedback from learners and Instructors from Institutions using the labs. All feedback messages are listed and grouped by status in an administrative feedback log.

## **Deployment Model**

In addition to Virtual Lab management, the ability to create automated deployment environment is a key to rapidly deploying the VL. Multiple deployment models are supported by the platform including the local institute cloud model and the hosted model. A key difference in our model for supporting development by multiple institutions using multiple technologies is to provide a central but distributed content repository depending on the technologies supported by the platform

## **Findings**

The clear advantages of having a collaborative development platform for Virtual Lab include the ability to consult and broaden perspective of experiments and build experiments without having to rely on IT resources for multimedia and/or publishing needs. As an example of the effectiveness, a case study was conducted amongst lab developers of the consortia. Close to 80% of the faculty in this study hailed from a variety of backgrounds in science and engineering. They have never built a web page and/or published anything online on their own in spite of being every day users of technologies and simulation packages in their respective areas of expertise.

A full-time deployment at our University suggested that VLCAP encourages new self-motivated learning patterns amongst learners and collaborative exercise development among interacting faculty (data not shown). Currently some tests are underway with both teachers and students and we are quantifying an estimate on teacher collaborations, joint content generation apart assessing static and dynamic learners and users. We are also estimating the cost effectiveness of VLCAP as a viable e-learning platform for real laboratory work, with focus of ease of accessibility and analyzing patterns on user-motivated self-learning. Online learners also appreciated that information suggestions offered could be quickly re-introduced by the educator due to the ease of collaborative exchange among lab developers and faculty, although more data will be needed to show this assessment.

Large scale tests will be needed to analyze and provide the assessment. These tests will also require both learners and educators (lab faculty) to use the software platform. Tests in biotechnology, physics and chemistry are already underway via the VALUE labs initiative [10] and the school Simulation Labs [11].

Several users have raised the issue of how to support learners using VL. In real-world labs, learners work in the same place at the same time so there is teacher or peer support available. This kind of support is not immediately available to remote learners. VLCAP is being enhanced to provide tools to compensate for this.

## **Conclusions and Future work**

Developing comprehensive Virtual Lab modules that include theory, quizzes, animations, simulations and remote triggered experiments with audio and visual content that is interactive

for every experiment can be expensive when developing multiple labs in multiple disciplines. When technical know-how to create an experiment along with the tools or equipment are available, the technology framework for a collaborative platform discussed in this paper can mitigate many challenges to building virtual labs: exorbitant cost, knowledge of integrating technologies for web publication, lack of IT resources, providing services such as authentication, scheduling, deployment challenges etc.

The key aspect of this framework is, it allows optimization, integration of VL services, easy retrieval and maximization of content usage, independence of technologies underlying them and thereby enhancing the Return on Investment in these labs. This technology platform is highly scalable and can accommodate hundreds of concurrent virtual lab developers in a distributed environment. Based on the initial positive feedback, VLCAP is being rolled out to several institutes developing VL.

Enhancements to this framework include building a library of simulation objects and integration with Learning Management Systems like Moodle, Sakai etc. as part of the VLCAP roadmap. Further investigations of the effectiveness of the collaborative development, learning under virtual laboratories and simultaneous analysis of learner perceptions of their experiences are planned

### **Acknowledgement**

This project derives direction and ideas from the Chancellor of Amrita University, Sri Mata Amritanandamayi Devi. This work was funded by National Mission on Education ICT ERP project under the Ministry of HRD, Govt. of India. The authors would like to acknowledge the contributions of faculty at Amrita and other partner universities whose feedback was invaluable.

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## **Biography**

PREMA NEDUNGADI is a Co-Principal Investigator for the Online Labs for Schools from Department of IT and a joint Director for the Center for REsearch in Advanced Technologies for Education (CREATE) at Amrita Vishwa Vidyapeetham where her research projects include areas of Adaptive Assessment and Learning, Virtual Simulation Labs, Language Labs and Collaborative Authoring and Learning Platforms. Her prior background includes 15 years of Software Architecture and Management at Sybase Inc. and Redbrick Systems (IBM), California.

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