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Integrating Collaboration and Accessibility for Deploying Virtual Labs using VLCAP

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ABSTRACT

The Virtual Labs Collaboration and Accessibility Platform (VLCAP) provides tools to further India's National Mission project: the building of over 150 Virtual Labs (VL) for over 1450 multi-disciplinary undergraduate- and postgraduate-level experiments. VLCAP optimizes VL development and deployment costs and ensures a rich, consistent learning experience. Its multi-tier, scalable architecture allows VL builders to focus on their experiments. Its modules (VL workbench, collaborative content management, repositories) have axiomatically-designed interfaces that bring speed and efficiency to design. Its integration of user-management tasks (single sign-on, role-based access control, etc.) enhances flexibility without compromising security.

The key accomplishments include its application of simulation VL and its provision of easily usable authoring tools, pre-configured templates, and management and assessment modules for instructors. VLCAP's support of multiple deployment models, including the cloud, hosted, and mixed models, ensures scalable and reliable usage in hosted environments, and secure access for learners in remote locations.

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1. Background

The National Mission Project on Virtual Labs by the Government of India under the National Mission on Education through Information and Communication Technology (NME ICT), launched in March 2009, is a long-term, multi-institutional collaborative project. Its objective is to develop and deploy, by 2012, over 150 Virtual Labs that cover various engineering fields in the undergraduate curriculum. These virtual tools are designed to enrich the course material in Indian universities for both educators and learners. Each virtual lab developer uses different software technology to develop the virtual experiments. The design, implementation and usage of these multi-institutional virtual labs is thus explored with various methodologies and technologies. VLCAP uses an integrated portal to create a similar look and feel for all the distributed labs, and to and reliably serve large numbers of users requiring various levels of scalability, service and security. Only a few projects like LiLa [10] and iLabs [4] have attempted to support, integrate and offer faculty and learners a single platform to help develop and deploy such labs.

One of the unique aspects of the virtual lab is that it brings people with very different technological and cultural backgrounds together. The VLCAP consortium consists of twelve academic partners with expertise in various engineering fields, multimedia, animation and simulation, cloud computing, and other disciplines. The project involves the collaboration of 12 premier institutions, and many more will be involved in its course. Nine fields of science and engineering were chosen for the project.

2. Introduction

VLCAP's multimedia online educational content is created and deployed collaboratively by course developers, subject matter experts, graphic designers, animation experts and software developers. Large multi-institutional projects for various labs increase the project's complexity, since the various software- and hardware- interfacing technologies used by multiple institutions need to be integrated into one platform.

This paper presents the architecture, methodology and deployment of the Virtual Labs Collaboration and Accessibility Platform. This platform is designed, principally, to enable the deployment of multi-site virtual labs that provide a similar look and feel for the diverse experiments, and also to reduce the cost of development and deployment of multimedia by reusing and repurposing it, and by minimizing dependency on individual IT and programming skills. Further, this paper discusses VLCAP's challenges, which include the joint development of distributed labs that use different software and interfacing technologies.

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 have to be programmed, lab resources have to be managed and allocated, learner data needs to be gathered, recorded and stored. Often the VL faculty does not have the time to work on these lab management tasks. We also found that the faculty has to maintain a separate set of learner data for each VL. If the learner was registered with multiple VLs, this becomes complicated. Thus, there is a need for a platform that provides services for all the commonly performed tasks of the VL.

The VLCAP project is unusual in its methodology because it distributes the technology-independent content of all institutions into one repository. Content that is dependent on various software technologies is isolated, while the metadata from and access to the host institute is maintained. Thus, every institution is provided with the ability to choose among various technologies. Content is reusable, and integrated into a common platform that includes templates, pre-existing simulations, and wizard-based instructions. This content is also very adaptable – educators can use it to create their own learning objectives, assignments, step-by-step instructions, worksheets, control quizzes, and so on.

3. Relevant literature and previous work

Since 1996 [1], virtual labs have been increasingly popular, and have developed according to their technical feasibility. Though the remote laboratory platforms have matured, however, they are usually still built without a shared interoperable approach [2] - [3].

A popular example of distributed architecture for remote labs is iLabs [4], 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 [6], most existing Learning Management Systems (LMSs) support rich functionality, much of which is highly relevant to remote laboratories (grade tracking, collaboration tools, management of assessment tasks, and so on). However, as [9] Rapuano and Zoino report, research to integrate Remote Labs into LMS has been slowed by the fact that LMSs are usually closed proprietary software systems that are not customizable at all.

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Previous studies [3, 5, 10] indicate some instances of integration between LMSs and remote labs. The research lines are several: for example in the MARVEL3 pilot project, financed by the Leonardo programme of the European commission [10], Richter, Boehringer, Jeschke, Ferreira, and Cardoso [3], developed a booking system integrated with Moodle LMS. It was 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 [11], also known as Physics Applets, is a collection of Java applets. It is one of the only existing tools that aims at enabling faculty to create their own online virtual experiments. However, its usage among faculty of online science courses is limited because users are still required to know how to program in Java Script. LiLa [10], an EC-founded project 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, and to perform them through a 3D integrated web portal enabling their collaborative use. LiLa uses BweLabs [5], an open source framework dedicated to complex experiments (initially dedicated to nanotechnologies) and based on Web Services and Semantic Web technologies.

4. VLCAP Designs and Goals

VLCAP is intended to:

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

5. Architecture

VLCAP uses N-tier architecture to support web-based collaborative development of distributed content for Virtual Labs (VL). It is designed to enable educators to bypass issues such as user management, deployment, security, auditing, collaboration, and access control, and thus to focus on the experiments themselves.

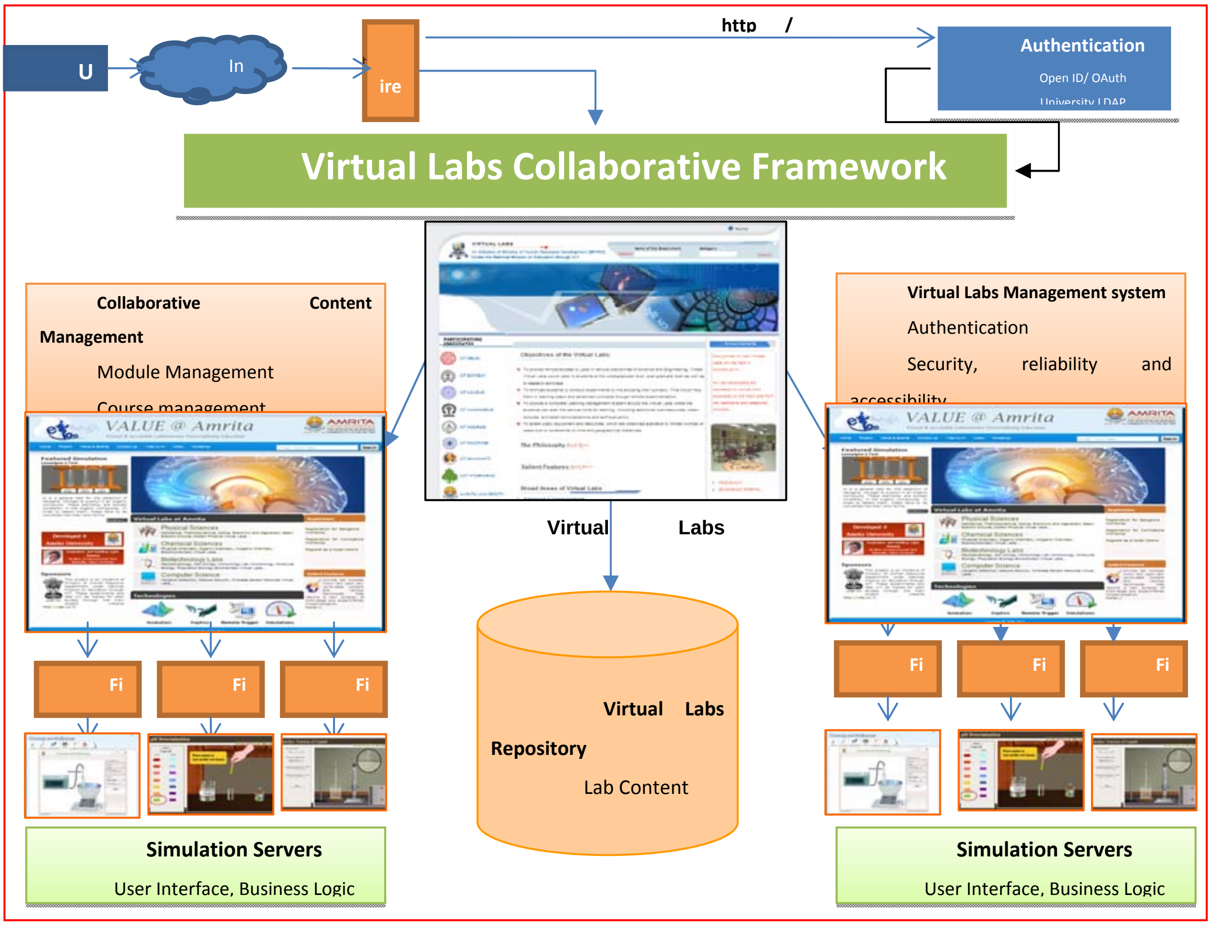

Figure 1: VLCAP Component level diagram.

VLCAP allows VL to be deployed in a hosted environment and securely accessed by learners in remote locations. It facilitates the development, management, and sharing of VL, and supports hundreds of labs and thousands of users. Its 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.

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- VL Collaborative Content Management.
- VL Management system.

5.1 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 various experiments. It communicates with all other components.

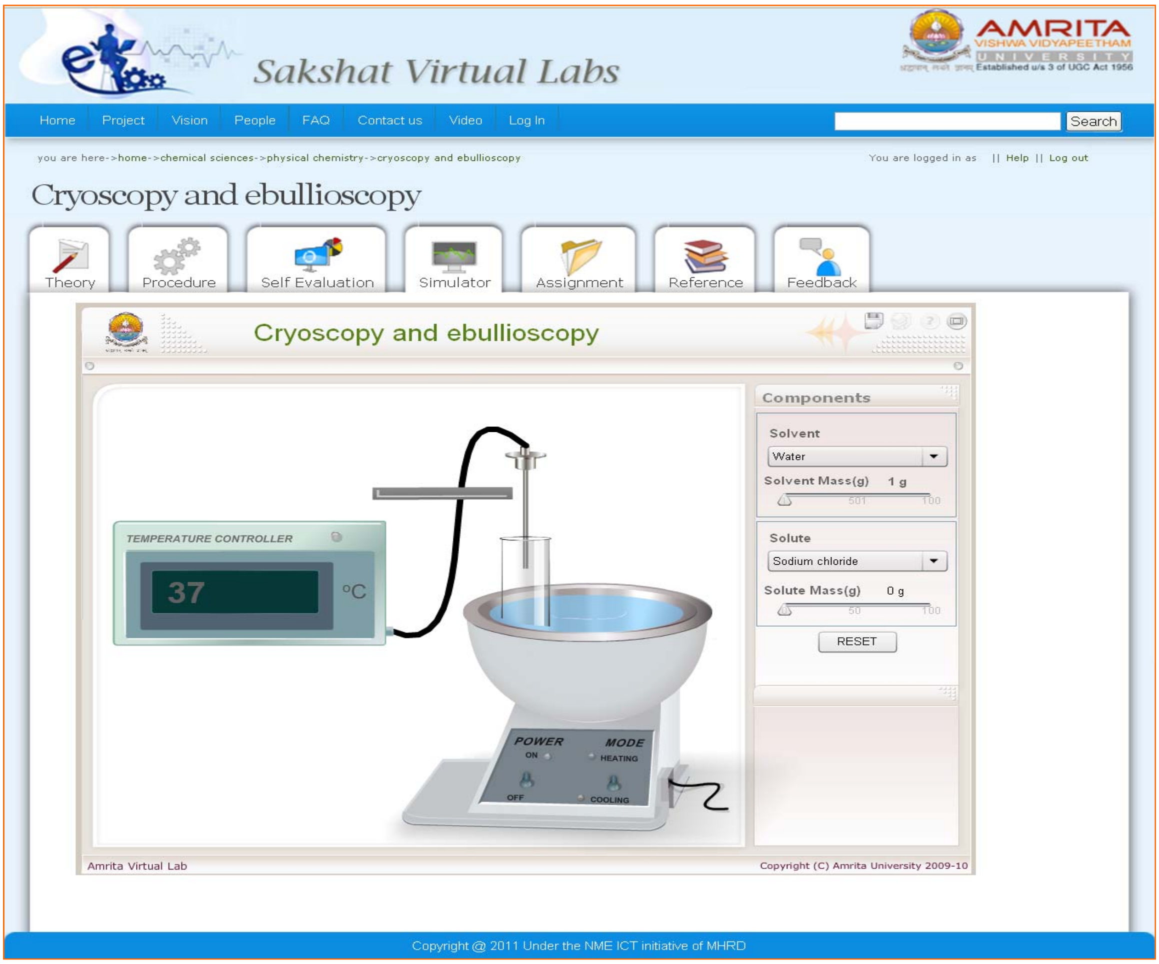

Figure 2: Template for an experiment.

VLCAP provides a standard set of layouts, locations for audio, video and images, and links for navigation. Faculty and course developers can create their own coursework by reusing or replacing the content, without worrying about developing multimedia content.

5.2 VL Repository

VLCAP maintains and manages a centralized virtual lab repository for each institute that it supports. Access is based on authentication, as defined by the lab developer and the user. The repository maintains records of:

- 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.

5.3 VL Collaborative Content Management

By providing a development environment that is both customizable and easy to use, VLCAP allows teams in multiple institutions to collaboratively develop, assemble, re-use, manage and deploy virtual labs content. This content has been put in three hierarchichal tiers (Figure 3) that consist of subject, topic and experiment. The content may be in different forms: theory, procedure, simulation, etc.

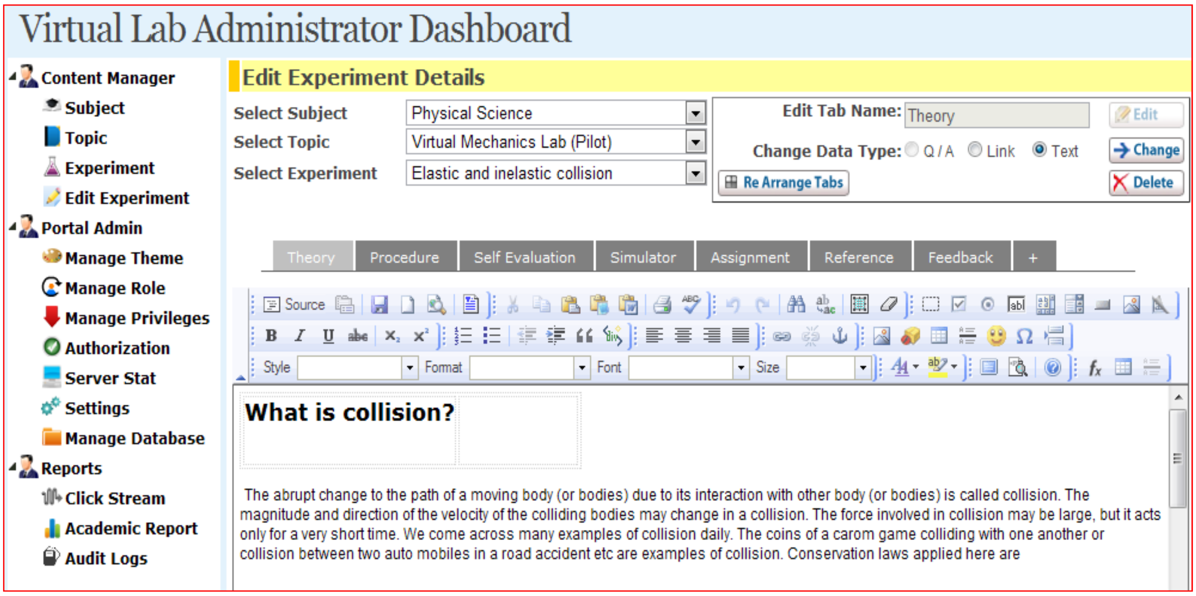

Figure 3: Content Management Interface.

VLCAP maintains a library of templates in its repository, including simulations, animations, and hypertext. It allows the creation of reusable learning objects, automatizing content development by providing customizable templates (Figure 4). Educators can create entire courses by using the existing learning objects in the repository, by creating new learning objects, or by using a combination of old and new objects. Multimedia or written content can be easily added from the same or another approved repository.

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Figure 4: Pre configured set of templates and designs.

Review comments between the author and developer may be exchanged using VLCAP. Instructors may add their knowledge to a course without having to do any programming: they can provide the storyboard to the animation artist, or the requirements for a simulation to the software developer.

5.4 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, and to manage the content, schedule, template engine, version control, lab usage, deployment dependencies, and so on. Virtual Lab Management System supports the following:

5.4.1 Single sign-on

The login at the main site provides access to labs from all institutions on any server: the main site authenticates access to other sites. Kerberos-based single sign-on reduces the burden of having different username and password combinations on various Virtual Lab servers. The central server generates a Kerberos One-Time Password (OTP) token that handles the entry, exit, and access to systems without having to re-prompt users.

5.4.2 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 and/or modify labs based on their access privileges.

Typical Roles are:

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

5.4.3 Assessments

Faculty may create assessment excersizes by setting appropriate properties for questions, so that they can be reused for more than one experiment. After submission of the questions and answers, the system automatically generates HTML pages with the appropriate code to make the pages interactive. Any instructor can add to the question bank for a specific lab.

5.4.4 Feedback Loop

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

5.4.5 Deployment Model

In addition to management, the ability to create an automated deployment environment is key to good VL. Multiple deployment models, including the local institute cloud model and the hosted model, are supported by the VLCAP platform. A key difference in our model is that we provide a central but distributed content repository that is accessable through multiple technologies and is thus usable by multiple institutions.

6. Evaluating collaborations and usage

Our experience with virtual lab development suggested an 18-week time-frame for a single lab developer. This development time includes the design of the experiment and the base setup period for a device-based lab. We have also designed detailed mathematical simulators as part of virtual lab creation. 18 weeks, however, does not include the usual software development cycle for setting up a virtual lab experiment as a product. A virtual lab process starts with one developer.

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Assuming a single developer needed 18 weeks with 100% time for one experiment, we estimated lab development time as follows:

$$Lab\ development\ time = 18\ weeks \times e^{\frac{num\_users}{percentage\_dedicated\_time}} \qquad (1).$$

Where num_users indicated the total number of users and percentage_dedicated_time = 100% implying that the developer spends all effort.

This allows that for every developer (working without collaboration), 18 weeks of time would mean slightly more than one lab (1.05 lab units). Approximately 17.8 week time would suffice to complete a lab unit. One lab unit means the time to set up one laboratory exercise or one piece of lab equipment or simulator.

We estimated the same base time-frame for collaborative labs. In recent workshop on disseminating virtual labs with over 100 participants, learning became self-organized as groups of teachers started suggesting the experiments that could be generated with some common base of content – in this case a physics simulator. With that experience in mind, we suggested the use of a VL collaboration platform for developers and teachers. A seemingly exponential increase in online collaborators has resulted ("collaborator" here refers to a participant contributing to the development of newer content for virtual labs).

Our estimate for online collaborations amongst contributors was based on user numbers and previously calculated lab development time:

$$Number\ of\ collaborations\ = num\_users \times e^{\frac{num\_users}{\left(\frac{1}{percentage\_dedicated\_time}\right) * lab\_develop\_time}} \qquad (2).$$

Calculations for collaborations are quantified based on lab development time per unit; collaboration per user involved (i.e. $\frac{1}{percentage\_dedicated\_time} = \frac{1}{100} = 0.01$). As the number of collaborations increased the average possibility of making more labs from the same experiment, or making similar simulators, increases due to available development time. The formula did not include the case of no collaboration (i.e. when percentage_dedicated_time=0). When no collaboration was involved, the number of collaborations will be zero.

We also found that as users increase, content coverage increased in a seemingly linear fashion. Our initial trials indicated that content coverage (expressed as an equivalency in the number of new labs generated) could be modeled as follows:

$$Content\ coverage = num\_users \times e^{\left(\frac{1}{percentage\_dedicated\_time}\right)*lab\_develop\_time} \quad (3).$$

Here too, in the case of no collaboration (when percentage_dedicated_time=0), content coverage will be equivalent to 1 lab unit.

We noticed a tendency among teachers who collaborated actively to generate separate experiments from the same work – for instance, generating a variety of questions by changing the numbers fed to a mathematical simulator. In our case, as users collaborate an almost linear tendency in new content creation through collaboration was observed.

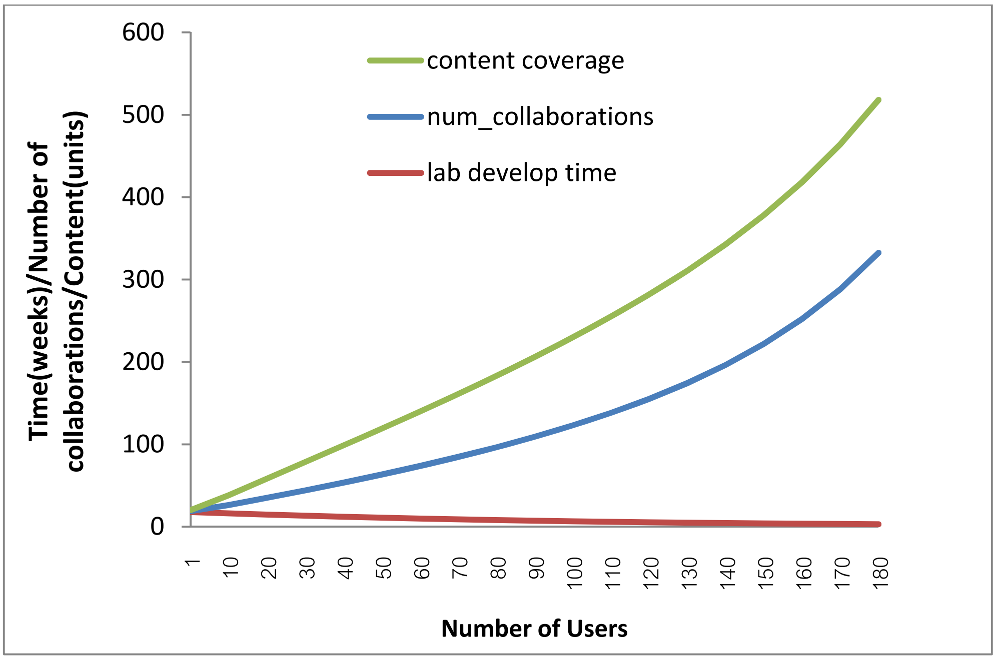

Figure 5: Collaboration activity and content coverage in VLCOP.

7. Findings

The advantages of having a collaborative development platform for virtual labs include the range of perspectives and expertise that it makes available, the ability to build experiments without having to rely on IT resources for multimedia and/or publishing needs. Its effectiveness is suggested by a case study conducted amongst lab developers of the consortia. Close to 80% of the faculty in this study hail from a variety of backgrounds in science and engineering. They have never built a web page, or published anything online on their own, in spite of being

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everyday users of technologies and simulation packages in their respective areas of expertise.

VLCAP's full-time use at our University suggests that it encourages new, self-motivated learning patterns amongst learners, and collaborative exercise development among interacting faculty (data not shown). Currently some studies involving both teachers and students are underway. We therefore quantified using a metric, an estimate on teacher collaborations, joint content generation apart from assessing static and dynamic learners and users. We also estimated the cost- effectiveness of VLCAP as a viable e-learning platform for real laboratory work, focusing on ease of accessibility, and analyzing patterns on user-motivated self-learning. Online learners appreciated that their information and suggestions can be quickly re-introduced by the educator, due to the ease of collaborative exchange among lab developers and faculty(data not shown). Many large-scale tests will be needed, that will 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 [8] and the school Simulation Labs [7].

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.

8. Conclusions and Future work

Developing comprehensive, interactive virtual lab modules in multiple disciplines that include theory, quizzes, animations and simulations with audio and visual content, can be expensive. 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, by providing services such as authentication and scheduling, addressing deployment challenges, and so on.

This framework allows optimization, integration of VL services, easy retrieval and maximization of content usage, and technological independence. It thereby maximizes the return on investment. 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 shared with several institutes developing VL.

Ongoing enhancements to this framework include support for development, security and modelling of remote equipment lab. Other enhancements to this framework of interest include adding to a library of simulation objects, and integrating it with Learning Management Systems like Moodle, Sakai, etc. Further investigations of its effectiveness in enabling collaboration and achieving learning goals are planned.

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