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XUNTA DE GALICIA

Shareable Educational Architectures for Remote Laboratories

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***Abstract*—The proliferation of remote laboratories in multiple disciplines of science has removed the cost and administration burdens that hinder the adoption of practical sessions in engineering education. Remote laboratories provide online workbenches unconstrained by neither temporal nor geographical considerations and allow an interactive learning that maintains student attention. Recently, remote laboratories have been developed at multiple universities and adopted in engineering education. Furthermore, some of these laboratories are replicated at many universities such as the electronic circuit's remote labs: NetLab, VISIR, and labs based on NI ELVIS II. This was the commence of a new mainstream which advocates a better remodeling of those laboratories to allow their allocation, sharing among universities, and their communication with other heterogeneous systems, e.g., Learning Management Systems (LMS). In this context, numerous shareable educational architectures for remote labs integration have emerged such as LiLa, Lab2go, ISILab, DCL, WebLab Deusto, iLab (ISA), and Labshare (Sahara). This paper reports on the emerging solutions for remote laboratories implementation and deployment in engineering education in an efficient way. The paper discusses different integration scenarios pointing out features, limitations, and upcoming challenges.**

Keywords; remote laboratory; elearning; distance education; online learning

I. INTRODUCTION

Recently, remote laboratories have widely been adopted in all electrical and electronics engineering education disciplines [1-3]. Sharing and reusing remote laboratories among universities in an efficient way could increase the lab availability, decrease cost, and foster collaboration among universities. However, in the literature review [2], a study was realized on 42 different remote laboratories and concluded that they use different software architectures without being reused nor shared among universities. Thus, several approaches have been realized in order to integrate remote laboratories within shareable educational architectures, on the one hand, to allow inter-institutional operation and efficient administration and management of those laboratories. On the other hand, this integration could provide additional services to enrich online practical sessions such as assessment and communication tools. This paper presents a thorough study on remote laboratories implementation and integration with shareable educational architectures, shedding light on the most outstanding approaches and pointing out the exclusive features and the limitations of each. This is in order to predict and describe the more likely to be the applied criteria for the next generation remote laboratories and how they could be properly implemented and deployed in electrical and electronics engineering education.

The paper is structured as follows: Section II provides a general overview on remote laboratory design; Section II provides case studies on remote laboratories for electronic circuits practices; Section IV discusses remote laboratories integration with metadata repository; Section V discusses remote laboratories integration with Learning Management Systems (LMSs); Section VI discusses remote laboratory integration with generic shareable architectures; Finally, a conclusion is derived in Section VII.

II. OVERVIEW

Remote laboratories are those laboratories that can be controlled and administrated online. They differ from the virtual simulated laboratories as they are interacting with physical instruments. The common generic architecture design of today's remote laboratory is shown in Figure 1. The user interface is the virtual end-user workbench that handles all the lab administration process. It is a web site that runs on the user's web browser and usually requires a server-side programming language to retrieve user's data from database, along with a Graphical User Interface (GUI), which is built by an animation technology embedded in the HTML code to

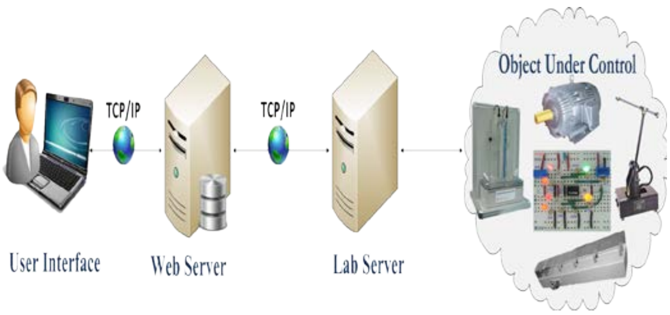

Figure 1. Generic architecture design of remote laboratory.

resemble the real lab workbench. The webserver hosts the web site and the database files and sends the user requests to the lab server in the form of XML messages through TCP/IP model over HTTP layer. The lab server hosts the instrumentation control software and it is connected directly to the instruments. The instrumentation control software sends commands to the object under control with regarding to the received requests from the user.

III. Case Studies

Measurement and wiring of electronic circuit's practices have an essential role in all electrical and electronics engineering disciplines. Among the most noticeable remote laboratories for this purpose are NetLab [4, 5] and Virtual Instrument Systems in Reality (VISIR) [4, 6-8]. Both laboratories have been adopted at many universities. As well, it is important to address the commercial versatile design and prototyping educational platform, NI ELVIS II [9]. Even though, NI ELVIS II itself is not a remote laboratory but it has 12 of the most commonly used laboratory instruments embedded in it and totally controlled by LabVIEW and thus, can be easily controlled remotely. Moreover, it has a variety of experiment plug-in boards and kits, from National Instruments (NI) and from other third-party companies, to teach concepts in controls, telecommunications, fiber optics, embedded design, bioinstrumentation, and digital electronics. Remote laboratories applications based on NI ELVIS II are found in [10, 11]. Other remarkable approaches have been developed as in [12], a remote lab is developed for measuring circuits with operational amplifier, recording the amplitude characteristics of a T-notch filter, and measuring the I/O characteristics of diodes, PNP and NPN transistors and RC filters. In [13] a remote lab is developed for running experiments on a normal BJT common emitter amplifier circuit, while maintaining the possibility for the students to use a wide range of different setups and measurements.

IV. Integration with Metadata Repository

Nowadays, a remote laboratory of a university is scarcely reused by other universities due to the lack of information about the laboratory. The Lab2go project [14, 15] was launched to fill this gap. The Lab2go project is inspired from the semantic web feature of Web 3.0. It is a web portal that acts as a repository and provides a common framework for on-line laboratories providers all over the world. The laboratories with all their related information, running projects, status, etc. are added with metadata by using semantic web technologies, which allows to express a piece of data about some entity in a way that it can be combined with information from other sources to facilitate their allocation and precise the searching criteria rather than the traditional available searching tools that are oriented to the keyword. This allows individuals and researchers to find information about certain types and architectures of laboratories in a specific field all over the world with an intelligent way. Lab2go created a generic model ontology consisting of various properties to add laboratories such as remote laboratories, virtual laboratories, hybrid laboratories, experiments, access URL, status, cost, release date, languages, description, administrator, etc. Likewise, the ontology consists of properties to add experiments such as description, scientific field, documentation duration, etc. basic terminology and data types from Dublin Core [16] are adopted to the models. Basic terminologies from other standard are adopted likewise, e.g., the difficulty property (very easy, easy, medium, difficult, and very difficult) from Learning object metadata (LOM) [17]. The Friend of a Friend (FOAF) [18] ontology is adopted to describe persons, organizations, and projects along with the technical aspects. The open-source software "Protégé" [19] was used to design the ontologies and the framework of the portal was developed by OntoWiki[20]. Lab2go, however, is a metadata architecture and it is not structured to provide access to the on-line laboratories.

V. Integration with Learning Management Systems (LMSs)

A LMS is a software application that facilitates the provision of theoretical online classrooms by means of integrated features and tools such as administrative tools, synchronous and asynchronous communication tools, assessment and tracking tools, multimedia sharing tools, and standard compatibility. Even though, most of the features provided by LMS are of crucial importance to practical sessions. LMS, however, is confined to theoretical resources and doesn't support their practical counterparts. The goal is to make use of all the services provided by open source LMSs such as Moodle, DotLRN [21] and Sakai [22], and apply them in the remote practical lab sessions as shown in Figure 2. Thus, several initiatives have been launched in order to integrate remote laboratories into LMS.

The MARVEL project [23] has created a booking module for the most popular open source LMS, (Moodle), that is based on hour-slots. A further modification to such booking system has been made [24] to facilitate the integration of remote laboratories based on LabVIEW publishing tools. In [25], a similar approach to integrate a remote laboratory into Moodle via plug-ins.

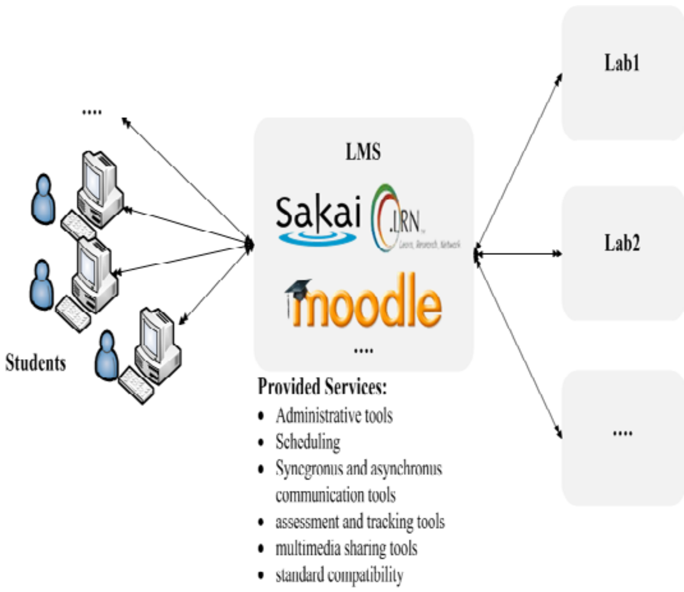

Figure 2.Remote labs integration with LMS.

The Lila Project [26] creates a repository portal that includes remote and virtual laboratories from distinct universities. The experiments are provided in form of Sharable Content Object Reference Model (SCORM) [27] objects and can be downloaded as Sharable Content Objects (SCOs) to be reused in other SCORM-Complaint Learning Management system (LMS). The portal provides access control and booking systems as an inherent part of SCO to have the same effect if the SCO is deployed out of LiLa portal (in a LMS). The access to the experiment, either in the LiLa portal or in the LMS, is provided by a URL. If the user is authenticated by the LMS he will be automatically authenticated to the experiment. Nonetheless, the user must have reserved a time slot to access to the experiment. This is done by a reservation code provided by the teacher. The teacher negotiates first with the experiment provider to be delegated for the experiment administration during a period of time and to get reservation codes for his students. Shibboleth [28] (A standards based, open source software package for web single sign-on across or within organizational boundaries) is selected for the authentication and authorization among the experiment provider, the teacher, and the student.

The Middleware Architecture [29] is a web services-based architecture for integrating remote laboratories with open source LMSs such as Moodle and DotLRN. The architecture would allow the communication of remote laboratories by means of web services with created modules designed for adding experiments within the LMS. Moreover, it would support the access on experiments within iLab Shared Architecture (ISA) [30-32] through the LMS [33].

In the mentioned integration approaches within LMS, in general, it is not evident the relation between the course activity and the practical session. Moreover, it is not clear whether the collaborative tools of the LMS is supported or that it is only created to allow sequential access to the experiment [34]. One of the factors that have slowed down the integration of remote laboratories into LMSs is that LMSs were usually closed proprietary software systems and not customizable [35] until the prevalent of the open source solutions. Other approaches attempt to integrate remote laboratories into standards compatibles with most of LMSs such as SCORM [26] and IMS-LD [36] but without a notable outcome. Moreover, it is still not clear whether if they are generic integration for all remote laboratories and for other LMSs or they are special cases.

VI. INTEGRATION WITH GENERIC SHAREABLE ARCHITECTURES

A generic shareable architecture encompasses several remote laboratories from several universities in order to span their dissemination and inter-institutional operation. Consequently, this will allow the reduction of cost and the increase of availability. The most pioneer generic shareable architectures that have been adopted at many universities are ISA and Sahara [37-39].

A. iLab Shared Architecture (ISA)

The iLab project provides a middleware infrastructure based on web services and developed by .NET technology, known as iLab Shared Architecture (ISA). ISA is an efficient management framework that can support administration and access to a wide variety of platform-independent developed online laboratories. The architecture started with a three-tiered model, consisting of lab clients, service broker middleware, and lab servers. The service broker is responsible for providing generic functionalities such as authorization, scheduling, data storage, etc. It is typically located at the client side campus and it is able to be connected to multiple lab servers at distinct institutions with web services as shown in Figure 3. Conversely, a given lab server can receive experiments from an arbitrary number of service brokers. The lab server implements this queue using a database. This architecture is only valid for batched experiments those in which the student query is queued and results returns back to him after being executed. The student doesn’t have to be connected while his experiment is being executed as he is not directly connected to the lab server. Electronics WebLab [40] is the first developed lab that is based on iLab batched architecture. Interactive experiments differ from their batched counterparts; they require control of lab hardware while the user sets parameters and observes results, thus, they require a greater bandwidth between the lab client and the lab server. In order to accommodate these requirements, ISA has been extended to include Lab Side Scheduling Service (LSS), User Side Scheduling Service (USS), Experiment Storage Service (ESS), Ticketing, and support for high bandwidth communication between the lab client and server. LSS, USS, ESS, and Ticketing are based on web services. USS and LSS set the policy of the student institution and the laboratory, respectively. But both are designed to work together. The service broker only vouch for the user to the lab server, then it retires and permits the direct control of the student to the lab server leaving the storage task

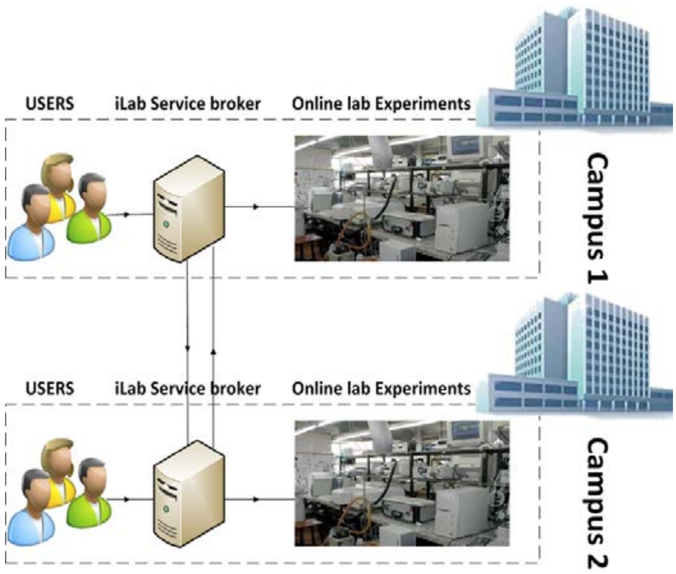

Figure 3. Batched iLab Shared Architecture (ISA).

of experiment data to ESS. The service broker is still responsible for authentication and authorization. It issues a ticket stub (coupon) for the user, when he logs in, to be redeemed by the lab server and the ESS before execution. LabVIEW Integrated Interactive Lab Server (LVILS) is developed to integrate laboratories based on LabVIEW GUI by a standard and easy way to the iLab interactive architecture. Consequently, multiple remote laboratories based on LabVIEW have been deployed in ISA such as NI ELVIS [40]. In the case where LabVIEW is not the chosen technology, the lab client and server must implement the web service interfaces according to the Client to Service Broker API as defined by ISA in order to access its generic functionality. In [41], a LabVIEW toolkit has been developed to simplify the integration of batched experiments. An approach to integrate VISIR within ISA is stated in [42].

B. Sahara

The Labshare [37] project provides a common integrated platform (Sahara) that allows remote laboratories (so-called rigs) to be accessed and shared among institutions. Sahara includes booking functionalities, queuing, support for federated access, and additional administrative tools. The authentication is based on a simple database authentication, or local institution interface such as Lightweight Directory Access Protocol (LDAP). Each user is associated with one or more user classes and each user class is associated with resource permissions. Interactive experiments, batched experiments, and monitoring (collects data but doesn't require user interaction) are supported. Sahara implements different user modes: master users (who are granted access and have full control of rigs), active slave users (allowed to join a rig session and either allow control), and passive slave user (just allowed to view the session). Sahara supports the automatic allocation of individual rigs of the same kind (replications). Sahara is based on a client-server architecture and it is developed by PHP (for the web interface), MySQL or PostgresSQL/Apache (for the scheduling server), and Java (for the simulated experiment workbench), which are all cross-platform. Web services are adopted for the communication means.

Sahara and ISA offer similar functionalities but their architectures are different [38]. ISA offers a relative comparative advantage in batched labs, whereas, Sahara offers advantages for interactive labs [39]. The main upcoming challenge in remote laboratories implementation is to have a single architecture that encompasses the discussed features such as interoperability, compatibility, metadata, standardization, and integration of educational contents. For these reasons, the founders of the above mentioned projects (Lab2go, LiLa, iLab, and Labshare), together with other partners have formed the Global Online Laboratory Consortium (GOLC) [43] to research into, and promote the development of a common infrastructure for a unified and an interoperable architecture that is able to share online laboratories efficiently around the world. A major research task within GOLG is to create LabConnectors [39], based on an interoperable cross-system protocol, to allow interchangeability of remote laboratories between ISA, Sahara, and other architectures such as WebLab Deusto [44], ISILab [45], and DCL [46]. LabConnectors is a common API that establishes common nomenclatures of web services-calls for several architectures to allow calling experiments integrated in an architecture from another architecture as shown in Figure 4. Web services have a significant role in creating an interoperable architecture. Web services are a programming language–independent solution design that allows communication between heterogeneous software applications over a network by means of ad-hoc standard protocols. Despite the high interoperability of web services, they have intrinsic weakness on latency, interoperability, and performance owing to the high number of transport layers used to wrap instruments into web services and the overhead of using Simple Object Access Protocol (SOAP) [47]. Thus, web services are not adequate for real-time control of instruments [3], but still its advantages outweigh its disadvantages. Recently, many approaches are moving from SOAP towards Representational State Transfer (REST) [3, 48, 49] which uses as a data format JavaScript Object Notation (JSON) rather than XML, owing to its simplicity and high transfer speed, avoiding the heavy-weight of XML libraries in APIs of client and lab server sides.

VII. CONSLUSION

The integration of remote laboratories with heterogeneous educational architectures is a step forward towards more efficient implementation and deployment of remote laboratories in engineering education. In this paper, different facets of remote laboratories integration have been presented highlighting the novelty of each approach and the upcoming challenges. The aforementioned approaches reflect the more likely to be the applied criteria on the development and implementation which requires: ease of allocation using semantic web technology; standard toolkits to facilitate integration of several lab architectures; administration, scheduling, and queuing services; integrated features to allow

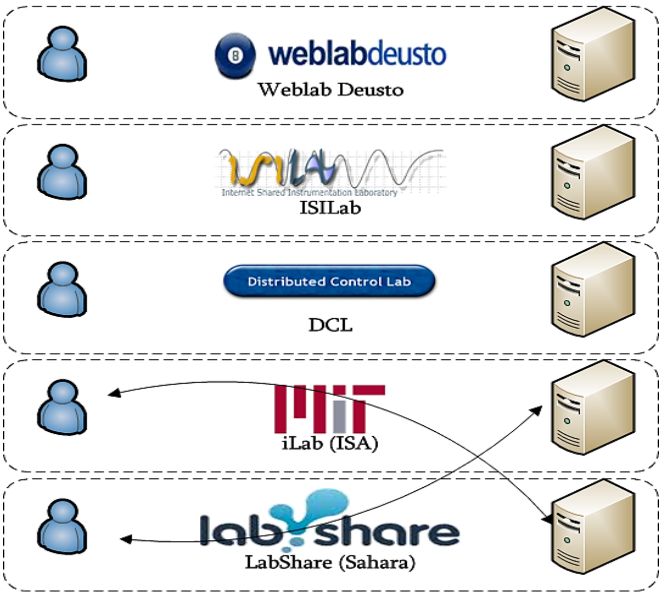

Figure 4. Interoperability in shareable architectures of remote labs.

communication, evaluation, and assessment within the lab sessions; scalability and multiple access; Interoperability with other architectures and heterogeneous systems; and standardization to export experiments as learning objects.

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REFERENCES

[1] L. Gomes and S. Bogosyan, "Current Trends in Remote Laboratories," *Industrial Electronics, IEEE Transactions on*, vol. 56, pp. 4744-4756, 2009.

[2] C. Gravier, J. Fayolle, B. Bayard, M. Ates, and J. Lardon, "State of the Art About Remote Laboratories Paradigms – Foundations of Ongoing Mutations," *International Journal of Online Engineering (iJOE)*, vol. 4, pp. 19-25, 2008.

[3] E. G. Guimaraes, E. Cardozo, D. H. Moraes, and P. R. Coelho, "Design and Implementation Issues for Modern Remote Laboratories," *Learning Technologies, IEEE Transactions on*, vol. 4, pp. 149-161, 2011.

[4] I. Gustavsson, K. Nilsson, J. Zackrisson, J. Garcia-Zubia, U. Hernandez-Jayo, A. Nafalski, Z. Nedic, O. Gol, J. Machotka, M. I. Pettersson, T. Lago, and L. Hkansson, "On Objectives of Instructional Laboratories, Individual Assessment, and Use of Collaborative Remote Laboratories," *Learning Technologies, IEEE Transactions on*, vol. 2, pp. 263-274, 2009.

[5] NetLab - The Online Remote Laboratory - University of South Australia, Retrieved January 1, 2012, from: http://netlab.unisa.edu.au/index.xhtml.

[6] M. Tawfik, E. Sancristobal, S. Martín, C. Gil, A. Pesquera, P. Losada, G. Díaz, J. Peire, and M. Castro, "A New Node in the VISIR Community," presented at the REV 2011 Proceedings, Brasov, Romania, 2011.

[7] M. Tawfik, E. Sancristobal, S. Martin, C. Gil, P. Losada, G. Diaz, and M. Castro, "Remote laboratories for electrical & electronic subjects in new engineering grades," in *Promotion and Innovation with New Technologies in Engineering Education (FINTDI), 2011*, 2011, pp. 1-6.

[8] M. Tawfik, E. Sancristobal, S. Martin, C. Gil, A. Pesquera, P. Losada, G. Diaz, J. Peire, M. Castro, J. Garcia-Zubia, U. Hernandez, P. Orduna, I. Angulo, M. C. Costa Lobo, M. A. Marques, M. C. Viegas, and G. R. Alves, "VISIR deployment in undergraduate engineering practices," in *Global Online Laboratory Consortium Remote Laboratories Workshop (GOLC), 2011 First*, 2011, pp. 1-7.

[9] NI ELVIS: Educational Design and Prototyping Platform, Retrieved January 1, 2012, from: http://www.ni.com/nielvis/.

[10] P. Nakazinga, P. Karumuna, A. T. Asiimwe, C. Mwikirize, P. I. Musasizi, S. S. Tickodri-Togboa, J. Butime, and A. Katumba, "An Interactive Control Systems Online Laboratory Utilizing NI ELVIS IITM and the Quanser 010 DC Motor Control Trainer," presented at the REV 2011 Proceedings, Brasov, Romania, 2011.

[11] C. Mwikirize, A. T. Asiimwe, L. Musasizi, V. Namuswa, M. D. Nakasozi, C. Mugga, A. Katumba, S. S. Tickodri-Togboa, J. Butime, and P. I. Musasizi, "Development of Online Laboratories for Modulation and Combinational Logic Circuit Analysis Using NI ELVIS II™ Platform," in *Information Technology: New Generations (ITNG), 2010 Seventh International Conference on*, 2010, pp. 1069-1073.

[12] B. Popović, N. Popović, D. Mijić, S. Stankovski, and G. Ostojić, "Remote control of laboratory equipment for basic electronics courses: A LabVIEW-based implementation," *Computer Applications in Engineering Education*, pp. n/a-n/a, 2011.

[13] D. A. H. Samuelsen and O. H. Graven, "Low Cost Implementation of Remote Lab with Large Number of Configurations for a BJT Amplifier," *International Journal of Online Engineering (iJOE)*, vol. 7, pp. 31-36, 2011.

[14] C. Maier and M. Niederstätter, "Lab2go – A Repository to Locate Online Laboratories," *International Journal of Online Engineering (iJOE)*, vol. 6, pp. 12-17, 2010.

[15] Lab2go: the semantically enriched repository of online labs, Retrieved December 30, 2011, from: http://www.lab2go.net/.

[16] DCMI Home: Dublin Core® Metadata Initiative (DCMI), Retrieved January 1, 2012, from: http://dublincore.org/.

[17] Learning Object Metadata (LOM), Retrieved January 1, 2012, from: http://ltsc.ieee.org/wg12/.

[18] The Friend of a Friend (FOAF) project, Retrieved January 1, 2012, from: http://www.foaf-project.org/

[19] Protégé – an ontology editor and knowledge-base framework, Retrieved January 1, 2012, from: http://protege.stanford.edu/.

[20] OntoWiki, Retrieved Jaunuary 1, 2012, from: http://ontowiki.net/Projects/OntoWiki.

[21] .LRN Project Site, Retrieved January 1, 2011, from: http://openacs.org/projects/dotlrn/.

[22] Sakai Project | collaboration and learning - for educators by educators, Retrieved January 1, 2011, from: http://sakaiproject.org/.

[23] J. M. Ferreira and A. M. Cardoso, "A Moodle extension to book online labs," *iJOE International Journal on Online Engineering*, vol. 1, 2005.

[24] S. Uran, D. Hercog, and K. Jezernik, "Remote Control Laboratory with Moodle Booking System," in *Industrial Electronics, 2007. ISIE 2007. IEEE International Symposium on*, 2007, pp. 2978-2983.

[25] A. G. Vicente, Mu, x00F, I. B. oz, J. L. L. Galilea, and P. A. R. del Toro, "Remote Automation Laboratory Using a Cluster of Virtual Machines," *Industrial Electronics, IEEE Transactions on*, vol. 57, pp. 3276-3283, 2010.

[26] A. Gallardo, T. Richter, P. Debicki, L. Bellido, V. Mateos, and V. Villagra, "A rig booking system for on-line laboratories," in *Global Engineering Education Conference (EDUCON), 2011 IEEE*, 2011, pp. 643-648.

[27] SCORM, Retrieved January 1, 2012, from: http://scorm.com/.

[28] Shibboleth®, Retrieved January 1, 2012, from: http://shibboleth.internet2.edu/.

[29] E. Sancristobal, M. Castro, S. Martin, M. Tawkif, A. Pesquera, R. Gil, G. Diaz, and J. Peire, "Remote labs as learning services in the educational arena," in *Global Engineering Education Conference (EDUCON), 2011 IEEE*, 2011, pp. 1189-1194.

[30] J. L. Hardison, K. DeLong, P. H. Bailey, and V. J. Harward, "Deploying interactive remote labs using the iLab Shared Architecture," in *Frontiers in Education Conference, 2008. FIE 2008. 38th Annual*, 2008, pp. S2A-1-S2A-6.

[31] V. J. Harward, J. A. del Alamo, S. R. Lerman, P. H. Bailey, J. Carpenter, K. DeLong, C. Felknor, J. Hardison, B. Harrison, I. Jabbour, P. D. Long, M. Tingting, L. Naamani, J. Northridge, M. Schulz, D. Talavera, C. Varadharajan, W. Shaomin, K. Yehia, R. Zbib, and D. Zych, "The iLab Shared Architecture: A Web Services Infrastructure to Build Communities of Internet Accessible Laboratories," *Proceedings of the IEEE*, vol. 96, pp. 931-950, 2008.

[32] N. E. Cagiltay, E. Aydin, C. C. Aydin, A. Kara, and M. Alexandru, "Seven Principles of Instructional Content Design for a Remote Laboratory: A Case Study on ERRL," *Education, IEEE Transactions on*, vol. 54, pp. 320-327, 2011.

[33] E. Sancristobal, M. Castro, J. Harward, P. Baley, K. DeLong, and J. Hardison, "Integration view of Web Labs and Learning Management Systems," in *Education Engineering (EDUCON), 2010 IEEE*, 2010, pp. 1409-1417.

[34] M. A. Bochicchio and A. Longo, "Extending LMS with Collaborative Remote Lab Features," in *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on*, 2010, pp. 310-314.

[35] S. Rapuano and F. Zoino, "A Learning Management System Including Laboratory Experiments on Measurement Instrumentation," in *Instrumentation and Measurement Technology Conference, 2005. IMTC 2005. Proceedings of the IEEE*, 2005, pp. 1227-1232.

[36] N. Abdellaoui, C. Gravier, B. Belmekki, and J. Fayolle, "Towards the loose coupling between LMS and Remote Laboratories in online engineering education," in *Education Engineering (EDUCON), 2010 IEEE*, 2010, pp. 1935-1940.

[37] Labshare - Home, Retrieved December 30, 2011, from: http://www.labshare.edu.au/.

[38] D. Lowe, S. Murray, E. Lindsay, and L. Dikai, "Evolving Remote Laboratory Architectures to Leverage Emerging Internet Technologies," *Learning Technologies, IEEE Transactions on,* vol. 2, pp. 289-294, 2009.

[39] H. Yeung, D. Lowe, and S. Murray, "Interoperability of Remote Laboratories Systems," *International Journal of Online Engineering (iJOE),* vol. 6, pp. 71-80, 2010.

[40] J. Hardison, D. Zych, J. A. d. Alamo, V. J. Harward, S. R. Lerman, S. M. Wang, K. Yehia, and C. Varadharajan, "The microelectronics WebLab 6.0--an implementation using web services and the iLab shared architecture," presented at the Exploring Innovation in Education and Research, Tainan, Taiwan, 2005.

[41] M. E. Auer, D. G. Zutin, and C. Rajyaguru, "A LabVIEW toolkit for the development of iLab batched lab servers," in *Global Engineering Education Conference (EDUCON), 2011 IEEE*, 2011, pp. 26-29.

[42] D. G. Zutin, M. E. Auer, and I. Gustavsson, "A VISIR lab server for the iLab Shared Architecture," in *Global Engineering Education Conference (EDUCON), 2011 IEEE*, 2011, pp. 30-33.

[43] GOLC - Global Online Laboratory Consortium, Retrieved January 1, 2012, from: http://online-lab.org/.

[44] J. Garcia-Zubia, P. Orduna, D. Lopez-de-Ipina, and G. R. Alves, "Addressing Software Impact in the Design of Remote Laboratories," *Industrial Electronics, IEEE Transactions on,* vol. 56, pp. 4757-4767, 2009.

[45] A. Bagnasco, A. Boccardo, P. Buschiazzo, A. Poggi, and A. M. Scapolla, "A Service-Oriented Educational Laboratory for Electronics," *Industrial Electronics, IEEE Transactions on,* vol. 56, pp. 4768-4775, 2009.

[46] P. Tröger, A. Rasche, F. Feinbube, and R. Wierschke, "SOA Meets Robots - A Service-Based Software Infrastructure for Remote Laboratories," *International Journal of Online Engineering (iJOE),* vol. 4, pp. 24-30, 2008.

[47] Y. Yuhong, L. Yong, D. Xinge, H. S. Hassane, and A. Ghorbani, "Putting labs online with Web services," *IT Professional,* vol. 8, pp. 27-34, 2006.

[48] J. Zornig, S. Chen, and O. A. Kylaney, "A REST API Architecture for Remote Labs," presented at the REV 2011 Proceedings, Brasov, Romania, 2011.

[49] M. F. Schulz and A. Rudd, "Design and Implementation Issues in a Contemporary Remote Laboratory Architecture," presented at the REV 2011 Proceedings, Brasov, Romania, 2011.