ISBN: 978-989-8533-23-4 © 2014 IADIS

ASK4LABS: A WEB-BASED REPOSITORY FOR SUPPORTING LEARNING DESIGN DRIVEN REMOTE AND VIRTUAL LABS RECOMMENDATIONS

Panagiotis Zervas, Stefanos Fiskilis* and Demetrios G. Sampson
Information Technologies Institute (ITI), Centre for Research and Technology Hellas (CERTH) and Department of Digital Systems, University of Piraeus, 150, Androutsou Str., 185 32 Piraeus, Greece
**Department of Digital Systems, University of Piraeus, 150, Androutsou Str., 185 32 Piraeus, Greece*

ABSTRACT

Over the past years, Remote and Virtual Labs (RVLs) have gained increased attention for their potential to support technology-enhanced science education by enabling science teachers to improve their day-to-day science teaching. Therefore, many educational institutions and scientific organizations have invested efforts for providing online access to state-of-the-art science experiments via RVLs. Currently, there are existing initiatives for the storage and organization of existing RVLs into web-based repositories towards increasing their findability and enabling science teachers to search and retrieve them for further usage into their lesson plans. Nevertheless, most of these repositories adopt metadata models that store limited information related to the pedagogical context of their lesson plans. As a result, science teachers are not supported in selecting RVLs taking into consideration core elements of their lesson planning. In this paper, we aim to tackle this problem by proposing the ASK4Labs a web-based repository for supporting learning design driven RVLs recommendations. Preliminary evaluation results are also described, which indicate that the proposed recommender system can provide robust identification of appropriate RVLs based on the pedagogical context elements of the intended lesson plans.

KEYWORDS

Remote labs, Virtual Labs, Web-based Repositories, Metadata Model, Learning Design, Recommender Systems

1. INTRODUCTION

Over the past years, technological advancements in the field of World Wide Web have allowed the advancement of physical laboratories and their partial replacement by remotely-operated labs ("remote labs") and virtual labs (de Jong et al. 2013; Balamuralithara & Woods 2009). More specifically, remote labs provide students with the opportunity to collect data from a real physical laboratory, including real equipment from remote locations (Gomes & Bogosyan 2009). On the other hand, virtual labs represent interactive environments for designing and conducting simulated experiments (Balamuralithara & Woods 2009). Both, Remote and Virtual labs (RVLs) have gained increased attention for their potential to support technology-enhanced science education by enabling science teachers to improve their day-to-day science teaching. Additionally, it has been shown that RVLs are more effective in increasing students' interest in science and their engagement in related learning activities compared to traditional laboratories (Jaakkola et al. 2011; de Jong 2010; Kong et al. 2009). Thus, many educational institutions and scientific organizations have invested efforts for providing online access to state-of-the-art science experiments via RVLs (Gravier et al. 2008).

Nevertheless, most RVLs currently available online are still scattered around the web. As a result, in order to increase their findability and enable science teachers to search and retrieve them for further usage, there are existing initiatives for their storage and organization into web-based repositories (Richter et al. 2011; Maier & Niederstätter 2010). However, existing RVL repositories are adopting different metadata models for characterizing their RVLs. Furthermore, most of these repositories adopt metadata models that store limited information related to the pedagogical context of their lesson plans such as the teaching approach adopted, the subject domain, the intended educational objectives and the grade level. As a result, science teachers are not supported in selecting RVLs taking into consideration core elements of their lesson planning. Within this context, the aim of this paper is to tackle this problem by proposing the ASK4Labs a web-based repository for supporting learning design driven RVLs recommendations. Moreover, preliminary evaluation results are described, which indicate that the proposed recommender system can provide robust identification of appropriate RVLs based on the pedagogical context elements of the intended lesson plans..

The paper is structured as follows. Following this introduction, section 2 reviews existing RVLs repositories and their metadata models and identifies their limitations related to the pedagogical information that they store. Section 3 presents the proposed ASK4Labs repository by presenting its main functionalities and the recommender system that it incorporates. Section 4 comprises the evaluation of the proposed recommender system. Finally, we discuss our main conclusions and ideas for further work.

2. REVIEW OF EXISTING REPOSITORIES OF REMOTE AND VIRTUAL LABS

According to Conole & Fill (2005) there are two (2) dimensions that constitute a learning design:

- **The pedagogical context** within which the learning design occurs. This includes, among others, the following elements: (a) the subject domain (i.e., physics, geography, math, arts, etc.), (b) the intended educational objectives (i.e., recall, understand, etc.), (c) the grade level (i.e. primary education, secondary education, higher education etc.) and (d) the teaching approach adopted (i.e., problem based learning, inquiry based learning, etc.).
- **The learning activities** undertaken to achieve the intended educational objectives.

Thus, it is important that the pedagogical context elements are accommodated by the metadata model adopted by a RVL repository. This is essential in order to facilitate search and retrieval of RVLs taking into consideration elements of the pedagogical context of learning designs.

In previous work, a review of existing repositories of remote and virtual labs was performed in order to highlight the metadata models adopted by existing RVLs repositories. Furthermore, we conducted a comparative analysis of the elements used by the metadata models of these repositories (Zervas et al. 2014). In the context of the present study, a meta-analysis of those results was performed in order to identify for each metadata model those metadata fields that store information related to the pedagogical context elements of a learning design. Table 1 presents the results of our findings.

Table 1. Overview of Existing RVLs Repositories and their Metadata Models

No	RVLs Repositories	Type of Labs		Learning Design Pedagogical Context Elements			
		Remote Labs	Virtual Labs	Subject Domain	Educational Objectives	Grade Level	Teaching Approach
1	PhET[1]	-	√	√	√	√	-
2	Library of Labs[2]	-	√	√	-	-	-
3	Labshare[3]	√	-	√	-	-	-
4	Open Sources Physics[4]	-	√	√	-	√	-
5	Smart Science[5]	√	-	√	√	-	-
6	Molecular Workbench[6]	-	√	√	-	-	-
7	Explore Learning[7]	-	√	√	√	√	-
8	ChemCollective[8]	-	√	√	-	-	-
9	Remotely Controlled Laboratories (RCL)[9]	√	-	-	-	-	-

[1] http://phet.colorado.edu
[2] https://www.library-of-labs.org/
[3] http://www.labshare.edu.au/
[4] http://www.compadre.org/osp
[5] http://www.smartscience.net/
[6] http://mw.concord.org/
[7] http://www.explorelearning.com
[8] http://www.chemcollective.org/

ISBN: 978-989-8533-23-4 © 2014 IADIS

10	Skoool[10]	-	√	√	-	√	-
11	iLabCentral[11]	√	-	√	-	√	-
12	Lab2Go[12]	√	√	√	-	-	-
13	WebLab Deusto[13]	√	-	√	-	-	-

As we can notice from Table 1, 12 (92,30%) of the examined repositories characterize their RVLs based on the subject domain, whereas only 5 (38,46%) characterize their RVLs based on the grade level. Moreover, only 3 (23,07) of the examined repositories adopt a metadata model that stores information about the educational objectives that their RVLs address. Finally, none of the examined repositories includes information about the teaching approach that their RVLs can be used.

Following this analysis, we can identify that none of the examined repositories support all learning design pedagogical context elements. We consider this a major shortcoming in facilitating search and retrieval of RVLs based on their pedagogical characteristics. Within this context, our research problem is the design and evaluation of a recommender system that aims to support science teachers in selecting RVLs stored in a web repository taking into consideration pedagogical characteristics for given lesson plans. Our proposed solution is presented in this paper with the ASK4Labs web-based repository of RVLs that incorporates (a) an appropriately designed metadata model and (b) a recommender system that addresses this problem.

3. THE ASK4LABS WEB-BASED REPOSITORY

The ASK4Labs is a web-based repository that provides access to RVLs. It has been developed based on Drupal, which is a widely used, open source content management system and content management framework based on PHP and MySQL. For the purpose of our research, the ASK4Labs repository was populated with 45 RVLs. In the next paragraphs, we describe (a) the metadata model of the ASK4Labs repository, (b) its main functionalities and (c) the recommender system that incorporates the metadata model for facilitating selection and retrieval of appropriate RVLs based on the pedagogical context elements of given learning designs.

3.1 Metadata Model

The ASK4Labs repository adopts a metadata model that has been described in previous work (Zervas et al. 2014). More specifically, the starting point for developing this metadata model was the outcomes of an extensive review of the metadata models of existing repositories of RVLs. Additionally, we considered for our model metadata elements that store information about the pedagogical context of a learning design, as described in section 2. Table 2 presents the metadata elements of the proposed metadata model.

Table 2. ASK4Labs Repository Metadata Elements (Zervas et al. 2014)

No	Metadata Group	Metadata Sub-Group	Element Name	Description	Taxonomy Available?
1	**General Metadata**	-	Title	Refers to the complete title of the lab	No
2			Description	Provides a textual description of the lab	No
3			Lab Type	Refers to the specific kind of the lab	YES
4			Language	Refers to the languages that the lab is available in	YES
5			Keyword	Refers to a set of terms that characterize the content of the lab	No
6	**Organizational Metadata**	-	Access Rights	Refers to the lab's access permissions	YES
7			Rights Holder	Refers to those entities that hold the lab's	No

[9] http://rcl-munich.informatik.unibw-muenchen.de
[10] http://skoool.com
[11] http://ilabcentral.org
[12] http://www.lab2go.net
[13] https://www.weblab.deusto.es/weblab/client/#page=home

				copyrights	
8			Lifecycle Date	Refers to critical dates related to the lab's lifecycle	No
9			Contact Details	Provides information about contact details of the person or the organization responsible for the lab	No
10			Cost	Refers to any payment required for using the lab	YES
11			Licence	Provides information about copyrights and restrictions applied to the use of the lab.	YES
12			Provider	Provides information about the provider of the lab.	No
13			Contributor	Refers to each person (or entity) that has contributed in the making of the lab in its current state	No
14			Version	Provides information about the current version of the lab	No
15			Status	Provides information about the availability status of the lab	YES
16		**Learning Design Pedagogical Context Metadata**	Teaching Approach	Refers to the teaching approach where the lab can be used	No
17			Subject Domain	Refers to the lab's subject domain	YES
18	**Pedagogical Metadata**		Grade Level	Refers to the grade level for which the lab can be used	YES
19			Educational Objectives	Refers to the educational objectives that the lab addresses	No
20			Level of Difficulty	Refers to the level of difficulty of the lab	YES
21		-	Intended End User Role	Refers to the principal users for whom the lab was designed	YES
22			Location URL	Provides a URL for accessing the lab	No
23	**Technical Metadata**	-	Technical Requirements	Refers to the technical requirements that are needed for using the lab.	YES
24			Technical Format	Refers to lab's technical format.	YES
25			Student's Resource	Refers to the type and the URL of student's resource that is connected to the lab	No
26	**Content Metadata**	-	Teacher's Resource	Provides the URL for accessing any lesson plan that can be used for exploiting the lab.	No
27			Supportive App	Provides the URL for accessing any supportive app that is connected to the lab.	No

3.2 Main Functionalities

The ASK4Labs Repository targets the following user groups:

- **RVLs owners,** who want to characterize their RVLs with metadata and store them to the ASK4Labs repository, so as to increase their visibility and share them with science teachers for further usage into their day-to-day teaching activities.
- **Science teachers,** who want to search and find RVLs for using them into their lesson plans

The main functionalities of ASK4Labs Repository can be summarized as follows:

Store RVLs: RVLs owners are able to store in the ASK4Labs repository their RVLs along with metadata descriptions following the metadata model described in section 3.1. Figure 1 presents the process of storing a RVL to the repository by completing the appropriate metadata fields.

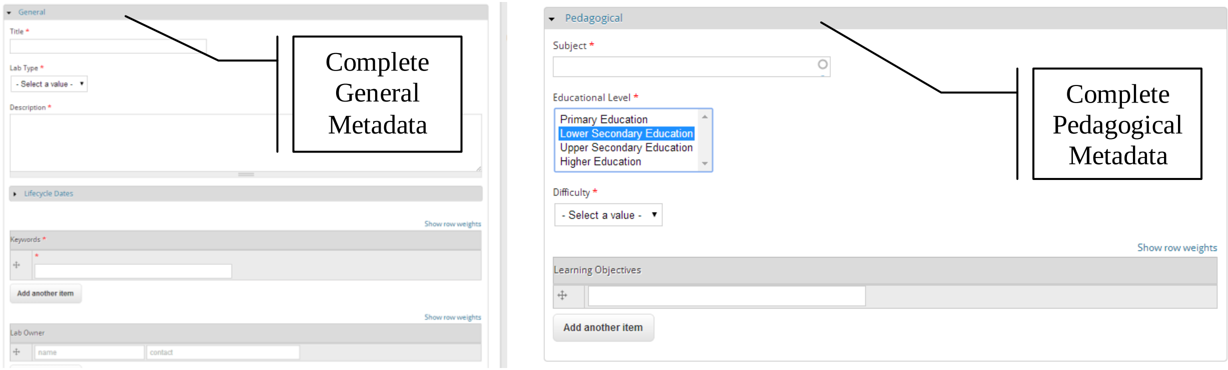

Figure 1. Store a RVL to the ASK4Labs Repository by characterizing it with metadata

Search for RVLs: Science teachers are able to search, browse and retrieve RVLs by using terms, which are matched with metadata descriptions of RVLs. Moreover, the searching mechanism incorporates a recommender system (it will be further described in section 3.3), which enables science teacher to receive recommendations about RVLs based on the pedagogical context elements of their lesson plans. Figure 2 presents the process of searching RVLs in the ASK4Labs repository.

View RVLs' Metadata: Science teachers have the capability to view in details the metadata descriptions of RVLs, so as to be able to decide whether to use or not a specific RVL. Figure 3 presents the educational metadata of a selected RVL.

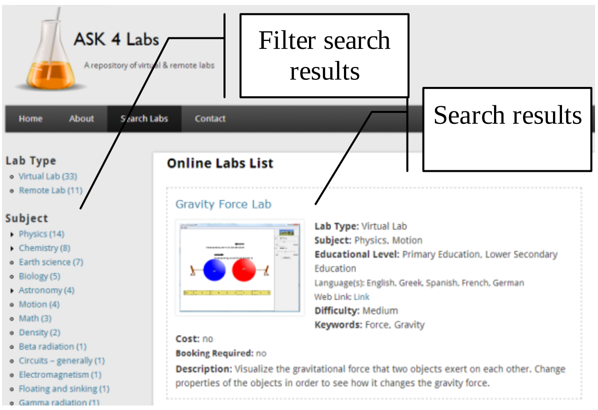

Figure 2. Search RVLs

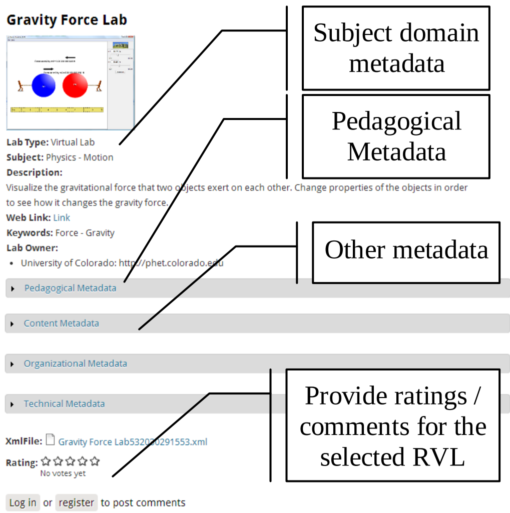

Figure 3. View RVL Metadata and Provide Ratings / Comments

Rate/Comment RVLs: Science teachers are able to provide their ratings and comments for the RVLs stored in ASK4Labs Repository. These ratings and comments can be related to the impressions of the science teachers who have used a specific RVL. Figure 3 presents the process of providing ratings/comments to a selected RVL.

3.3 Recommender System

The recommender system that has been incorporated in the ASK4Labs repository is a content-based recommender system that uses Vector Space Model (VSM) with basic TF-IDF (Term Frequency–Inverse Document Frequency) weighting (Lops et al. 2011). The recommender system aims to provide an ordered list of RVLs based on the learning design pedagogical context elements that are used during search by the science teachers.

More specifically, the pedagogical context of a learning design can be modelled as follows: $Learning\_Design_i = \{LD_1, LD_2, LD_3, LD_4\}$ where LD_i represents the elements of the pedagogical context of a learning design. Additionally, for each element a different weighting factor can be applied namely $Weight_j = \{w_1, w_2, w_3, w_4\}$ corresponding to each learning design vector space model elements. Different instantiations of the weight vector space model can be defined manually by each science teacher.

On the other hand, a RVL can be modelled based on the different metadata elements already described in section 3.1, as follows: $Metadata_y = \{MD_1, MD_2, \ldots, MD_{27}\}$, where MD_i corresponds to each of the RVL metadata elements. However, not all metadata elements can be exploited in the context of the specific recommender system because not all of them can be mapped to the learning design vector space model elements. Thus, we performed a mapping between the learning design vector space model elements and the RVL metadata vector space model elements. Additionally, for the purpose of our research, we assigned percentages of relevancy for each metadata element that was mapped to the learning design pedagogical context elements. Table 3 presents this mapping and the assigned percentages of relevancy.

Table 3. Learning Design Pedagogical Context Elements mapped to RVL Metadata

Learning Design Pedagogical Context Elements	**Percentage of Relevancy**	**RVL Metadata**
Subject Domain	60%	Subject Domain
	20%	Keyword
	10%	Title
	10%	Description
Educational Objectives	70%	Learning Objectives
	20%	Keyword
	10%	Description
Grade Level	80%	Grade Level
	20%	Description
Teaching Approach	70%	Teaching Approach
	30%	Description

Based on the mapping presented in Table 3, the RVL metadata vector space model can be limited to 7 distinctive elements as follows: $Metadata_y = \{MD_1, MD_2, \ldots, MD_7\}$ where MD_1=title, MD_2=description, MD_3=keyword, MD_4=subject domain, MD_5=Educational Objectives, MD_6=grade level and MD_7=teaching approach.

According to the above modelling, next we present the process of generating the RVL recommendations in pseudo-code. As we can notice, the recommender system calculates an overall score for each RVL based on the query terms provided by the science teacher. It should be noted that we consider four query terms, each related to a separate Learning Design Vector Space Model element. Based on the calculated score, the RVLs are ranked from the most relevant to least relevant.

```
For each query_term in LD_i field {
       If (LD_i = teaching approach) then {
                     If query_term found in MD_7
                            Score+= w_j* tf-idf (query_term, MD_4, #RVLs) * 0,7
                     If query_term found in MD_2
                            Score+= w_j* tf-idf (query_term, MD_3, #RVLs) * 0,3
              }
       If (LD_i = grade level) then {
                     If query_term found in MD_6
                            Score+= w_j* tf-idf (query_term, MD_4, #RVLs) * 0.8
                     If query_term found in MD_2
                            Score+= w_j* tf-idf (query_term, MD_3, #RVLs) * 0.2
              }
...
}
```

4. PRELIMINARY EVALUATION

4.1 Method

An experiment was performed towards the initial evaluation of the proposed recommender system. More specifically, the focus of the experiment was to evaluate the ranking accuracy of the recommender system utilizing the spearman's rank correlation coefficient (Shani & Gunawardana, 2011). The evaluation methodology that was conducted included the following steps:

Step 1: two queries were created representing two different pedagogical contexts for a learning design, as follows: $Learning\_Design_1$ = {subject domain = "chemistry", educational objectives = "learn to carry out tests with chemical solutions", grade level = "lower secondary education", teaching approach = "inquiry based learning"}, $Learning\_Design_2$ = {subject domain = "physics", educational objectives = "learn about forces and balance", grade level = "primary education", teaching approach = "problem based learning"}. Additionally, three instances of the weight vector space model were created, namely $Weight_1$ = {0.5, 0.2, 0.2, 0.1} (emphasis given to the subject domain), $Weight_2$ = {0.2, 0.2, 0.5, 0.1} (emphasis given to the grade level), $Weight_3$ = {0.2, 0.5, 0.1, 0.2} (emphasis given to the educational objectives). For both queries, each instance of the weight vector space model was applied and run at the ASK4Labs repository. Finally, the recommender system provided us with six ranked lists of RVLs.

Step 2: we asked 30 secondary education science school teachers to validate the ranked lists produced from the recommender system. Each of the teachers was given the option to agree with the ranking or to propose his/her own ranked list.

Step 3: Finally, we calculated the spearman's rank correlation coefficient between the ranked lists produced by the recommender system and the ones provided by the science teachers.

4.2 Results

The preliminary evaluation results for ranking accuracy of the recommender system are presented in Figure 4.

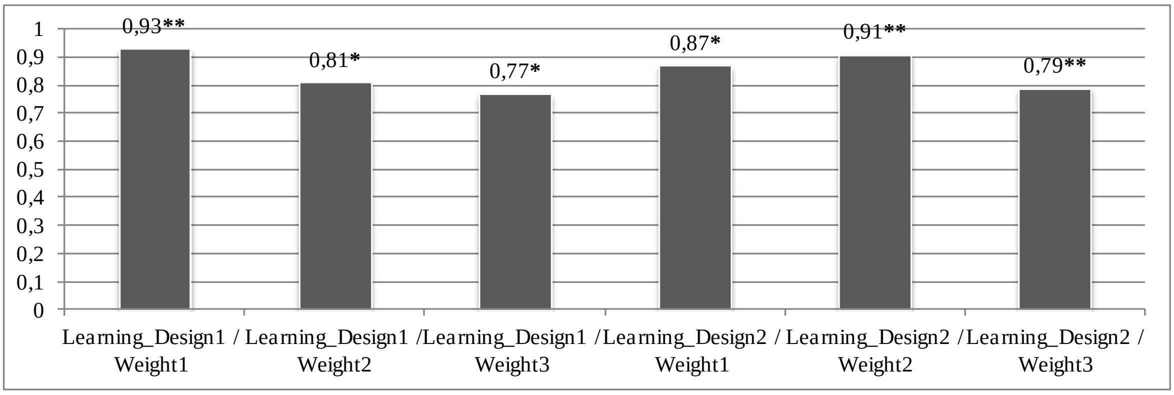

Figure 4. Spearman's Rank Correlation Coefficient per Ranked List (*= p<0,05, **=p<0,01)

As we can notice from Figure 4, the spearman's rank correlation coefficient was very high for all ranked lists produced by the recommender system. This provided us with evidence about the validity of our proposed mapping between leaning design elements and the RVL metadata elements, as well as about the usefulness of the percentages of relevancy for this mapping, as presented in Table 3.

Furthermore, it is worth to notice that the ranking accuracy of the recommender system achieved the highest values for queries, where the emphasis to the weighting factors was given to those learning design pedagogical context elements that are mapped to RVL metadata modelled with taxonomies (see Table 2) compared to those modelled as free text elements. This can be explained by the fact that when metadata values are added as free text, polysemy and synonymy could be increased and the error margin of the recommender system could be also increased.

5. CONCLUSIONS AND FUTURE WORK

In this paper, it was argued that there is a growing trend for the development of web-based repositories that provide access to RVLs. However, existing RVLs repositories are adopting different metadata models for characterizing their RVLs and these metadata models store limited information related to the core elements of lesson planning. Therefore, we presented the ASK4Labs, a web-based repository for supporting learning design driven RVLs recommendations. A preliminary evaluation was also performed, which focused on the ranking accuracy of the proposed recommender system. The results showed a high level of ranking accuracy especially when the weighting factors were assigned with emphasis given to learning design pedagogical context elements mapped to RVL metadata elements modeled with taxonomies.

Future work includes additional evaluations of the ranking accuracy of the proposed recommender system with more users and with more search queries including different combinations of the weighting factors. Moreover, the recommender system could be enhanced by taking into account ratings of the users towards providing more accurate rankings of RVLs.

ACKNOWLEDGMENTS

The work presented in this paper has been partially funded by the European Commission in the context of the Go-Lab project (Grant Agreement no. 317601) under the Information and Communication Technologies (ICT) theme of the 7th Framework Programme for R&D (FP7. This document does not represent the opinion of the European Commission, and the European Commission is not responsible for any use that might be made of its content.

REFERENCES

Balamuralithara, B, and Woods, PC, 2009. Virtual laboratories in engineering education: The simulation lab and remote lab. *Computer Applications in Engineering Education,* Vol.17, No. 1, pp. 108-118.

de Jong, T, et. al., 2013. Physical and virtual laboratories in science and engineering education. *Science,* Vol. 340, No. 6130, pp. 305-308.

de Jong, T, 2010, 'Technology supports for acquiring inquiry skills', in B. McGaw, et. al. (eds.), *International encyclopedia of education*, Oxford, Elsevier.

Conole, G and Fill, K, 2005. A learning design toolkit to create pedagogically effective learning activities. *Journal of Interactive Media in Education, Special Issue Portable Learning,* Vol. 2005 No. 08.

Gomes, L, and García-Zubia, J (eds.) 2007, *Advances on remote laboratories and e-learning experiences,* University of Deusto, *viewed July 21, 2014,* https://www.weblab.deusto.es/Advances_on_remote_labs.pdf.

Gravier, Cet. al, 2008. State of the Art About Remote Laboratories Paradigms - Foundations of Ongoing Mutations. *International Journal of Online Engineering,* Vol. 4, No. 1.

Jaakkola, T, et. al, 2011. A comparison of students' conceptual understanding of electric circuits in simulation only and simulation-laboratory contexts. *Journal of Research in Science Teaching,* Vol. 48, No. 1, pp. 71-93.

Kong, SC, et. al, 2009. An experience of teaching for learning by observation: Remote-controlled experiments on electrical circuits. *Computers & Education,* Vol. 52, No. 3, pp. 702-717.

Lops, P, et. Al, 2011. 'Content-based recommender systems: State of the art and trends', In *Recommender systems handbook,* Springer, US.

Maier, C, and Niederstätter, M, 2010. Lab2go – A Repository to Locate Online Laboratories. *International Journal of Online Engineering (iJOE),* Vol. 6, No. 1, pp. 12-17.

Richter, T. et. al, 2011, 'LiLa: A European project on networked experiments', in S. Jeschke, et. al, (eds.), *Automation, Communication and Cybernetics in Science and Engineering,* Heidelberg, Germany, Springer.

Shani, G, and Gunawardana, A, 2011, 'Evaluating recommendation systems', in *Recommender systems handbook*, Springer, US.

Zervas P, et. al, 2014, 'A Method for Organizing Open Access to Virtual and Remote Labs', in D. Sampson, et. Al, (eds.), *Digital Systems for Open Access to Formal and Informal Learning,* Springer, US.