TOWARDS A METADATA SCHEMA FOR CHARACTERIZING LESSON PLANS SUPPORTED BY VIRTUAL AND REMOTE LABS IN SCHOOL SCIENCE EDUCATION

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ABSTRACT

Technological advancements in the field of World Wide Web have led to a plethora of remote and virtual labs (RVLs) that are currently available online and they are offered with or without cost. However, using a RVL to teach a specific science subject might not be a straightforward task for a science teacher. As a result, science teachers need to be able to find existing lesson plans supported by RVLs (designed by other science teachers), so as to (a) be informed on how specific RVLs can be used in the context of a science education lesson and (b) be inspired and possibly adapt existing lesson plans supported by RVLs to cover their specific teaching needs. The most common way to facilitate this process using web technologies is to (a) characterize lesson plans with appropriately selected educational metadata and (b) to build a web repository that collects the metadata descriptions of lesson plans following a common metadata schema and offers search and retrieval facilities. Within this context, the scope of this paper is twofold: (a) to propose a metadata schema that can be used for characterizing school science education lesson plans supported by RVLs and (b) to validate this metadata schema with 82 European school science teachers that was performed in the framework of a major European Initiative namely, the Go-Lab project, so as to identify which metadata elements are considered important when science teachers are searching in web-based repositories.

KEYWORDS

School education, science education, inquiry-based learning, remote lab, virtual lab, web-based repository, metadata schema, lesson plan, validation study

1. INTRODUCTION

Remote and Virtual Labs (RVLs) constitute significant educational tools for supporting science teachers in their daily teaching practice, especially when adopting the inquiry-based teaching model (de Jong et al., 2013). In particular, remote labs provide teachers with the opportunity to engage their students in the process of data collection data from a real physical laboratory, including real equipment from remote locations (Gomes & Bogosyan, 2009), whereas virtual labs constitute interactive environments for designing and conducting simulated experiments (Balamuralithara, & Woods, 2009). However, using a RVL to teach a specific science subject might not be a straightforward task for a science teacher, especially a novice one (Govaerts et al., 2013). As a result, science teachers could benefit from having access to existing lesson plans supported by RVLs (developed by other science teachers), so as to (a) be informed on how specific RVLs can be used in the context of a science inquiry-based education lesson and (b) be inspired and possibly adapt existing lesson plans supported by RVLs to cover their specific teaching needs. A lesson plan describes how a lesson should take place, which planned activities will be executed by students (individually or at groups) and teachers/tutors, the order in which the activities are planned to be executed, the required contextual conditions within which the activities will be executed, how learners will be grouped (if appropriate) and which educational resources and/or tools will be used for each activity (Van Es & Koper, 2005).

A key problem then emerges on how to support school science teachers to select and find lesson plans supported by RVLs in an efficient (that is, easily via simple web-based searches) and effective (that is, according to their teaching needs and conditions) way. The most common way to address this need by using web technologies is to:

- Characterize lesson plans with appropriately selected educational metadata (Dagienė & Kubilinskienė, 2010; Battigelli & Sugliano, 2009)
- Build a web application that facilitate lesson plans' search and retrieval according to a specific user (that is, science teacher) defined requests, i.e. searching with specific elements of lessons plans such as subject domain, educational objectives or age range addressed. Such applications are typically build in the form of a web repository that collects the metadata descriptions of lesson plans following a common metadata schema and offers search and retrieval facilities (Dong et al., 2009)

Within this context, the scope of this paper is twofold: (a) to propose a metadata schema that can be used for characterizing lesson plans supported by RVLs and (b) to validate this metadata schema with 82 European school science teachers that was performed in the framework of a major European Initiative namely, the Go-Lab project[1], so as to identify which metadata elements are considered important when science teachers are searching for lesson plans supported by RVLs in web-based repositories.

The remainder of the paper is structured as follows. Following this introduction, section 2 reviews existing repositories of school education science lesson plans supported by RVLs and performs an analysis of the metadata elements used by these repositories towards identifying common metadata elements. Section 3 presents the proposed metadata schema for characterizing RVL-supported school science education lesson plans, which consists of the synthesis of the metadata elements identified in section 2. Section 4, presents the methodology that was followed for validating the proposed metadata schema. Section 5 presents and discusses the validation results. Finally, we discuss our main conclusions and our future work in this agenda

2. REVIEW OF REPOSITORIES OF LESSON PLANS SUPPORTED BY RVLS

The aim of this section is to review existing repositories of school science education lesson plans supported by RVLs and identify common metadata elements used for characterizing these lesson plans. A set of ten (10) repositories is reviewed. These repositories have been selected because their purpose is twofold: (a) they store and provide searching facilities for RVLs and (b) they store and provide searching facilities for lesson plans supported by these RVLs. As a result, we consider them as the most appropriate for review towards defining our proposed metadata schema. Table 1 presents the existing repositories that were reviewed, the number of lesson plans that they store (at the time of our study), as well as the number of metadata elements used by each repository for characterizing its lesson plans.

Table 1. Overview of Existing Repositories of Lesson Plans supported by RVLs

No	Name	Repository URL	# Lesson Plans[2]	# Metadata Elements used
1	PhET	http://phet.colorado.edu	552	13
2	Labshare	http://www.labshare.edu.au/	12	13
3	Explore Learning	http://www.explorelearning.com	478	13
4	Open Sources Physics	http://www.compadre.org/osp	355	12
5	Lab2Go	http://www.lab2go.net	**N/A**	11
6	ChemCollective	http://www.chemcollective.org/	55	10
7	Intel Education Resources - STEM	http://inteleducationresources.intel.co.uk/index.aspx	264	10
8	iLabCentral	http://ilabcentral.org	21	10
9	Molecular Workbench	http://mw.concord.org/	75	3
10	Remotely Controlled Laboratories (RCL)	http://rcl-munich.informatik.unibw-muenchen.de	17	3

[1] http://www.go-lab-project.eu/

[2] Data retrieved on 22/5/2015

As Table 1 depicts, the number of metadata elements used by the different repositories to characterize the RVL-supported school science education lesson plans that they store, varies from a small number of elements (namely, 3 elements) to a larger number of elements (namely, 13 elements). This is due to the fact that each repository uses its own customized metadata schema for characterizing the RVL-supported school science education lesson plans that it stores without following a specific metadata standard (such as IEEE LOM (IEEE LTSC, 2005)). As a result, some of the metadata schemas adopted by the examined repositories are richer than others. Moreover, in some cases a metadata element used by the metadata schema adopted by one repository might not be used by others. To this end, in order to come up with an initial proposal about a metadata schema of lesson plans supported by RVLs, we harmonized the lesson plan's metadata elements used by the repositories presented in Table 1 and we produced a master list (comprising a synthesis of the different metadata elements used by the examined repositories), which is presented in the next section.

3. PROPOSED METADATA SCHEMA OF LESSON PLANS SUPPORTED BY RVLS

As already mentioned, the starting point for developing our proposed initial metadata schema was the outcomes of the study of the metadata schemas of existing repositories of RVL-supported science education lesson plans presented in section 2. Table 2 presents our proposed initial metadata schema which consists of the synthesis of metadata elements identified from the review presented in section 2. Moreover, Table 2 presents for each metadata element the frequency of use at the repositories that were reviewed in section 2.

Table 2. Proposed Metadata Schema of Lesson Plans supported by RVLs

No	Element Name	Description	Taxonomy Available?	Usage Frequency
1	Title	This metadata element refers to the title of the lesson plan	No	10 (100%)
2	URL	This metadata element provides a URL for accessing the lesson plan	No	10 (100%)
3	Description	This metadata element provides a textual description of the lesson plan	No	8 (80%)
4	Subject Domain	This metadata element refers to the lesson plan's subject domain	Yes	8 (80%)
5	Lab(s) Used	This metadata element denotes the online labs used in the lesson plan	Yes	8 (80%)
6	Owner(s) and Contributor(s)	This metadata element provides information about the owner, as well as entities that have contributed to the authoring of the lesson plan	No	8 (80%)
7	Additional Materials included	This metadata element describes additional supportive material that can facilitate teachers to deliver the lesson (based on the lesson plan) and students to execute the lesson	No	8 (80%)
8	Language(s)	This metadata element refers to the languages that the lesson plan is available in.	Yes	7 (70%)
9	Age Range	This metadata element refers to the age range for which the lesson plan can be used.	Yes	7 (70%)
10	Keyword(s)	This metadata element refers to a set of terms that characterize the content of the lesson plan	No	5 (50%)
11	Status	This metadata element provides information about the current status of the lesson plan.	Yes	4 (40%)
12	Educational Objectives	This metadata element refers to the educational objectives that the lesson plan addresses	Yes	3 (30%)
13	Organizational Requirements	This metadata element refers to the requirements that are needed in order to carry out the lesson plan without troubleshooting.	No	3 (30%)
14	Level of Difficulty	This metadata element refers to the level of difficulty of the lesson plan.	Yes	2 (20%)
15	Average Learning Time	This metadata element refers to the amount of time that the lesson plan requires in order to be completed	Yes	2 (20%)
16	Group Learning Method used	This metadata element indicates whether the lesson plan follows a specific group learning method (such as jigsaw, changing hats etc)	Yes	2 (20%)
18	Access Rights	This metadata element refers to the lesson plan's access permissions	Yes	1 (10%)
18	Level of Interaction	This metadata element refers to the level of interaction the lesson plan offers in terms of (a) variables manipulation during experimentation and (b) interaction and collaboration with peers	Yes	1 (10%)
19	Students' prior Knowledge	This metadata element refers to students' prior knowledge in order to execute the lesson	Yes	1 (10%)

As we can notice from Table 2, our proposed initial metadata schema includes 19 metadata elements. 10 out of 19 metadata elements are used in more than fifty percent (50%) of the repositories that were reviewed in section 2, whereas 9 out of 19 metadata elements are used in less than fifty percent (50%) of the reviewed repositories. The proposed metadata schema has been used for storing and classifying lesson plans in a web-based repository, namely the Go-Lab Repository (http://www.golabz.eu/) developed in the framework of the Go-Lab Project and presented in (Dikke et al., 2014). The Go-Lab project (http://www.go-lab-project.eu/) aims to establish an online portal, namely the Go-Lab Portal that will facilitate the federation of existing virtual and remote labs (de Jong et al., 2014; Govaerts et al., 2013). In the context of the Go-Lab project, a lesson plan comprises (a) a set of technology-supported activities structured in inquiry phases that follow parts of the full inquiry-based teaching model and they are executed individually by the students with the support of the Go-Lab Portal and the RVLs that includes (this set of activities is referred to as an inquiry learning space-ILS) and (b) a set of supplemental activities to the aforementioned technology-supported activities, which are not supported by technology and they are executed by the teacher or the students (individually or at groups) (de Jong et al., 2014). The Go-Lab Repository is part of the Go-Lab portal, it has been populated with 137[3] RVL-supported science education lesson plans, and provides functionalities for facilitating search and retrieval of these lesson plans by school science teachers.

4. VALIDATING THE PROPOSED METADATA SCHEMA OF LESSON PLANS SUPPORTED BY RVLS

4.1 Related Studies

In order to develop our methodology for validating our proposed metadata schema, we reviewed existing works on validating metadata schemas with real users Since there are not related works that focus on validating metadata schemas for lesson plans supported by RVLs, the review is performed on related works for validating metadata schemas for educational resources in general. Table 3, presents briefly these studies along with their basic parameters.

Table 3. Studies on Validating Metadata Schemas of Educational Resources

Study	Application Domain	Validation Instrument	Users
Palavitsinis et al. (2009)	Agriculture and Agroecology	Questionnaire	Subject Domain Experts
Krull et al. (2006)	Interdisciplinary	Questionnaire	Teachers/Trainers
Howarth (2003)	Interdisciplinary	Questionnaire	Subject Domain Experts and Teachers/Trainers
Carey et al. (2002)	Interdisciplinary	Questionnaire & Interview	Subject Domain Experts

As we can notice from Table 3, commonly used validation instruments are questionnaires through which end-users (teachers/trainers or subject domain experts) are asked to validate one by one the various metadata elements of the proposed metadata schema. As a result, a similar methodology has been followed in our case and it is described in details in the next section.

4.2 Study Methodology

4.2.1 Sample

The study was conducted with N=82 European School science teachers who were invited to be part of the Go-Lab Project pilot activities. Our sample included school science teachers from thirteen (13) European member states. Moreover, in our sample there was a gender balance between the participants (52% female, 48% male). The majority of the participants were experienced science teachers (69% of the participants had more than 6 years of teaching experience). Furthermore, almost all science education school teachers in our

[3] Data retrieved on 13/7/2015

sample were experienced in using ICT for their daily teaching activities and the majority of them had previous experience in working with RVLs (66% using virtual labs and 23% using remote labs). Finally, 61% of them have at least a master's degree. Thus, overall we consider that our sample is well selected for the purpose of our study.

4.2.2 Procedure

In order to validate the proposed metadata schema, we provided to the participated science teachers a questionnaire. The aim of the questionnaire was to collect participants' opinions on the importance of certain metadata elements from our proposed metadata schema. More precisely, the teachers were asked to rate each metadata element with a five-point like scale, where 1 denotes "low importance" and 5 denotes "high importance" for the following there different contexts of use: (a) importance of metadata elements within the context of "*making a general search for lesson plans*" in the Go-Lab repository, (b) importance of metadata elements within the context of "*filtering search results for lesson plans*" in the Go-Lab repository and (c) importance of metadata elements within the context of "*viewing the preview page of a Go-Lab lesson plan*" in the Go-Lab repository

It should be noted that out of the 19 elements that are part of the metadata model, 17 were included in the questionnaire. Elements such as "Location URL" and "Description" were not included in the questionnaire, because we consider them essential for our proposed metadata model and thus no further investigation was needed on validating their importance. In order to receive feedback from the participants based on the questionnaire that was designed, appropriate workshops were organized that had the following structure:

- **During the workshops:** all participants attended a demonstration of the Go-Lab repository. More specifically, the main functionalities of the repository, as well as the search and retrieval facilities were presented, along with the lesson plans that were stored in the repository. Moreover, all participants could navigate within the Go-Lab repository during the workshop, through their personal devices (laptops or tablets) and use it themselves directly. Thus, they had a concrete idea of how lesson plan's metadata elements have been deployed within the Go-Lab repository.
- **After the workshops:** all participants were asked to rate the lesson plan's metadata elements by completing the designed questionnaire.

5. RESULTS

This section presents quantitative data analysis results for participants' feedback regarding the importance of lesson plan's metadata elements (see Table 4) for the different contexts of use (as described in section 4.2.1).

Table 4. Ranking of the Importance of Metadata Elements

Ranking	Making a General Search			Filtering Search Results			Viewing the Preview Page		
	Metadata Element	Mean	SD	Metadata Element	Mean	SD	Metadata Element	Mean	SD
1	Title	4,39	0,84	Title	4,40	0,68	Lab(s) used	4,45	0,69
2	Subject Domain	4,28	0,91	Keyword(s)	4,38	0,75	Title	4,39	0,86
3	Keyword(s)	4,18	1,06	Language(s)	4,30	0,87	Subject Domain	4,22	0,95
4	Lab(s) used	4,17	0,91	Lab(s) used	4,29	0,79	Language(s)	4,20	0,99
5	Language(s)	4,17	0,83	Subject Domain	4,21	0,77	Keyword(s)	4,16	0,90
6	Age Range	4,15	0,93	Age Range	4,12	0,75	Organizational Requirements	4,09	1,05
7	Educational objectives	3,87	1,05	Organizational Requirements	3,98	0,97	Age Range	4,07	1,00
8	Students' prior knowledge	3,76	1,00	Average learning time	3,96	1,02	Educational objectives	4,01	1,00
9	Average learning time	3,70	1,01	Students' prior knowledge	3,92	1,03	Status	4,01	1,20

10	Organizational Requirements	3,70	0,98	Additional materials included	3,90	1,03	Additional materials	4,00	1,04
11	Status	3,65	1,17	Educational objectives	3,89	0,89	Students' prior knowledge	3,94	1,11
12	Collaborative learning method used	3,63	1,11	Status	3,89	1,14	Average learning time	3,93	1,13
13	Additional materials	3,63	1,04	Level of interaction	3,86	0,97	Level of interaction	3,88	1,07
14	Level of interaction	3,58	0,99	Level of difficulty	3,86	1,05	Collaborative learning method used	3,84	1,12
15	Level of difficulty	3,57	0,99	Collaborative learning method used	3,68	0,95	Level of difficulty	3,77	1,16
16	Access rights	3,43	1,17	Access rights	3,43	1,17	Access rights	3,65	1,27
17	Owner and Contributor(s)	3,10	1,24	Owner and Contributor(s)	3,23	1,24	Owner and Contributor(s)	3,31	1,37

It is worth noticing that no elements received very low score, in fact, the lowest score in average was 3.10 - corresponding to element "Owner and Contributor(s)" (for the context of use related to general search for lesson plans in the Go-Lab repository), which is still on the positive side of the likert scale. Thus, an overall indication could be that none of the metadata elements can be regarded as non-important and our proposed metadata schema can be considered as valid and useful for the science teachers participated in our study. Nevertheless, besides this general indication, it is worth further analyzing the ranking of the metadata elements based on their average score for each context of use. More specifically, as we can notice from Table 4, there are some elements which are highly ranked across all three contexts of use. These elements are (as presented in Table 5): (a) "Title" (1-2-1: ranked 1st for the context of use related to making a general search for lesson plans in the Go-Lab Repository, 1st for the context of use that was related to filtering search results of lesson plans in the Go-Lab Repository and 2nd for the context of use that was related to viewing the preview page of a lesson plan in the Go-Lab Repository), (b) "Lab(s) used" (4-4-1), (c) "Subject Domain" (2-5-3), (d) "Keywords" (3-2-5), (e) "Language(s)" (5-3-4) and (f) "Age Range" (6-6-7).

Table 5. Highly Ranked Lesson Plan Metadata Elements across all three Contexts of Use

No	Metadata Element	General Search (Average Value - Rank)	Filtering (Average Value - Rank)	Preview Page (Average Value - Rank)
1	Title	4,39 (1)	4,40 (1)	4,39 (2)
2	Labs used	4,17 (4)	4,29 (4)	4,45 (1)
3	Subject Domain	4,28 (2)	4,21 (5)	4,22 (3)
4	Keyword(s)	4,18 (3)	4,38 (2)	4,16 (5)
5	Language(s)	4,17 (5)	4,30 (3)	4,20 (4)
6	Age Range	4,15 (6)	4,12 (6)	4,07 (7)

Based on these results presented in Table 5, we can identify that:

- Science teachers are interested in searching lesson plans using the title and the languages used in the lesson plans. This was an expected finding since these elements are very general and they are very important in any type of search performed on web based repositories of educational resources as highlighted by other studies (Tsourlidaki et al., 2015; Palavitsinis et al. 2009; Krull et al. 2006)
- Science teachers are interested in searching lesson plans that are developed around specific online labs that they are probably competent in using.
- Science teachers are interested in searching lesson plans with metadata elements that are mapped to the science curriculum. These elements are 3 out of the 6 most highly ranked elements (namely, subject domain, keywords and age range).

On the other hand, the elements that were ranked low across all three contexts were the following (as presented in Table 6): (a) "Lesson Plan Owner and Contributors" (18-18-18), (b) "Lesson Plan Access Rights" (17-17-17), (c) "Level of Difficulty" (16-14-16) and (d) "Level of Interaction" (15-13-13).

Table 6. Lowest Ranked Lesson Plan Metadata Elements across all three Contexts of Use

No	Metadata Element	General Search (Average Value - Rank)	Filtering (Average Value - Rank)	Preview Page (Average Value - Rank)
1	Owner and Contributor(s)	3,10 (18)	3,23 (18)	3,31 (18)
2	Access Rights	3,43 (17)	3,43 (17)	3,65 (17)
3	Level of Difficulty	3,57 (16)	3,86 (14)	3,77 (16)
4	Level of Interaction	3,58 (15)	3,86 (13)	3,88 (13)

Nevertheless, the average scores (as presented in Table 6) of these metadata did not call for an automatic elimination from the list of metadata elements of our proposed metadata schema. Moreover, we can identify that it makes sense that "Lesson Plan Owner and Contributors" and "Lesson Plan Access Rights" metadata elements are at the bottom of the ranking list since they do not offer rich information in order to facilitate the selection of a certain Lesson Plan, but they are essential in order to give credits to the owner of the offered Lesson Plan and to clarify the access rights in order to avoid legal issues.

6. CONCLUSIONS AND FUTURE WORK

Building on an identified need of science teachers to be able to find and select lesson plans supported by RVLs, in an efficient and effective way, the main contribution of the paper is the proposal for a metadata schema that can be used for characterizing lesson plans supported by RVLs. Moreover, the validation of this metadata schema with 82 European school science teachers demonstrated (a) the added value of the proposed metadata schema and (b) important elements are those that describe the RVLs utilized by a lesson plan, as well as those metadata elements that provide a concrete mapping to the science curriculum (namely, subject domain, keywords and age range).

Future work will focus on two main strands. First, we aim to collect teachers' search logs through the Go-Lab repository and analyze them for validating further the significance of the metadata elements of our proposed metadata schema. Secondly, we aim to combine the proposed metadata schema for lesson plans supported by RVLs with our previous work on describing RVLs with appropriate metadata (Zervas et al., 2014) towards developing decision support systems that will facilitate science teachers to select appropriate RVLs during the lesson planning process. An initial work towards this direction was reported in Zervas et al. (2015) and it could be significantly enhanced by incorporating the results of this study.

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