Chapter 15

A METHODOLOGY FOR ORGANIZING VIRTUAL AND REMOTE LABS

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Abstract: Virtual and remote labs provide access to state-of-the-art science experiments and are capable of providing students with innovative learning opportunities. Such environments can be highly effective in increasing students' interest in science and their engagement in relevant learning activities. In order to increase the findability of available virtual and remote labs, we propose their storage and organization into web-based repositories. To this end, this chapter aims: (a) to take stock of the current landscape of available repositories of virtual and remote labs and identify common metadata elements, (b) to propose a methodology for organizing virtual and remote labs by exploiting common metadata elements from existing repositories, and (c) to introduce the concept of big ideas of science for classifying virtual and remote labs based on fundamental ideas of the real world.

Keywords: Virtual labs, remote labs, lab metadata, lab repositories, open access, big ideas of science

1. INTRODUCTION

During the past years, traditional laboratories have been significantly benefited by the technological advancements in the field of World Wide Web (de Jong et al., 2013; Balamuralithara & Woods, 2009). This has enabled many educational institutions and scientific organizations to provide online access to state-of-the-art science experiments. This has been achieved via remote labs, which are based on actual experimental devices accessed remotely, as well as via virtual labs, which represent software simulations of science experiments (Gomes & Bogosyan, 2009; Gravier et al., 2008).

Virtual and remote labs have been proved to be 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). Additionally, the use of virtual and remote labs provides a significant number of benefits, which could be summarized below (Martinez et al., 2011; Gomes & García-Zubia, 2007):

- Provides access to science experiments without location and time restrictions;
- Supplements or even substitutes traditional laboratory assignments;
- Facilitates better scheduling and execution of laboratory activities;
- Offers significant return of investment in laboratory equipment due to laboratory devices sharing via remote labs;
- Facilitates research collaborations between individuals and educational institutions or scientific organizations world wide;
- Supports autonomous learning, since students can use them and conduct experiments outside the formal borders of classroom teaching;
- Supports students with disabilities to conduct experiments, when it is not possible for them to be present at the traditional laboratory.

Virtual and remote labs that are currently available, are promoted mainly by their owners and, thus, are scattered around the web. As a result, interested parties are facing difficulties in searching and retrieving them for further usage. A potential solution to this problem is the storage and organization of virtual and remote labs into web-based repositories (Li et al., 2007).

Within this context, a number of lab repositories have been recently developed aiming to provide interested parties with convenient access to existing remote and virtual labs (Richter et al., 2011; Maier & Niederstätter, 2010). However, existing lab repositories are adopting different metadata models for characterizing their virtual and remote labs. To this end, this chapter aims: (a) to take stock of the current landscape of available repositories of virtual and remote labs and identify common metadata elements, (b) to propose a methodology for organizing virtual and remote labs by exploiting common metadata elements from existing repositories, and (c) to introduce the concept of big ideas of science, as a complementary way of organizing virtual and remote labs based on fundamental ideas of the real world.

The book chapter is structured as follows. Following this introduction, section 2 reviews existing repositories of virtual and remote labs and performs a comparative analysis of the metadata elements used by these repositories towards identifying common metadata elements. Section 3 introduces the concept of the big ideas of science as a complementary way of organizing virtual and remote labs. Section 4 presents the proposed methodology for organizing virtual and remote labs in web-based repositories, which consists of the synthesis of common metadata elements identified in section 2 and the set of big ideas of science identified in section 3. Finally, we discuss our main conclusions and ideas for further work.

2. REVIEW OF EXISTING REPOSITORIES OF VIRTUAL AND REMOTE LABS

2.1 Description of Existing Repositories of Virtual and Remote Labs

The aim of this section is to provide an overview of existing repositories of virtual and remote labs. A set of thirteen (13) repositories of virtual and remote labs have been assembled throughout research in related publications and Internet sources. Each repository has been visited and thoroughly analyzed, according to the following dimensions:

- The types of labs included, namely virtual and/or remote labs, as well as the number of labs per category.
- The metadata elements used by each repository. These were classified in two categories: (a) lab owner metadata, which are added by the owners of a remote or virtual lab and (b) social metadata, which are added by the end-users of virtual and remote labs and could include social tags, ratings and comments.
- The types of additional resources and apps connected to a remote or virtual lab. More precisely, the additional resources and apps were classified in three categories: (a) student’s resources, which include resources that can be used by the students before, during or after the execution of an experiment with an online lab, (b) teacher’s resources, which include resources that can be used by the teacher to

design and develop learning activities supported by virtual and remote labs, and (c) supportive apps, which include apps that can support students during the execution of an experiment with a remote or virtual lab.

Table 1 provides an overview of the existing repositories of virtual and remote labs which were analyzed.

Table 1: Overview of Existing Repositories of Virtual and Remote Labs

No	Name	Lab Types		Number of Labs		Number of Lab Owner Metadata Elements	Social Metadata			Additional Resources and Apps		
		Virtual Labs	Remote Labs	Virtual Labs	Remote Labs		Tags	Ratings	Users' Comments	Students' Materials	Teachers' Materials	Supportive Apps
1	PhET[1]	√	-	125	-	10	No	No	No	No	Yes (Lesson Plan)	No
2	Library of Labs[2]	√	-	274	-	17	No	Yes (Like Ratings)	Yes	Yes (Student's Guide, Assignment Sheet)	Yes (Lesson Plan)	No
3	Labshare[3]	-	√	-	11	10	No	No	No	No	Yes (Lesson Plan)	No
4	Open Sources Physics[4]	√	-	100	-	13	No	Yes (1-5 Star Rating)	Yes	Yes (Student's Guide)	Yes (Lesson Plan)	No
5	Smart Science[5]	-	√	-	164	4	No	No	No	Yes (Glossary, Student's Guide, Tutorial)	Yes (Lesson Plan)	Yes
6	Molecular Workbench[6]	√	-	946	-	3	No	No	No	No	Yes (Lesson Plan)	Yes
7	Explore Learning[7]	√	-	450	-	6	No	No	No	Yes (Assignment Sheet, Glossary)	Yes (Lesson Plan)	No
8	ChemCollective[8]	√	-	40	-	8	No	No	No	Yes	Yes	No

[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

										(Assignment Sheet)	(Lesson Plan)	
9	Remotely Controlled Laboratories (RCL)[9]	-	√	-	17	4	No	No	No	Yes (Student's Guide)	Yes (Lesson Plan)	No
10	Skoool[10]	√	-	4.950	-	5	No	No	No	Yes (Assignment Sheet)	Yes (Lesson Plan)	No
11	iLabCentral[11]	-	√	-	21	7	No	No	No	Yes (Assignment Sheet)	Yes (Lesson Plan)	No
12	Lab2Go[12]	√	√	157	51	13	No	Yes (1-5 Star Rating)	No	Yes (Student's Guide)	No	No
13	WebLab Deusto[13]	-	√	-	15	3	No	No	No	Yes (Tutorial)	No	No
Total Number of Labs				**7.042**	**279**							

As we can notice from Table 1, the majority of the examined repositories include mainly virtual labs, whereas the number of remote labs included in these repositories is more limited. This is reasonable because remote labs are based on actual experimental devices, which might be very expensive and require high maintenance costs. On the other hand, virtual labs are computer programs, which can simulate a science experiment and they can be developed more easily. Finally, the total number of virtual and remote labs included in the examined repositories constitutes an adequate sample for our comparative analysis, which is presented in the next section.

2.2 Comparative Analysis and Outcomes

The aim of this section is to perform a comparative analysis of the metadata elements used by existing repositories of virtual and remote labs.

2.2.1 Lab Owner Metadata

As we can notice from Table 1, each repository is using a different number of metadata elements for describing their virtual and/or remote labs. As a result, we harmonized the lab owner metadata elements used by the

[8] http://www.chemcollective.org/
[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

examined repositories, so as to produce a master list of lab owner metadata elements, as well as to identify frequently used metadata elements. Figure 1 presents the frequencies of the lab owner metadata elements.

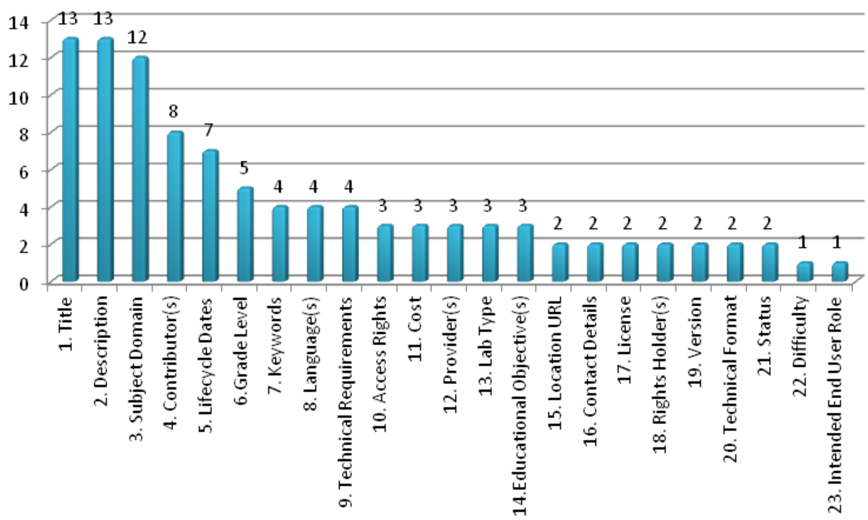

Figure 1: Frequency of Lab Owner Metadata Elements used by Existing Repositories Virtual and Remote Labs

As we can notice from Figure 1, a master list of 23 lab owner metadata elements has been assembled. The most frequently used lab owner metadata elements, considering that they are used in more than fifty percent (50%) of the examined repositories are the following:

- ***Title***: refers to the complete title of the lab *(13 occurrences).*
- ***Description***: provides a textual description of the lab *(13 occurrences).*
- ***Subject Domain***: refers to the lab's subject domain (.e.g., physics, chemistry, biology etc.) *(12 occurrences).*
- ***Contributor(s)***: refers to each person (or entity) that has contributed in the making of the lab in its current state *(8 occurrences).*
- ***Lifecycle Date(s)***: refers to critical dates related to the lab's lifecycle *(7 occurrences).*

Most of these elements store general information about the lab except from the "*subject domain*" element, which stores information about the scientific discipline where the lab can be used. This means that existing repositories rarely use metadata elements that store information about the educational use of virtual and remote labs. Such metadata elements, according to the master list presented in Figure 1, are the following:

- ***Grade Level*****:** refers to the grade level for which the lab can be used *(5 occurrences).*
- ***Educational Objective(s)*****:** refers to the educational objectives that the lab addresses *(3 occurrences).*
- ***Difficulty*****:** refers to the level of difficulty of the lab *(1 occurrence).*
- ***Intended End User Role*****:** refers to the principal users for whom the lab was designed *(1 occurrence).*

These elements can provide teachers with important information about the aforementioned educational aspects of the virtual and remote labs. However, they are not adequate to assist teachers in the process of designing meaningful learning activities using virtual and remote labs that will facilitate their students in understanding fundamental ideas of the real world.. In order to address this issue, we introduce the concept of big ideas of science, as a complementary way for characterizing virtual and remote labs. This is further discussed in section 3.

2.2.2 Social Metadata

As it is evident from Table 1, the majority of the examined repositories do not offer the opportunity to their end-users (namely, teachers and learners) to participate in the characterization of virtual and remote labs. More specifically, concerning social tags, none of the examined repositories provide a social tagging system. Moreover, we can notice limited usage of users' comments and ratings. These options are offered by only 3 (23%) of the examined repositories.

The overall absence of social tags and limited usage of users' comments and ratings to the examined repositories provide us with evidence that most of the repositories were developed on the basis of a sharp distinction between lab owners and end-users. While the former are the only responsible for the development and characterization of a virtual or remote lab, the latter are mostly assigned the role of a passive user. The limitation of this approach is that end-users are given limited opportunities to provide their feedback and experiences about the use of virtual and remote labs that are stored in these repositories, as well as end-users interactions are not facilitated and creation of users' communities is not supported.

As a result, it is important to consider social metadata options, namely social tags, ratings and user's comments when organizing virtual and remote labs, as they could significantly facilitate the empowerment of the end-users and their active participation and interaction with the these labs.

2.2.3 Additional Resources and Apps

As we can notice from Table 1, 10 (77%) of the examined repositories offer student's materials, which are linked with the virtual or remote labs provided by these repositories. These materials include: (a) student's guides, (b) assignment sheets, (c) glossaries and (d) tutorials. Moreover, 11 (85%) of the examined repositories offer teacher's materials, which are linked with the virtual or remote labs provided by these repositories. These materials mainly include lesson plans for exploiting virtual and remote labs in the context of learning activities to be conducted by their students. Finally, only 2 (15%) of the examined repositories offer supportive apps that aim to facilitate students during the process of using a virtual or remote labs. However, these apps are very important, since they can facilitate students to formulate hypothesis or interact with experimental data.

As a result, it is important to consider additional resources and apps when organizing virtual and remote labs, as they could significantly facilitate teachers when using virtual and remote labs for designing learning activities for their students, as well as students when using virtual and remote labs online in the context of these learning activities.

3. BIG IDEAS OF SCIENCE: A COMPLEMENTARY WAY FOR ORGANIZING VIRTUAL AND REMOTE LABS

3.1 Definition

In order to help young students in learning science, there are several aspects teachers should take into consideration. One of those aspects is the fact that students appear to miss the connection between what they are being taught at school and the world around them. It is often the case that although students learn about fundamental principles, they fail to understand the connection between them as well as their connection to our life and to the world. These gaps in students' cognition often appear due to the fact that certain ideas are too abstract and thus difficult for them to grasp. Additionally, the fact that students often engage in several activities which are isolated and do not follow a meaningful sequence, which would allow them to build on the experience acquired by previous activities, acts as one more drawback to helping students understand the fundamental principles of our world.

Consequently, in order to succeed in helping students understand such fundamental ideas, it is necessary to create concrete learning experiences that are close to their everyday life and that are interconnected and presented within a common context. This way, students have the opportunity to build on them and ultimately develop a better understanding of fundamental principles by identifying the connections between different natural phenomena. The common context behind a set of learning episodes could be a fundamental concept that can be deployed to explain different phenomena under investigation. Such concepts are usually interdisciplinary and are often referred to as "Big ideas" of science. Big ideas of science can enable learners as individuals to understand aspects of the world around them, both the natural environment and that created through application of science (Harlen, 2010).

The term "Big Ideas of Science" has several similar definitions. For example, Harlen (2010) defines big ideas as: "*ideas that can be used to explain and make predictions about a range of related phenomena in the natural world*". The term "Big Idea" also refers to a statement that summarizes the core knowledge in a discipline that we would like students to understand (Wiggins, 1999).

In this chapter we refer to "Big Ideas" as "*a set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena*". A "Big Idea" is a concept that connects different subject domains of science and is the common denominator of different natural phenomena. For example, the fact that "Objects can affect other objects at a distance" is the big idea behind the movement of celestial objects but also explains why magnets can attract iron objects. Thus, big ideas contribute in changing students' view of science and allow them to learn coherent concepts rather than a set of disconnected concepts and facts.

3.2 Review of Existing Sets of Big Ideas of Science

Different sets of Big Ideas have been developed over time either for different domains of science or for science as a whole. One of the most popular set of Big Ideas of science has been introduced by Harlen (2010) and is presented in Table 2.

Table 2: Big Ideas of Science (Harlen, 2010)

No	Big Idea
1	All material in the Universe is made of very small particles.
2	Objects can affect other objects at a distance.
3	Changing the movement of an object requires a net force to be acting on it.
4	The total amount of energy in the Universe is always the same but energy can be transformed when things change or are made to happen.
5	The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate.
6	The solar system is a very small part of one of billions of galaxies in the Universe.

7	Organisms are organized on a cellular basis.
8	Organisms require a supply of energy and materials for which they are often dependent on or in competition with other organisms.
9	Genetic information is passed down from one generation of organisms to another.
10	The diversity of organisms, living and extinct, is the result of evolution.

The aforementioned set of Big Ideas concerns science education as a whole and covers multiple subject domains. However other attempts have also been made in order to produce set of big ideas on specific subjects. Such sets are presented in Table 3, 4, 5 and 6.

Table 3: Big Ideas in Physics (Denver Public Schools, 2009)

No	Big Idea
1	Motion can be measured and described using a variety of methods.
2	Forces and energy are essential to understanding motion.
3	Collisions can be described using forces, energy, and momentum.
4	Energy and its conservation are essential in describing and analysing motion.
5	The properties of sound and light demonstrate wave behaviour.
6	Electricity is caused by the movement and energy transfer of electrons.
7	Electric fields and magnetic fields are related and can be used for mechanical energy output (motor) or electrical energy generation (generator).
8	The nature of atoms cannot be directly observed but can be described through models.

Table 4: Big Ideas in Chemistry (Talanquer, 2013)

No	Big Idea
1	Atoms, molecules, and ions are the basic components of matter.
2	Chemical bonds are formed by electrostatic attractions between positively charged cores and negatively charged valence electrons.
3	Atoms in molecules and crystals arrange in particular geometries.
4	Atoms and molecules are in constant motion.
5	Atoms in molecules and crystals can reorganize to form new molecules and crystals.
6	Reactions occur when the disorder of the Universe is increased.

Table 5: Big Ideas in Biology (Wood, 2009)

No	Big Idea
1	Evolution as the basis for both the diversity and the unity of life
2	Biological systems and their properties, including energy use, molecular components, growth, reproduction, and homeostasis.
3	Information: how organisms store it, retrieve and use it, transmit, and respond to it.
4	Interaction of systems components and the emergent properties of the resulting entities, from DNA molecules to cells to organisms to ecosystems

Table 6: Big Ideas in Earth Science (Ross & Duggan-Haas, 2010)

No	Big Idea

1	The Earth is a system of systems.
2	The flow of energy drives the cycling of matter.
3	Life, including human life, influences and is influenced by the environment.
4	Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.
5	To understand (deep) time and the scale of space, models and maps are necessary

3.3 Proposed Set of Big Ideas of Science

Our proposed set of Big Ideas of Science is produced by adopting, combining and extending the existing sets while taking into consideration some adaptations that are presented below.

One aspect that seems to be absent and needs to be introduced is that there are certain ideas like the universal application of fundamental principles that can be applied to all subject-domains of science. Such an idea is even more generic than all the ideas presented above. Thus, it is important to have two distinct levels of Big Ideas. The first would be the "*General Level*" which will consist of big ideas that are completely generic and apply to all fields of science. These general ideas will be broken down into more focused ones in the second level, the "*Specific Level*" that will reflect the principle ideas of our world and that to their total will cover all different subject-domains of science. Conclusively, the Big Ideas of the general level are wider compared to those in the specific level. This set of ideas, as a whole, can be considered to be the background context for every single idea in the specific level. Respectively, every idea of the specific level targets particular concepts (e.g. evolution, energy, fundamental forces) while it is still a component of all of the ideas in the general level.

Additionally, by reviewing the sets of Big Ideas presented in section 3.2, there is the possibility of merging a number of them into even bigger ones. Consequently, a part of our work focused on reviewing and comparing ideas from different or from within the same set that have similar meanings. This comparison led to the merging of some ideas and transforming them into bigger ones.

Another factor that we needed to consider was the fact that some ideas were in need of further elaboration so as to make them more complete and easier for learners to understand at various stages of their learning development. Thus, part of our work focused into further elaborating the existing Big Ideas so as to make them more complete. A more descriptive presentation of each Big Idea would also make them more comprehensible to students and allow them to identify connections between them more easily.

Overall, after reviewing the sets of Big Ideas presented in section 3.2 and working on them based on the adaptations mentioned above, our proposed set is presented in Table 7.

Table 7: Proposed Set of Big Ideas of Science

General Level	Specific Level
A. Physical and chemical principles are unchanging and drive both gradual and rapid changes in all systems throughout all scales of the Universe. B. The Universe and the world around us is not only composed of what we see around us. There are entities and phenomena that humans cannot grasp directly with their senses and yet they can be investigated and described using models and proper equipment.	1. Energy cannot be created or destroyed. It can only transform from one form to another. The transformation of energy can lead to a change of state or motion.
	2. There are four fundamental interactions/forces in nature; gravitation, electromagnetism, strong-nuclear and weak-nuclear. All phenomena are due to the presence of one or more of these interactions. Forces act on objects and can act at a distance through a respective physical field causing a change in motion or in the state of matter.
	3. The Universe is comprised of billions of galaxies each of which contains billions of stars and other celestial objects. Earth is a very small part of the Universe.
	4. All matter in the Universe is made of very small particles. They are in constant motion and the bonds between them are formed by interactions between them.
	5. All matter and radiation exhibit both wave and particle properties.
	6. Evolution is the basis for both the unity of life and the biodiversity of organisms (living and extinct). Organisms pass on genetic information from one generation to another.
	7. Organisms are organized on a cellular basis and require a supply of energy and materials. All life forms on our planet are based on a common key component.
	8. Earth is a system of systems which influences and is influenced by life on the planet. The processes occurring within this system shapes the climate and the surface of the planet.

4. THE PROPOSED METHODOLOGY FOR ORGANIZING VIRTUAL AND REMOTE LABS

This section presents our proposed methodology for organizing virtual and remote labs in web-based repositories, which consists of the synthesis of common metadata elements identified in section 2 and the set of big ideas of science identified in section 3.

4.1 Overview

The starting point for developing our proposed methodology was the outcomes derived from the review of existing repositories of virtual and remote labs performed in section 2. From this analysis, we identified three dimensions, namely (A) lab owner metadata, (B) social metadata and (C) additional resources and apps.

Regarding lab owner metadata, a list of 23 lab owner metadata elements was compiled. Additionally, we consider an additional lab owner metadata element that stores information about the proposed set of big ideas of science, as presented in section 3. These elements have been divided into three categories, namely: (1) general metadata, which stores general information about a virtual or remote lab, (2) pedagogical metadata, which stores information about the educational use of a virtual or remote lab and (3) technical metadata, which stores technical requirements and characteristics for a virtual or remote lab. Regarding the social metadata, we identified 3 options. Finally, 3 options were considered regarding additional resources and apps that could be connected to a virtual or remote lab.

Figure 2 provides an overview of the proposed methodology, as well as the different categories and metadata elements per category.

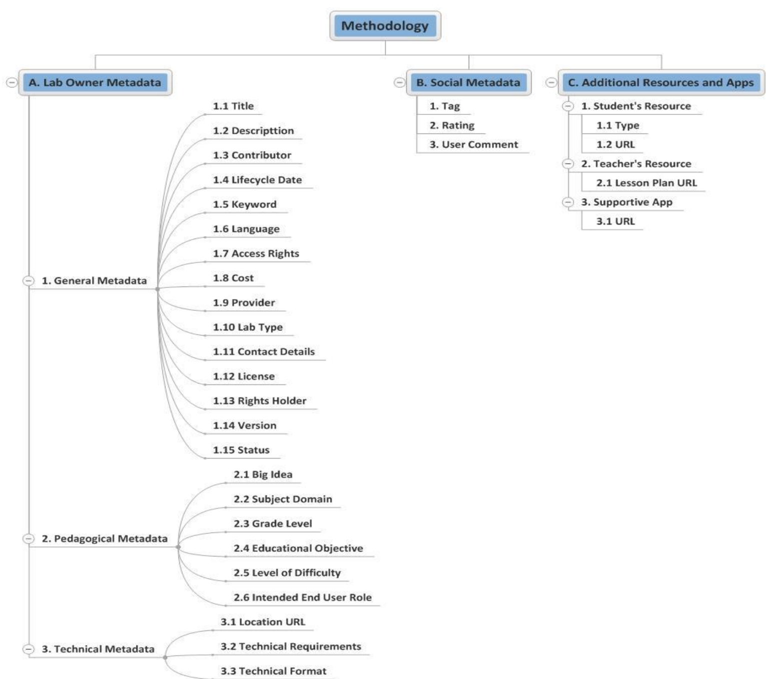

Figure 2: Overview of the Proposed Methodology for Organizing Virtual and Remote Labs

In the next section, we provide detailed description of each metadata element, as well as controlled vocabularies and taxonomies for selected metadata elements.

4.2 Full Element Set

This section presents the full element set of the proposed methodology for organizing virtual and remote labs. For each element of the methodology the following information is defined:

- ***Element Name:*** the title of the element
- ***Description:*** a short description explaining the information that the element can store
- ***Datatype:*** indicates whether the values of the element can be a character string or a vocabulary term
- ***Value Space:*** the set of allowed values for the element. More precisely, the values could be in the form of: (a) a vocabulary that has been compiled from the review of existing repositories of virtual and remote labs, as presented in section 2 or (b) a reference to an external taxonomy (from previously published works or existing standards)

The first category of lab owner metadata includes 14 elements, as they are described in Table 8.

Table 8: Lab Owner Metadata: General Category

No	Element Name	Description	Datatype	Value Space
A.1.1	Title	Refers to the complete title of the lab	Character string	N/A
A.1.2	Description	Provides a textual description of the lab	Character string	N/A
A.1.3	Contributor	Refers to each person (or entity) that has contributed in the making of the lab in its current state	Character string	N/A
A.1.4	Lifecycle Date	Refers to critical dates related to the lab's lifecycle	Character string	N/A
A.1.5	Keyword	Refers to a set of terms that characterize the content of the lab	Character string	N/A
A.1.6	Language	Refers to the languages that the lab is available in	Vocabulary Term	Based on ISO 639-1[14]
A.1.7	Access Rights	Refers to the lab's access permissions	Vocabulary Term	- Open access - Restricted access

[14] http://www.iso.org/iso/catalogue_detail?csnumber=22109

A.1.8	Cost	Refers to any payment required for using the lab	Vocabulary Term	- Yes - No
A.1.9	Provider	Provides information about the provider of the lab.	Character string	N/A
A.1.10	Lab Type	Refers to the specific kind of the lab	Vocabulary Term	- Virtual Lab - Remote Lab
A.1.11	Contact Details	Provides information about contact details of the person or the organization responsible for the lab	Character string	N/A
A.1.12	Licence	Provides information about copyrights and restrictions applied to the use of the lab.	Vocabulary Term	- CC – Zero (universal)[15] - CC BY (v3.0 Unported)[16] - CC BY-SA[17] - CC BY-NC[18] - CC BY-NC-SA[19] - CC BY-ND[20] - CC BY-NC-ND[21] - GNU General Public License[22] - Commercial - Other
A.1.13	Rights Holder	Refers to those entities that hold the lab's copyrights	Character string	N/A
A.1.14	Version	Provides information about the current version of the lab	Character string	N/A
A.1.15	Status	Provides information about the availability status of the lab	Vocabulary Term	- Available - Online - Offline - Unavailable

The second category of lab owner metadata includes 6 elements, as they are described in Table 9.

Table 9: Lab Owner Metadata: Pedagogical Category

No	Element Name	Description	Datatype	Value Space
A.2.1	Big Idea	Refers to the big ideas of science that the lab addresses	Vocabulary Term	Taxonomy of big ideas of science as defined in Table 7
A.2.2	Subject Domain	Refers to the lab's subject	Vocabulary	Taxonomy of

15 http://creativecommons.org/publicdomain/zero/1.0/
16 http://creativecommons.org/licenses/by/3.0/
17 http://creativecommons.org/licenses/by-sa/3.0/
18 http://creativecommons.org/licenses/by-nc/3.0/
19 http://creativecommons.org/licenses/by-nc-sa/2.0/
20 http://creativecommons.org/licenses/by-nd/2.0
21 http://creativecommons.org/licenses/by-nc-nd/1.0/
22 http://www.gnu.org/licenses/gpl.html

		domain	Term	science curriculum terms as proposed in Sampson et al. (2011)
A.2.3	Grade Level	Refers to the grade level for which the lab can be used	Vocabulary Term	- Primary Education - Lower Secondary Education - Upper Secondary Education - Higher Education Bachelor - Higher Education Master
A.2.4	Educational Objective	Refers to the educational objectives that the lab addresses	Vocabulary Term	Taxonomy of educational objectives as proposed in Sampson et al. (2011)
A.2.5	Level of Difficulty	Refers to the level of difficulty of the lab	Vocabulary Term	- Easy - Medium - Advanced
A.2.6	Intended End User Role	Refers to the principal users for whom the lab was designed	Vocabulary Term	- Learner - Teacher - Researcher - Practitioner - Administrator - General Public - Parent - Other

The third category of lab owner metadata includes 3 elements, as they are described in Table 10.

Table 10: Lab Owner Metadata: Technical Category

No	Element Name	Description	Datatype	Value Space
A.3.1	Location URL	Provides a URL for accessing the lab	Character string	N/A
A.3.2	Technical Requirements	Refers to the technical requirements that are needed for using the lab.	Vocabulary Term	***Operating System*** - Window - MacOS - Linux - iOS - Android ***Additional Software***

				- Java - Adobe Flash Player - LabView Runtime Engine - Other ***Supported Browsers*** - Mozilla Firefox - Internet Explorer - Google Chrome - Safari - Opera - Other
A.3.3	Technical Format	Refers to lab's technical format.	Vocabulary Term	- application/java - application/x-shockwave-flash - application/javascript - application/widget - application/zip - application/xhtml+xml - other

The next dimension of the proposed methodology, namely social metadata includes 3 categories, as they are described in Table 11.

Table 11: Social Metadata

No	Category	Description	Datatype	Value Space
B.1	Tag	Refers to a tag that characterize the content of the lab	Character string	N/A
B.2	Rating	Rating related to the quality of a lab.	Vocabulary Term	- One star - Two stars - Three stars - Four stars - Five stars
B.3	User's Comment	Textual comment including feedback from the use of a lab	Character string	N/A

The final dimension of the proposed methodology, namely additional resources and apps includes 3 categories, as they are described in Table 12.

Table 12: Additional Resources and Apps

No	Category	Element	Description	Datatype	Value Space
C.1	Student's Resource	C.1.1 Type	Refers to the type of student's resource that is connected to the lab	Vocabulary Term	- Student's guide - Assignment Sheet - Glossary - Tutorial
		C.1.2 URL	Provides the URL for accessing any student's resource	Character string	N/A

			that is connected to the lab		
C.2	Teacher's Resource	C.2.1 Lesson Plan	Provides the URL for accessing any lesson plan that can be used for exploiting the lab.	Character string	N/A
C.3	Supportive App	C.3.1. URL	Provides the URL for accessing any supportive app that are connected to the lab.	Character string	N/A

5. CONCLUSIONS

Within the landscape of the mainstream use of virtual and remote labs in science education, it seems that there is not a common and educationally meaningful way for organizing virtual and remote labs via web-based repositories. As a result, this creates barriers to teachers, who want to search and retrieve virtual and remote labs for designing appropriate learning activities for their students. Thus, in this chapter we set the ground for a common methodology for organizing virtual and remote labs, which builds upon approaches from existing lab repositories and by incorporating the concept of Big Ideas of Science.

It is worthy to mention that the results of this study are currently exploited by a major European Initiative referred to as: "Go-Lab – Global Online Science Labs for Inquiry Learning at School". The Go-Lab Project (http://www.go-lab-project.eu/) aims to establish a federation of virtual and remote labs where lab owners can promote their labs and teachers can discover and use virtual and remote labs for designing meaningful learning activities for their students. More precisely, the Go-Lab Project develops a repository, which follows the metadata elements of the methodology for organizing virtual and remote labs that is presented in this chapter.

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