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# GOLABZ: TOWARDS A FEDERATION OF ONLINE LABS FOR INQUIRY-BASED SCIENCE EDUCATION AT SCHOOL

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## Abstract

This paper represents a repository for online laboratories, learning applications and Inquiry Learning Spaces (ILS) towards introducing Inquiry-Based Science Education (IBSE) in schools. In the first part, a classification scheme for online labs and a methodology for creating a federation of online labs are described. In the second part, technical implementation of the defined classification in the Go-Lab Repository is represented. In the third part, a usage scenario is described targeting science teachers of primary and secondary schools, who want to use online labs in their classroom activities. In sum, this paper aims at communicating the pedagogical background and advantages of the represented approach, as well as opportunities opened up by the Go-Lab Repository for teachers practicing inquiry-based learning activities in their classes.

Keywords: Technology Enhanced Learning (TEL), Inquiry-Based Science Education (IBSE), school education, online laboratories, federation of online labs, metadata, classification, online lab repository, Inquiry Learning Space (ILS), usage scenario, Big Ideas of Science.

## 1 INTRODUCTION

In the recent years, Inquiry-Based Science Education (IBSE) has proved its efficacy in school education extending “traditional” frontal instruction and motivating students to actively participate in doing science [1]. IBSE-methods receive support by means of learning technology on both hardware and software side. Many European schools are equipped with computer classes, tablets and high-speed internet connection. A huge variety of web-based learning applications, simulations and visualisations, as well as remote experiments is available. However, there is a lack of pedagogical frameworks, supportive tools and best practices allowing school teachers to easily find and efficiently apply the available technologies.

The EU-project Go-Lab (Global Online Science Labs for Inquiry Learning at School, [www.go-lab-project.eu](http://www.go-lab-project.eu)) aims to support the implementation of the IBSE-approach by creating a pedagogical and a technical framework providing teachers and students with access to online (remote and virtual) science laboratories and supportive web-based learning tools. Furthermore, it gives teachers the opportunity to create their own virtual Inquiry Learning Spaces (ILS) deploying these labs and tools corresponding to their particular lesson plan. In scope of the Go-Lab project, the Go-Lab Repository (GoLabZ: <https://golabz.eu>) has been developed, which includes online labs, learning apps, and ILSs making them accessible to teachers all over the world.

The structure of the Go-Lab Repository is based on the approach for organizing online labs, which includes metadata elements that can be used to describe online labs in a common and systematic way. To develop this approach, multiple repositories and federations of online labs were analysed so as to elicit the necessary characteristics of the labs. Additionally, validation surveys were launched in order to ensure that the set of metadata elements produced is also in accordance with teachers’ needs. A set of online labs was analysed and categorised according to the proposed scheme so as to be included into the Go-Lab Repository. Thus, a comprehensive online lab classification scheme has been defined.

In addition, a categorization of online labs and ILSs based on the “Big Ideas of Science” was defined, allowing their presentation through a federated approach able to demonstrate clearly how experiments in different subject domains share a common background. This aims at helping the teachers to demonstrate to their students the universality of the concepts and phenomena investigated. The classification through the Big Ideas of Science also serves as a recommendation system for teachers, as it provides them with labs and ILSs from different subject domains that may at first sight look unconnected, but in reality they stem from the same fundamental principles of nature.

Based on the conceptual design and specifications described above, a selective list of metadata has been adopted for the first Go-Lab prototype. The metadata set for online labs has been specified and implemented in a filtering mechanism (based on a hierarchical taxonomy) assisting users in navigating these resources. Thus, the Repository provides school teachers with the opportunity to find and select online labs and additional tools based on multiple parameters, such as the subject domain, students’ age, level of complexity, etc. This first prototype is being further developed implementing users’ requirements.

This paper represents the Go-Lab Repository and its use for teaching science beginning with (1) derivation of the online labs classification scheme and definition of metadata elements providing pedagogic “added-value” for the users, towards (2) technical implementation of the defined classifications, and finally providing (3) a usage scenario targeting science teachers of primary and secondary schools wanting to use online labs in their classroom activities. In sum, this paper aims at communicating pedagogical background and the advantages of the represented approach, as well as opportunities opened up by the Repository for teachers practicing inquiry-based learning activities in their classes.

## **2 METHODOLOGY FOR CLASSIFYING ONLINE LABS**

### **2.1 Go-Lab set of Big Ideas of Science**

According to the Rocard report “Science Education NOW: a renewed pedagogy for the future of Europe” there is an alarming decline of students’ interest in taking up science studies and in following scientific careers [1]. One of the reasons behind this phenomenon could be the way science is taught in schools. Students appear to miss the links between what they are taught in school and the world around them. They “don’t see the point” of studying things that appear to them as a series of disconnected facts to be learned [2]. A proposal towards facing this problem is the introduction to the science class of the “Big Ideas of Science”. In the Go-Lab project we refer to “Big Ideas of Science” 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.

In the framework of the Go-Lab project it is our aim to classify all labs and Inquiry Learning Spaces included in the Go-Lab Repository according to the Big Ideas of Science in addition to the classical categorization based on subject domain and student age range. The labs will be classified based on the relation between each Big Idea and the primary aims they serve, as well as the relation between each Big Idea and the principles and phenomena they are designed to investigate. Respectively, the Go-Lab ILSs will be classified following the Big Ideas of Science based on their educational objectives and learning goals and to which Big Ideas they are related to. This classification will serve as a recommendation system for teachers allowing them to retrieve and connect labs, ILSs and activities not only based on their subject domain, but also according to the fundamental principles they are based on. Thus, every time teachers use either a lab or an ILS from the Repository they will have at their disposal the set of Big Ideas that are relative to that lab or ILS. By connecting different classroom activities that might be in different subject domains but share the same Big Ideas, we aim to demonstrate to students the connection between different principles and between different natural phenomena that at first sight may look unconnected but in reality they share a common background.

After making a review of several sets of Big Ideas of science in general as well as in different subject areas (Physics, Biology, Chemistry and Earth Sciences), we have concluded to a set of ten ideas. These ten ideas are separated in two levels: a general level and a specific level. There are two Big Ideas in the general level which are general principles that cover every single domain of science. In the specific level, there are eight Big Ideas that to their total describe the world around us and allow us to see connections between different subject domains. More specifically the Go-Lab set of Big Ideas of Science is represented in the Table 1:

Table 1: Go-Lab set of Big Ideas of Science

General Big Ideas	Specific Big Ideas
<p><b>A.</b> Physical and chemical principles are unchanging and drive both gradual and rapid changes in all systems throughout all scales of the Universe.</p>	<p><b>1.</b> 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.</p>
<p><b>B.</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.</p>	<p><b>2.</b> 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.</p>
	<p><b>3.</b> 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.</p>
	<p><b>4.</b> 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.</p>
	<p><b>5.</b> All matter and radiation exhibit both wave and particle properties.</p>
	<p><b>6.</b> 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.</p>
	<p><b>7.</b> 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.</p>
<p><b>8.</b> 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.</p>	

## 2.2 Review of existing online lab repositories

Before developing a methodology for organizing and classifying online labs, a research of existing online lab repositories has been conducted. More specifically, a set of thirteen (13) repositories of online labs has been assembled throughout research in related publications and Internet sources. Each repository has been thoroughly analyzed according to the following dimensions:

- The types of labs included in each repository, namely virtual and/or remote labs, as well as the number of labs per category.
- The metadata elements used in each repository. These were classified in two categories: (a) lab owner metadata, which are added by the owners of remote or virtual labs and (b) social metadata, which are added by the end-users of virtual and remote labs and can 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 (such as student's guides, tutorials, assignment sheets, etc.) that can be used by the students before, during or after conducting an experiment with an online lab, (b) teacher's resources including resources that can be used by the teacher to design and develop learning activities supported with online labs, and (c) supportive apps (such as apps that help students to formulate hypothesis or interact with experimental data) that can support students during the execution of an experiment with an online lab.

Table 2 provides an overview of the existing repositories of online labs which were analyzed.

Table 2: Overview of existing repositories of virtual and remote labs

No	Name	Web Link	Lab Types/ Number of Labs		Number of Lab Owner Metadata Elements	Social Metadata			Additional Resources and Apps		
			Virtual Labs	Remote Labs		Tags	Ratings	Users' Comments	Students' Materials	Teachers' Materials	Supportive Apps
1	PhET	<a href="http://phet.colorado.edu">http://phet.colorado.edu</a>	125	-	10	No	No	No	No	Yes (Lesson Plan)	No
2	Library of Labs	<a href="https://www.library-of-labs.org/">https://www.library-of-labs.org/</a>	274	-	17	No	Yes (Like Ratings)	Yes	Yes (Student's Guide, Assignment Sheet)	Yes (Lesson Plan)	No
3	Labshare	<a href="http://www.labshare.edu.au/">http://www.labshare.edu.au/</a>	-	11	10	No	No	No	No	Yes (Lesson Plan)	No
4	Open Sources Physics	<a href="http://www.compadre.org/osp">http://www.compadre.org/osp</a>	100	-	13	No	Yes (1-5 Star Rating)	Yes	Yes (Student's Guide)	Yes (Lesson Plan)	No
5	Smart Science	<a href="http://www.smartscience.net/">http://www.smartscience.net/</a>	-	164	4	No	No	No	Yes (Glossary, Student's Guide, Tutorial)	Yes (Lesson Plan)	Yes
6	Molecular Workbench	<a href="http://mw.ncord.org/">http://mw.ncord.org/</a>	946	-	3	No	No	No	No	Yes (Lesson Plan)	Yes
7	Explore Learning	<a href="http://www.explorelearning.com">http://www.explorelearning.com</a>	450	-	6	No	No	No	Yes (Assignment Sheet, Glossary)	Yes (Lesson Plan)	No
8	Chem-Collective	<a href="http://www.chemcollective.org/">http://www.chemcollective.org/</a>	40	-	8	No	No	No	Yes (Assignment Sheet)	Yes (Lesson Plan)	No
9	Remotely Controlled Laboratories (RCL)	<a href="http://rcl-munich.informatik.unibw-muenchen.de">http://rcl-munich.informatik.unibw-muenchen.de</a>	-	17	4	No	No	No	Yes (Student's Guide)	Yes (Lesson Plan)	No
10	Skool	<a href="http://skool.com">http://skool.com</a>	4.950	-	5	No	No	No	Yes (Assignment Sheet)	Yes (Lesson Plan)	No
11	iLab-Central	<a href="http://ilabcentral.org">http://ilabcentral.org</a>	-	21	7	No	No	No	Yes (Assignment Sheet)	Yes (Lesson Plan)	No
12	Lab2Go	<a href="http://www.lab2go.net">http://www.lab2go.net</a>	157	51	13	No	Yes (1-5 Star Rating)	No	Yes (Student's Guide)	No	No
13	WebLab Deusto	<a href="https://www.weblab.deusto.es/weblab/client/#page=home">https://www.weblab.deusto.es/weblab/client/#page=home</a>	-	15	3	No	No	No	Yes (Tutorial)	No	No
<b>Total Number of Labs</b>			<b>7.042</b>	<b>279</b>							

As represented in Table 2, each repository uses a different number of metadata elements for describing their virtual and/or remote labs. To this end, we harmonized the lab owner metadata elements used by the examined repositories, so as to produce a master list of lab owner metadata elements. Based on this analysis, a list of 23 lab owner metadata elements has been assembled (see section 2.3).

As it is also evident from Table 2, 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 online labs. More specifically, none of the examined repositories provides 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. Nevertheless, it is important to consider social metadata options, namely social tags, ratings and user's comments when organizing online labs, as they could significantly facilitate the empowerment of the end-users and their active participation and interaction with the labs.

Finally, 10 (77%) of the examined repositories offer student's materials, which are linked with the virtual or remote labs provided by these repositories. Moreover, 11 (85%) of the examined repositories offer teacher's materials, which are linked with the online labs provided by these repositories. Additionally, only 2 (15%) of the examined repositories offer supportive apps that aim to facilitate students during the process of using a virtual or remote lab. However, these apps are very important, since they can facilitate students to formulate hypotheses or interact with experimental data.

According to the aforementioned results, in the next section we present the proposed methodology for organizing online labs in web-based repositories, which has been adopted by the Go-Lab project.

### 2.3 Go-Lab methodology

The Go-Lab methodology for organizing virtual and remote labs is a synthesis of set of Big Ideas of Science identified in section 2.1 and common metadata elements identified in section 2.2. More specifically, it represents a list of 23 lab owner metadata elements. 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 2.1. These elements have been divided into three categories, namely: (1) general metadata, which stores general information about a lab, (2) pedagogical metadata, which stores information about the educational use of a lab and (3) technical metadata, which stores technical requirements and characteristics of an online lab. Regarding social metadata, we considered three options, namely tagging, rating and user comments. Finally, regarding additional resources and apps, we also considered three options, namely student's resources, teacher's resources and supportive apps. Figure 1 provides an overview of the proposed methodology, as well as the metadata categories and elements per category:

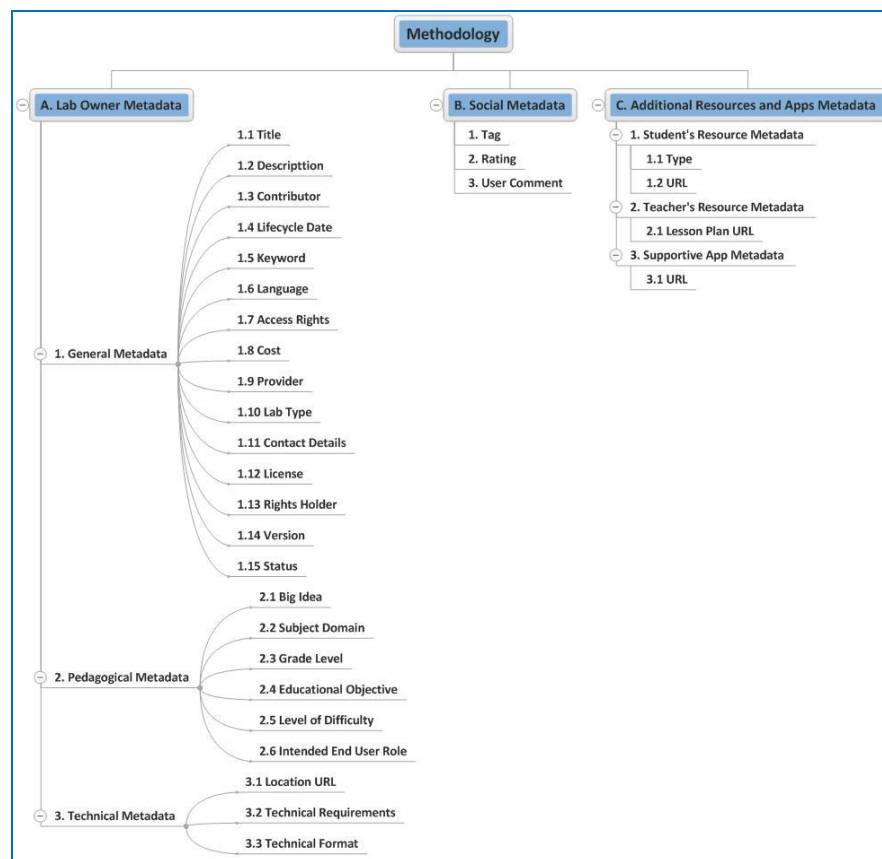


Fig. 1: Go-Lab methodology for organizing virtual and remote labs

The proposed approach can be used for organizing virtual and remote labs in web-based repositories towards facilitating their search and retrieval by the teachers. The Go-Lab project has developed a repository, which follows the metadata elements of the methodology. The first prototype of this repository is described in the next section.

### 3 TECHNICAL IMPLEMENTATION

The metadata elements set described above is implemented based on the content management system Drupal<sup>1</sup>. Drupal runs on the Apache web server using MySQL database. This section describes how the aforementioned metadata is registered in the Go-Lab Repository.

#### 3.1 Selection of lab metadata

Through our analysis and research described in section 2 we have concluded to a coherent and detailed set of metadata elements. This set is being implemented gradually in the Go-Lab Repository using the spiral model of software development [3]. After collecting requirements from the users, we designed and implemented a limited set of metadata elements (including the most important elements from the users' point of view) in the first prototype of the Repository. Following this step of implementation we are now in the process of the user evaluation and analysis of the users' feedback. The next step will be to improve the prototype based on that feedback and release the next version including the full metadata elements set. This approach ensures that the conceptual design and realisation meet with user community's needs and requests.

In the first prototype of the Go-Lab Repository, we have implemented the metadata elements for online labs represented in Table 3. We took into consideration metadata elements represented in the Part A and Part C (see Fig. 1), while Part B is planned to be implemented in later versions.

Table 3: Lab metadata implemented in the first prototype of Go-Lab Repository

Metadata group	Metadata element	Element number (methodology)	Taxonomy available?	Label in Go-Lab Repository
Lab owner/ General metadata	Lab title	A1.1		Title
	Lab description	A1.2		Brief description of the lab
	Lab owner	A1.3		Lab owner
	Keyword	A1.5		Keywords
	Language	A1.6	yes	Language
	Lab type	A1.10	yes	Lab type
Lab owner / Pedagogical metadata	Subject domain	A2.2	yes	Subject
	Grade level	A2.3	yes	Grade level
	Learning objective	A 2.4		Primary aims of the lab
	Level of difficulty	A 2.5	yes	Difficulty level
	Level of interaction	-	yes	Interaction level
Lab owner/ Technical metadata	Website URL	A3.1		Web link
Additional resources and apps metadata	Additional supportive material URL	C1.2		Additional supportive materials
	Learning scenario URL	C2.1		Description of a use case
	Supportive app URL	C3.1		Lab apps (source code)
Administrative metadata	Booking required	-		Booking required
	Certificate/badge	-		Go-Lab approved

The labels (see last column in Table 3) are used in the Go-Lab Repository to represent metadata elements to the users in a simple and understandable way. The labels can be easily changed

<sup>1</sup> <https://drupal.org/>

according to the user's feedback without changing the machine name of the metadata set. The labels of the metadata set are displayed to the users in the Go-Lab Repository, as depicted in Figure 2.

HY.P.A.T.I.A. - Hybrid Pupils' Analysis Tool for Interactions in ATLAS

**Go-lab approved**

Lab type: Analysis tools  
 Lab owner: Christine Kourkoumelis  
 Web link: <http://hypatia.iiasa.gr/>  
 Language: English, German, French, Greek

**Metadata values**

Grade level: Secondary Education (15-18 years old), Higher education bachelor, Higher education master  
 Interaction level: High  
 Difficulty level: Medium  
 Inquiry learning phases: Orientation, Conceptualisation, Investigation, Conclusion  
 Booking required: No

**Keywords:** [High energy](#), [ATLAS](#), [CERN](#), [LHC](#), [elementary particles](#), [boson](#), [electron](#), [muon](#), [positron](#), [proton](#), [neutron](#), [neutrino](#), [accelerator](#), [hadron](#), [collision](#), [momentum](#)

**Text is blue is clickable to filter content**

**Create Inquiry Space**

**Metadata labels**

**Subject:**  
 Electricity and magnetism, Electric charge – generally, Electromagnetism – generally, Energy, Conservation and dissipation, Internal Energy, Kinetic energy, Potential energy, Fields, Magnetic field, Electric field, Electromagnetic field, Angular velocity, Forces and motion, Conservation of momentum, Nuclear force, Collision, Tools for science, Accelerators & beams, Antimatter, Calorimeters, High Energy Physics, Charged particle acceleration, Dark matter, Higgs particle, Invariant mass, Leptons, QCD, jets & gluons, Quarks & hadrons, Standard model, Supersymmetry

**Primary aims of the lab:**  
 HYPATIA aims to show students how real high energy physic research is done. It provides the students with real data and an environment that closely resembles what actual researchers use, to give them the opportunity to conduct their own analysis and “discover” new particles.

**Brief description of the lab:**  
 HYPATIA is an event analysis tool for data collected by the ATLAS experiment of the LHC at CERN. Its goal is to allow high school and university students to visualize the complexity of the hadron - hadron interactions through the graphical representation of ATLAS event data and interact with them in order to study different aspects of the fundamental building blocks of nature.

Fig. 2. Online lab metadata in Go-Lab Repository

### 3.2 Implementation of taxonomy

Some metadata value input fields (including lab type, subject domain, language, grade level, level of difficulty and level of interaction) support taxonomy (cf. Table 3) in order to unify users' input text. The most taxonomy terms of these metadata sets are a list with no hierarchy levels. Due to its complexity, the metadata “subject domain” follows a hierarchy tree. In the domain of science, 6 subject domains are specified, including Physics, Chemistry, etc. Under these 6 domains, 34 sub-domains are specified, for example, Ecology as a sub-category of the Biology. These sub-domains can be further extended. In the Repository, either auto-completion or selecting from a list is supported. With regard to taxonomy in hierarchy, selecting from a list is the most effective approach. Additional teachers' resources (see Fig 1. Part C) are available for download from particular online lab pages.

### 3.3 Search and filtering

In the Go-Lab Repository, two kinds of search and filtering mechanism are implemented. One is the usual text-based search using a text input search box. The other is a faceted search in the side bar. Faceted search is an effective approach to interactive information retrieval and to browsing and navigating through the website content [4]. It enables users to select different metadata values for navigation and can be applied on multiple levels as well. This means that users can click metadata values to refine the online labs' search results. After one metadata value is clicked, a minus symbol is shown in front of this value to indicate the selection (see Fig. 3). It can be easily removed by clicking the minus symbol. In this sense, faceted search is an intuitive way to browse and navigate online lab content in the Go-Lab Repository. An example of using faceted search is provided in the next section.

## 4 FINDING ONLINE LABS AND LEARNING APPS

Based on previously introduced theoretical considerations and the description of the Go-Lab Repository, this section represents a usage scenario describing how a teacher can find and use online laboratories and learning applications to extend regular classroom activities with online experimentations. At the first step, educational settings and target group characteristics are described. At the second step, a step-by-step scenario of user-system interaction is provided. Finally, the Go-Lab Portal, a platform integrated with the Repository and allowing full use of its functionalities, is briefly introduced. The usage scenario represents a general path of handling the Go-Lab Repository and can be implemented in practice by any user.



## 4.1 Target group

Online laboratories and learning applications combined in Inquiry Learning Spaces together with additional educational resources like text documents, presentation slides, videos and web links can be used by science teachers (e.g., Physics, Astronomy, Chemistry, Mathematics, Biology, etc. teachers) together with their students aged from 10 to 18 years old in scope of classroom activities and students' learning activities at home. Remote labs are more suitable to be used in the classroom, as they mostly require booking of a time slot and assistance by the teacher. Virtual labs, on the other hand, can be easily used by the students themselves to simulate scientific experiments and conduct data analysis (explanations and supportive materials have to be provided by the teacher during the lesson).

In order to make this possible, the teacher has to prepare a lesson plan and create an Inquiry Learning Space including all tools and resources needed. The creation and use of ILs does not require advanced PC-skills, however, the teacher should be an experienced user of standard office programs, internet (browsing and collecting information) and communication tools (like e-mail, communities and chats) in order to be able to create and manage his/her own virtual learning space, its contents and users. The online labs also do not require any special skills, but the teacher should try them out and exercise in using them before the class. Although online labs are offered in multiple languages, good English skills are beneficial for using Go-Lab infrastructure.

## 4.2 Usage scenario

Mrs. Morgan is a Physics teacher in a secondary school. In the next lesson she wants to explain the Archimedes' Principle and make several experiments on buoyancy. Moreover, she wants her students to conduct online experiments themselves in the classroom and do some practical experiments at home. Mrs. Morgan decides to demonstrate an experiment on buoyancy using available laboratory equipment and, in addition, give the students the possibility to conduct the same experiment themselves using an online lab and to compare the results.

As Mrs. Morgan is aware of the Go-Lab project, she opens the Go-Lab Repository in her web browser and starts searching for appropriate tools. She clicks on the "Online Labs" button on the top of the homepage and is forwarded to the page representing remote and virtual laboratories, analysis tools and data sets. In the filtering tabs on the right of the page Mrs. Morgan selects characteristics of the desired lab (see Fig. 3):

- Subjects: Archimedes' Principle, Buoyancy, Density
- Grade level: Secondary education (12-15 years old)
- Language: English
- Lab types: Remote labs, Virtual experiments

The screenshot displays search results for two virtual laboratories. The first entry, 'WebLab-DEUSTO Aquarium', features an underwater scene with colorful coral and fish. Its description states the main objective is Archimedes' Principle, involving an aquarium with three balls of different liquids. The lab owner is Olga Dziabenko & Javier Garcia-Zubia, and it covers subjects like forces and motion, pressure, weight, and solids. It is available in multiple languages and suitable for primary and secondary education. The second entry, 'Splash: Virtual Buoyancy Laboratory', shows a virtual interface with a tube and a fluid. Its description explains that students can create objects with specific mass, volume, and density to observe buoyancy. The lab owner is Anjo Anjewierden & Ton de Jong, and it focuses on buoyancy, density, and relative density. It is available in English and suitable for primary and secondary education. On the right, a sidebar provides filtering options: Grade levels (Secondary education, Primary education), Subjects (Archimedes' Principle, Buoyancy, Density, Floating and sinking, Relative density), Lab types (Remote labs, Virtual experiments), Languages (English, Czech, French, German, Hungarian, Portuguese, Romanian, Russian, Slovak, Spanish), and Inquiry phases.

Fig. 3: Search results in the Go-Lab Repository

Applying these search criteria Mrs. Morgan finds two online laboratories: “WebLab-DEUSTO Aquarium”<sup>2</sup> and “Splash: Virtual Buoyancy Laboratory”<sup>3</sup>. Mrs. Morgan clicks on the first lab and views the description including characteristics of the lab (e.g., correspondence to the phases of inquiry learning process, difficulty and interaction levels, etc.), aims of the lab, sample use case and so on. “WebLab-DEUSTO Aquarium” demonstrates Archimedes’ Principle with a remote lab: there are three balls filled with different liquids (water, oil and alcohol), which can be thrown by the user (using a web interface) into an aquarium filled with water. The user can calculate the density of the balls and observe which of them sink or float. Mrs. Morgan decides to use this lab in her class.

After viewing the details of the virtual lab “Splash: Virtual Buoyancy Laboratory”, Mrs. Morgan decides that it can be used by her students at home. “Splash” is a simulation demonstrating the interconnection between object properties and fluid density. In this experiment the user can define the mass, volume, and density of several objects as well as fluid properties and simulate the experiment described above. In order to provide assistance to the students during the whole inquiry process, Mrs. Morgan searches for Inquiry Learning Spaces containing additional learning applications. By clicking the button “Inquiry Spaces” on the top of the page, she is forwarded to the page representing ILSs.

Mrs. Morgan finds the ILS “Sinking or floating” containing not only the Splash lab, but also apps supporting phases of the inquiry learning process [5]. To support the inquiry learning phase “Orientation”, the “Questioning Scratchpad”<sup>4</sup> tool for formulating research questions is available. The “Hypothesis tool”<sup>5</sup> supports the “Conceptualization” phase helping students to create and document hypotheses before starting an experiment. For the phases “Investigation” and “Conclusion” the “Experiment Design Tool”<sup>6</sup> helps to plan scientific experiments and the “File Drop”<sup>7</sup> allows students to upload their assignments to the ILS. No tools are assigned to the “Discussion” phase, as the results can be discussed by the students using the chat provided in the Inquiry Learning Space.

Mrs. Morgan already has all the tools she wants to use in the pre-defined ILS. She clicks on the “Create Inquiry Space” button at the “Sinking or floating” page to create an Inquiry Learning Space out of the pre-defined template. Mrs. Morgan is forwarded to the authoring interface of the Go-Lab Portal, where she can edit her ILS to adopt it to her needs.

### 4.3 Related Systems

The Go-Lab Repository can be used to find and select online laboratories and learning applications to construct Inquiry Learning Spaces supporting particular teaching needs. However, the Repository does not contain a learning environment allowing collecting and using selected tools directly on this platform. In order to be able to create Inquiry Learning Spaces, teachers have to be previously registered in the Go-Lab Portal based on the Web 2.0 platform Graasp (<https://graasp.epfl.ch>). In the Go-Lab Portal, they can assemble online labs, applications, and resources in an Inquiry Learning Space, structure this space according to the phases of inquiry learning process and share created ILS with students by providing an URL.

All online labs and apps represented in the Go-Lab Repository are compatible with the Go-Lab Portal. Each online lab’s description in the Repository provides a list of online labs apps with source codes. The links to the source codes can be easily added to the ILS in the Portal, thus, incorporating the lab. Another way is to use the “Create Inquiry Space” button, as described in the scenario above, which allows automatic adding of the lab and related learning applications to the ILS. In the Go-Lab Portal, teachers can modify created ILSs by adding additional sub-spaces, tools (out of Repository) and resources and deleting those they do not need. Thus, the Go-Lab Portal and Go-Lab Repository are two complementing systems allowing teachers to find and use online labs and learning apps.

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<sup>2</sup> WebLab-DEUSTO Aquarium: <http://www.golabz.eu/lab/weblab-deusto-aquarium-0>

<sup>3</sup> Splash: Virtual Buoyancy Laboratory: <http://www.golabz.eu/lab/splash-virtual-buoyancy-laboratory>

<sup>4</sup> Questioning Scratchpad: <http://www.golabz.eu/apps/questioning-scratchpad>

<sup>5</sup> Hypothesis Tool: <http://www.golabz.eu/app/hypothesis-tool>

<sup>6</sup> Experiment Design Tool: <http://www.golabz.eu/apps/experiment-design-tool>

<sup>7</sup> File Drop: <http://www.golabz.eu/apps/file-drop>

## 5 CONCLUSION

According to the recent research [1], new methodologies and tools are needed to make teaching of science in schools more motivating and efficient. For instance, traditional classroom activities and demonstration of scientific experiments can be accompanied by the use of online laboratories and interactive learning applications allowing investigating research questions by the students themselves using remote access to real scientific equipment of renowned institutions or virtual simulations of the experiments. School teachers have to be able to find appropriate online labs and tools, assemble them in Inquiry Learning Spaces, adopt these spaces to particular lesson plans, and share them with the students. To support this, a federation of online laboratories and learning applications is needed making the search and use of the tools easy for the teachers and providing necessary scaffolds and support. Such federation of online labs has to be based on scientifically and pedagogically reasonable methodology and consider already existing experience of the development of online lab repositories.

This paper represents the Go-Lab Repository for online laboratories, learning applications and Inquiry Learning Spaces. The Go-Lab set of Big Ideas of Science and the methodology for creating a federation of online labs, on which the classification of online labs implemented in the Repository is based, are described. The methodology includes the derivation of metadata taxonomy based on the review of already existing online lab repositories and user requirements. The taxonomy contains lab owner metadata of 23 elements (general, pedagogical and technical metadata), social metadata of 3 elements (tag, rating, user comment) and a typology of additional resources and apps including teacher's resources, student's resources and supportive apps. Technical implementation of the defined metadata taxonomy in the search and filtering mechanism of the Go-Lab Repository based on Drupal content management system is described. Finally, the paper provides the usage scenario describing how a school teacher can use the Repository to find online labs, apps and ILSs to be used by the students in classroom activities and out of class.

The first prototype of the Go-Lab Repository implements only a part of the proposed online lab classification scheme (see Table 3). Further prototypes will contain classification of labs according to the Go-Lab set of Big Ideas of Science demonstrating interconnection between different subject domains. Also other metadata elements described in section 2.3 will be implemented. The Go-Lab project conducts a series of pilot activities involving school teachers from 15 European countries. The pilot teachers use and evaluate the Go-Lab Repository, Inquiry Learning Spaces, online labs and learning tools and give their feedback to the Go-Lab project consortium. Furthermore, the pilot teachers evaluate mock-ups of the planned tools and interfaces before their development. This aims at involving the end-users in the development process in an early phase and assures consideration and implementation of the user requirements in the Go-Lab Repository. Finally, the project consortium together with school teachers is continuously developing new inquiry-based classroom scenarios and populates the Repository with appropriate online labs and learning applications. Thus, the Go-Lab Repository is being developed in accordance with outcomes of pedagogic and scientific research as well as with the user feedback and experiences from the practice.

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