Go-Lab

Global Online Science Labs for Inquiry Learning at School

Collaborative Project in European Union's Seventh Framework Programme

Grant Agreement no. 317601

Deliverable D2.4

The Go-Lab Inventory and Integration of Online Labs – Complete version

Editor(s)	Eleftheria Tsourlidaki (EA) and Panagiotis Zervas (CERTH)
Date	28 October 2016
Dissemination Level	Public
Status	Final

The Go-Lab Consortium

Beneficiary Number	Beneficiary name	Beneficiary short name	Country
1	University Twente	UT	The Netherlands
2	Ellinogermaniki Agogi Scholi Panagea Savva AE	EA	Greece
3	École Polytechnique Fédérale de Lausanne	EPFL	Switzerland
4	EUN Partnership AISBL	EUN	Belgium
5	IMC AG	IMC	Germany
6	Reseau Menon E.E.I.G.	MENON	Belgium
7	Universidad Nacional de Educación a Distancia	UNED	Spain
8	University of Leicester	ULEIC	United Kingdom
9	University of Cyprus	UCY	Cyprus
10	Universität Duisburg-Essen	UDE	Germany
11	Centre for Research and Technology Hellas	CERTH	Greece
12	Universidad de la Iglesia de Deusto	UDEUSTO	Spain
13	Fachhochschule Kärnten – Gemeinnützige Privatstiftung	CUAS	Austria
14	Tartu Ulikool	UTE	Estonia
15	European Organization for Nuclear Research	CERN	Switzerland
16	European Space Agency	ESA	France
17	University of South Wales	UoG	United Kingdom
18	Institute of Accelerating Systems and Applications	IASA	Greece
19	Núcleo Interactivo de Astronomia	NUCLIO	Portugal
20	Cardiff University	CU	United Kingdom

Contributors

Name	Institution
Eleftheria Tsourlidaki, Sofoklis Sotiriou	EA
Panagiotis Zervas	CERTH
Internal Reviewers	
Effie Law	ULEIC
Yiwei Cao	IMC
Internal Contributors of online labs in the Go-Lab repository	
Ton De Jong	UT
Wouter Rijke	UT
Anjo Anjewierden	UT
Jakob Sikken	UT
Eleftheria Tsourlidaki	EA
Eugenia Kypriotis	EA
Denis Gillet	EPFL
María Jesús Rodríguez-Triana	EPFL
Sten Govaerts	EPFL
Yiwei Cao	IMC
German Carro Fernandez	UNED
Panagiotis Zervas	CERTH
Stylianos Sergis	CERTH
Javier Garcia-Zubia	UDEUSTO
Olga Dziabenko	UDEUSTO
Cristian Kreiter	CUAS
Danilo Zutin	CUAS
Leo Siiman	UTE
José Gonçalves	NUCLIO

Legal Notices

Executive Summary

This document is the outcome of the work done during the 4th year of the project in task "*T2.3 – The Go-lab Inventory of Online Labs*" and task "*T2.4 – Populating the Go-Lab inventory"*. More specifically, this document presents:

- the process of populating the Go-Lab Inventory with online labs for year 4;
- the main characteristics of the online labs included in the repository (including characteristics, diversity, multilingualism);

Overall, the Go-Lab inventory currently includes **403 online labs** (number of labs on October 24, 2016; the initial indicator was to have 45 online labs at the end of the project and was extended to 150 online labs during the project's first review). Out of these labs 13 were integrated during the 1st year of the project, 35 during the 2nd year, 113 during the 3rd year of the project and 242 during the 4th year. The consortium continued its efforts to establish new collaborations with similar efforts all over the world. The repositories of Walter Fendt and the Physics Aviary repositories are examples of such collaborations. In addition, the consortium also continued the collaborations already established in the previous years like with the Phet Interactive Simulations and the Amrita University.

Overall, in this final year of the project, the Go-Lab repository is in position to offer to teachers a large repertoire of online labs on all subject domains of Science, Technology, Engineering and Mathematics (STEM) covering both primary and secondary education.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Scope

The goal of WP2 was to create a structured inventory of online labs for their further integration to the Go-Lab portal. The inventory was populated with online labs offered by the Go-Lab partners as well as by lab owners outside the Go-Lab consortium. The methodology for organizing the online labs as well as the validation of the proposed methodology were presented in the previous deliverables of WP2 namely:

D2.1 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Large Scientific Organisations";
D2.2 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Universities";
D2.3 - The Go-Lab Inventory and Integration of Online Labs – Labs offered by External Partners and Federations".

The main scope of this deliverable is to present the final version of the Go-Lab inventory following the additions made during the last year of the project. As it has been the case since the early stages of the project, aside from increasing the number of labs, special attention was paid to adding online labs of high quality that meet the needs of teachers and students covering all STEM domains and having labs available in as many languages as possible.

1.2 Audience

This document targets the Go-Lab partners, so that they can be aware of the final status and overall profile of the Go-Lab inventory and the online labs that are included until the end of the 4th year of the project.

2. Analysis of the Go-Lab Inventory of Online Labs

During the 4th year of the project, **242 online labs** were selected to be included in the Go-Lab Inventory. These online labs were described by following the Go-lab metadata schema presented in “D2.2 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Universities” and they further populate the Go-Lab Repository (http://www.golabz.eu/). Considering also the **161 online labs** that were already included in the Go-Lab repository during the previous years of the project, this has resulted in ***403 online labs*** that are available via the Go-Lab Repository. It should be noted that the initial target as mentioned in Go-Lab DoW was to include 45 online labs until the end of the project. This number was raised to 150 labs during the first review of the project. As a result, the Go-Lab repository can be a useful tool for teachers who search for online labs from different lab providers.

In this section, we present an analysis of the online labs’ metadata that have been included in the Go-Lab Repository until the end of the project. This analysis is based on the methodology that has been reported in Zervas et al. (2016)[1] and includes the calculation of the occurrence frequency of the values for the following metadata elements: (a) lab type, (b) age range, (c) subject domain, (d) Big Ideas, (e) language and (f) difficulty and interaction level.

2.1 Lab Type Element Analysis

As previously mentioned, the Go-lab Repository currently[2] includes 403 online labs. In respect to their type, 331 (82%) are Virtual Labs, 55 (14%) are Remote Labs and 17 (4%) are Data Sets (see Figure 1). Figure 1 presents also the growth of the different types of online labs included in the Go-Lab Repository from year 3 to year 4.

Virtual labs are still dominant in the Go-Lab Repository. This was also the case at the end of year 3 of the project. This is explained by the fact that virtual labs are not very costly to implement and many of them are currently available online. In addition, there are a lot more virtual labs available as they are often preferred by teachers since they can accommodate multiple users at the same time. As a result, it was easier to find available virtual labs and populate them in Go-Lab Repository.

On the other hand, remote labs require specialized equipment and they are difficult to develop and costly to maintain. This means that there are not many remote labs available online. Finally, data set analysis tools are not very abundant in Go-Lab Repository because their development requires specialized knowledge of the structure and format of the data set and this might be hindering factor for interested parties to develop them and offer them online. Nevertheless, in the fourth year of the project, the project consortium increased the number of remote labs and data set analysis tools.

1 Zervas, P., Tsourlidaki, E., Cao, Y., Sotiriou, S., Sampson, D. G., & Faltin, N. (2016), A study on the use of a metadata schema for characterizing school education STEM lessons plans by STEM teachers. Journal of Computing in Higher Education, 1-17.

2 Data retrieved on 27/10/2016

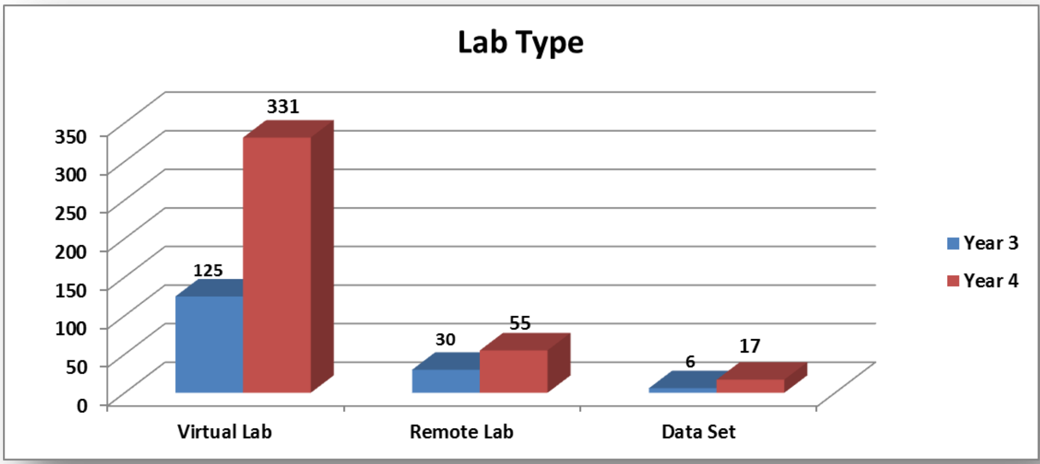

Figure 1. Frequency of the Vocabulary Values of the Metadata Element "Lab Type".

2.2 Age Range Element Analysis

The 403 online labs of the Go-lab Repository address all age ranges of students. More specifically, the dominant age ranges are those that are related to secondary education age ranges, namely 12-14, 14-16, 16-18. One of the reasons why there are more online labs addressing secondary education rather than primary, is because the use of online labs is much more common in secondary education and thus there is a greater need for online labs for ages between 12 and 18 years old. One of the reasons behind this is because for younger ages teachers usually do a lot simpler experiments with their pupils which only require simple materials. However, there are also adequate numbers of online labs that address primary education age ranges, namely 6-8, 8-10, 10-12 (see Figure 2). Finally, it should be noted that Go-Lab targets students between 10 and 18 years old. Nonetheless the consortium has decided to extend the age range covered starting from 6 years old students. However, as ages between 6 and 10 are not primarily addressed by the Go-Lab project, the number of labs covering these ages is lower.

Figure 2 presents also a comparison between the age ranges addressed by the online labs that were included in the Go-Lab Repository at the end of year 3 and the online labs that are currently available in the Go-Lab Repository, namely end of year 4. This comparison demonstrates that the distribution of the age ranges addressed by the online labs of the Go-Lab Repository at the end of year 3 and at the end of year 4 has remained nearly the same.

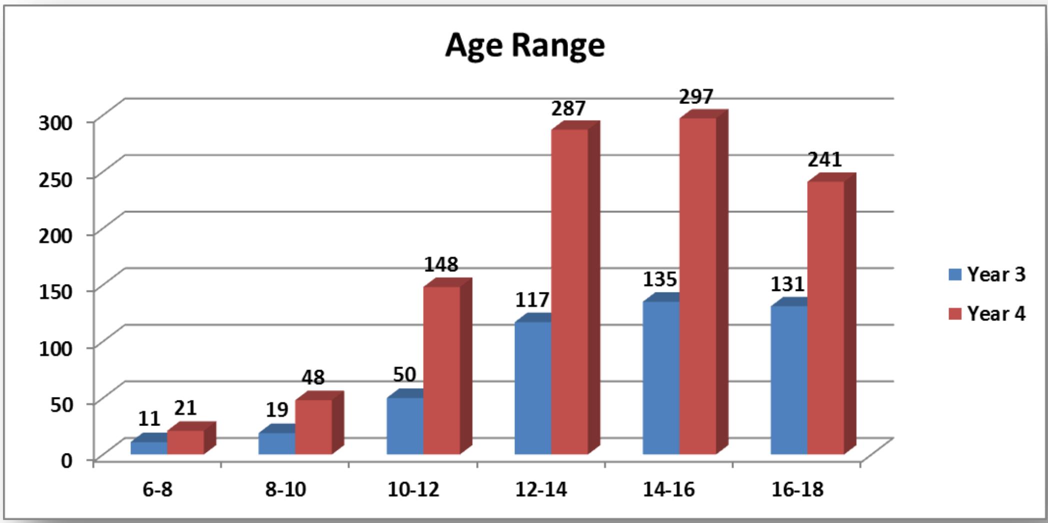

Figure 2. Frequency of the Vocabulary Values of the Metadata Element "Age Range".

2.3 Subject Domain Element Analysis

The Go-Lab project set out to create a federation of online science labs. Thus, the 403 online labs of the Go-Lab Repository cover mainly the Subject Domain of "Science Education" (namely, physics, chemistry biology, environmental education, astronomy and geography and earth science). However, during the 3rd year of the project the consortium decided to extend the subjects covered by the Go-Lab repository and also included labs that address "Mathematics", "Technology" and "Engineering". In this final version of the Go-Lab inventory there is an adequate number of online labs that focus on these additional subject domains (see Figure 3). Figure 3 presents also how the different subjects addressed by the online labs of the Go-Lab Repository have been increased from year 3 to year 4.

The dominant subject that is addressed by the online labs is physics. This is explained by the fact the physics includes many concepts that can be taught with the support of online labs following the inquiry process. During the fourth year of the project, the project consortium also put an effort to increase the number of online labs that address other sub-subjects of science education such as astronomy and geography and earth science and biology. Moreover, the consortium also focused on adding online labs that address Mathematics, as well as Technology and Engineering, so as to cover the full spectrum of STEM School Education. It should be noted that in year 3, there were no online labs that were covering these subjects, whereas in year 4 there are online labs that cover these subject domains.

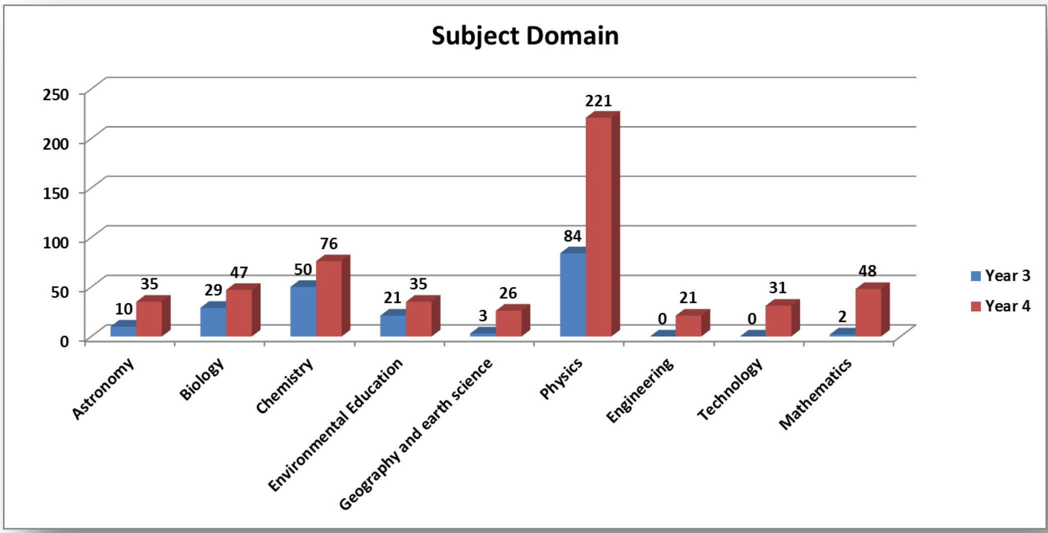

Figure 3. Frequency of the Vocabulary Values of the Metadata Element "Subject Domain".

2.4 Big Ideas of Science Element Analysis

The online labs of the Go-Lab Repository are addressing at least one of the 8 Big Ideas of Science, which have been extensively discussed in "D2.3 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by External Partners and Federations'. As we can see at Figure 4 below, the most dominant Big Ideas of Science (BIS) that are addressed by the online labs are BIS2: Fundamental Forces (258 out of 403 online labs, 64%), BIS1: Energy Transformation (207 out of 403 online labs, 52%), and BIS4: Structure of Matter (158 out of 403 online labs, 39%). The Big Ideas of Science #1 and #2 are most relevant to the subject domain of Physics which is the most dominant subject that is being addressed by the online labs (as described at Section 1.3 above) while they are also the most interdisciplinary ones. Big Idea of Science #4 is most relevant to the subject domain of Chemistry which is the second most dominant subject domain addressed by the online labs of the Go-Lab Repository. Figure 4 presents also a comparison between the Big Ideas addressed by the online labs that were included in the Go-Lab Repository at the end of year 3 and the online labs that are currently available in the Go-Lab Repository, namely end of year 4.

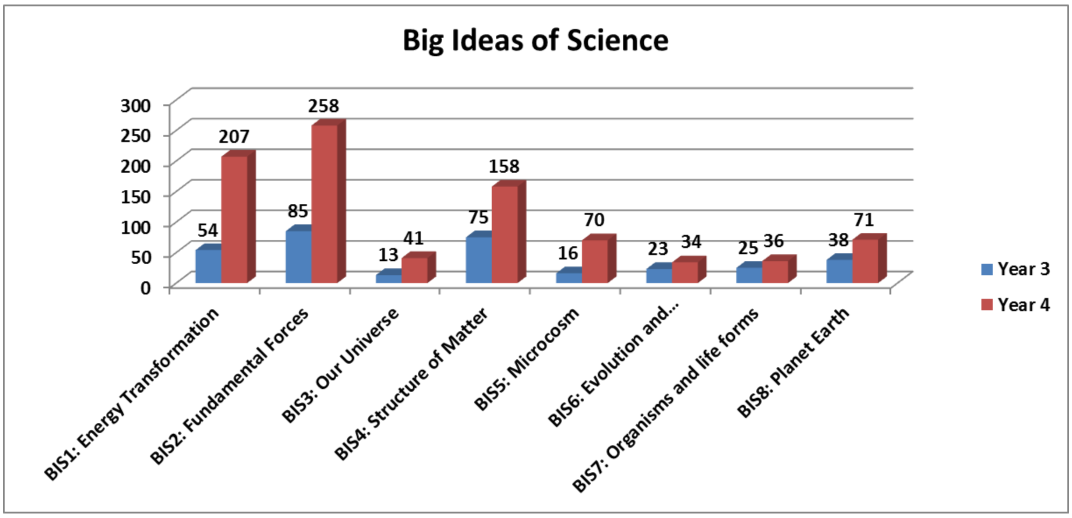

Figure 4. Frequency of the Vocabulary Values of the Metadata Element "Big Ideas of Science".

2.5 Multilingualism Element Analysis

The 403 online labs of the Go-Lab Repository are offered in different languages in order to provide multilingualism to the users who are not familiar with foreign languages. More specifically, there are 38 different languages that are supported by online labs included in the Go-Lab Repository. The most dominant language is English (398 out of 403 online labs, 99%) as depicted in Figure 5, thus we provide also a second level of analysis of the remaining languages in Figure 6.

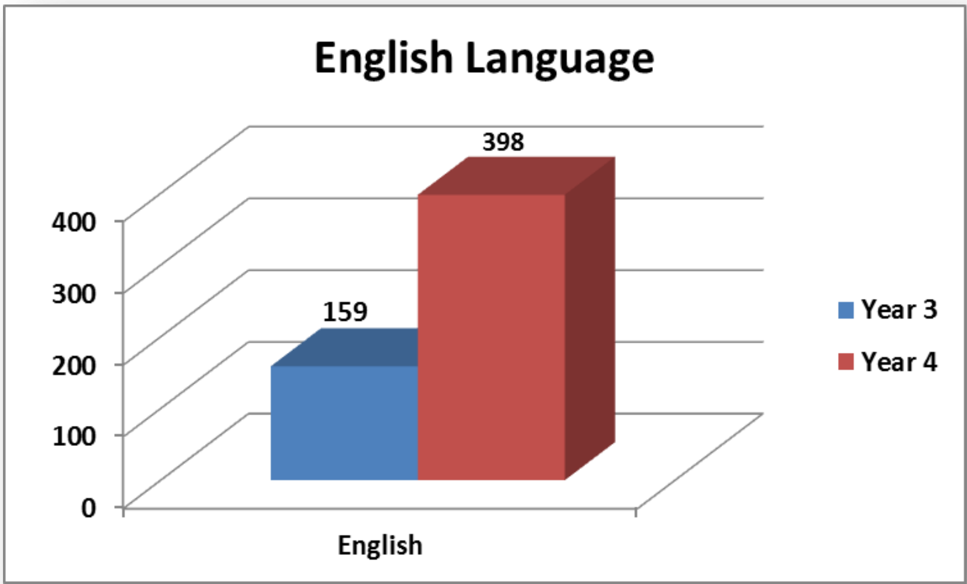

Figure 5. Frequency of the Vocabulary Values of the Metadata Element "Language" for the Value "English".

Regarding the remaining languages, the dominant languages are: (a) Spanish (79 out of 403 online labs, 20%), (b) German (78 out of 403 online labs, 20%) and (c) French (73 out of the 403 online labs, 18%). Figure 6 presents also a comparison between the languages that are supported by the online labs that were included in the Go-Lab Repository at the end of year 3 and the online labs that are currently available in the Go-Lab Repository, namely end of year 4. This comparison demonstrates that the available languages (except for English) have been increased from 33 to 37.

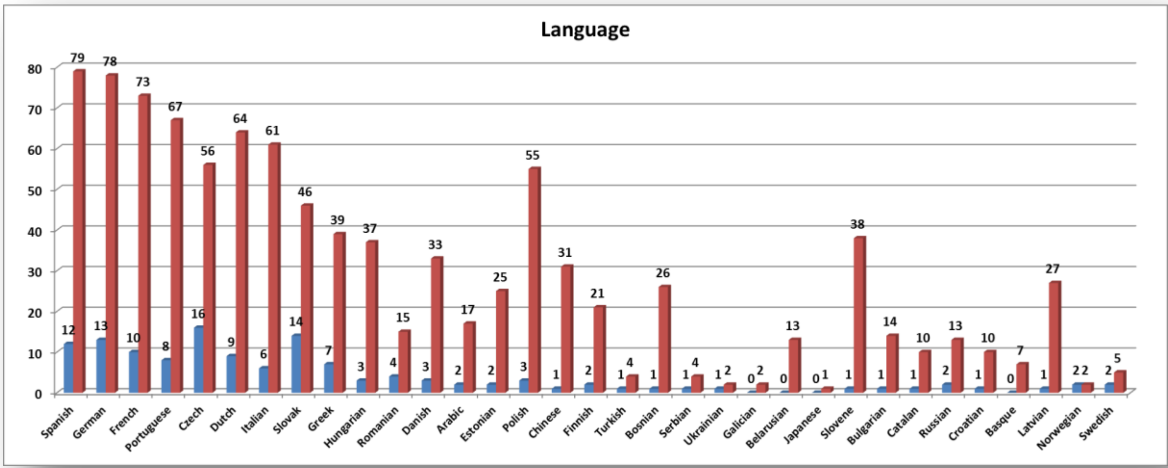

Figure 6. Frequency of the Vocabulary Values of the Metadata Element "Language".

2.6 Difficulty and Interaction Level Elements Analysis

The dominant level of difficulty of the online labs included in the Go-Lab repository is medium and easy, whereas online labs with advanced difficulty level are limited (see Figure 7). This means that most of the online labs in the Go-Lab repository can be operated by the students themselves or with slight assistance from their teachers. This can be explained by the fact that most online labs of the Go-Lab repository address secondary school education and at this grade level, online labs of medium or easy difficulty are needed towards engaging students in understanding and exploring STEM concepts.

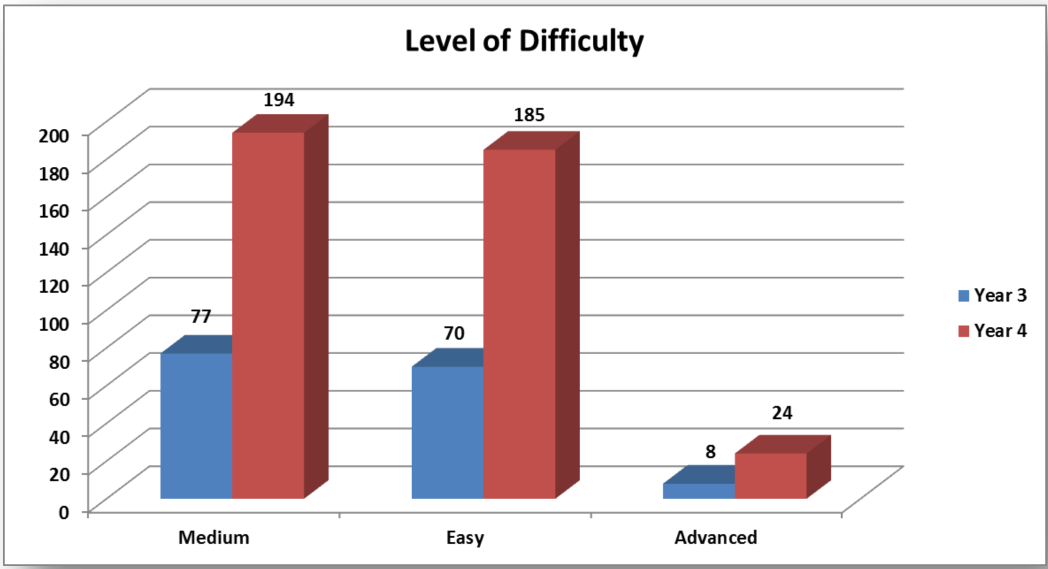

Figure 7. Frequency of the Vocabulary Values of the Metadata Element "Level of Difficulty".

The dominant level of interaction of the online labs included in the Go-Lab repository is high, whereas there are also several online labs with medium and low interaction level (see Figure 8). This means that most online labs in the Go-Lab repository require students to manipulate many variables in order to operate them. This is very important for providing students the capability to deeply engage in the experimental process.

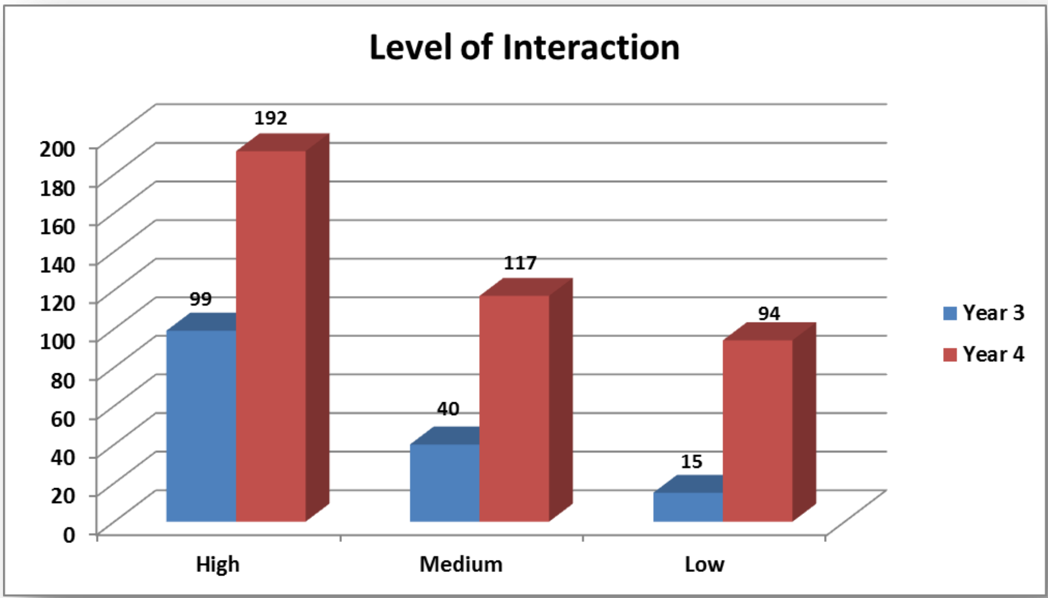

Figure 8. Frequency of the Vocabulary Values of the Metadata Element "Level of Interaction".

3. The profile of the Go-Lab Inventory

The Go-Lab project set out to create a federation of science online labs so as to make them easily accessible for the teaching community. Based on the project's description of work, by the end of the project the Go-Lab inventory would include a minimum of 45 online labs which would cover all science disciplines and target students between 10 and 18 years old. To achieve that, the project team would have to implement a three-stage deployment cycle. In the first year, the team would have to add a minimum of 10 labs mostly offered by large scientific organizations. In the second year, the team would have to add an additional 10 labs coming from Go-Lab partner universities. In the third year of the project the project team would have to add another 25 online labs provided by external partners.

The project team decided to extend the lifetime of WP2 for one more year and to add one additional deployment stage so that more labs from external owners could be added. Except the labs coming from project partners, by the end of the project (31st of October, 2016), there are online labs in the Go-Lab repository coming from 59 different external sources. During the four years of the project, the team has managed to create a federation of labs which included 403 online labs, covering not only science subjects but also mathematics, engineering and technology which target students from 6 to 18 years old. In the table below we present a comparison between the originally planned profile of the Go-Lab inventory and the actual profile at the end of year 4.

Table 1. Comparison of the originally planned profile and the actual profile of the Go-Lab inventory at the end of year 4.

	Planned Profile (based on DoW)	Actual Profile (at the end of year 4)
Online labs added	45 (150 after 1st review)	403
Age ranges covered	10-18	6-18
Subjects covered	Science	Science, Technology Engineering, Mathematics

In addition, in the figure below we present the growth in terms of labs added of the Go-Lab inventory in comparison to the milestones set at the beginning of the project.

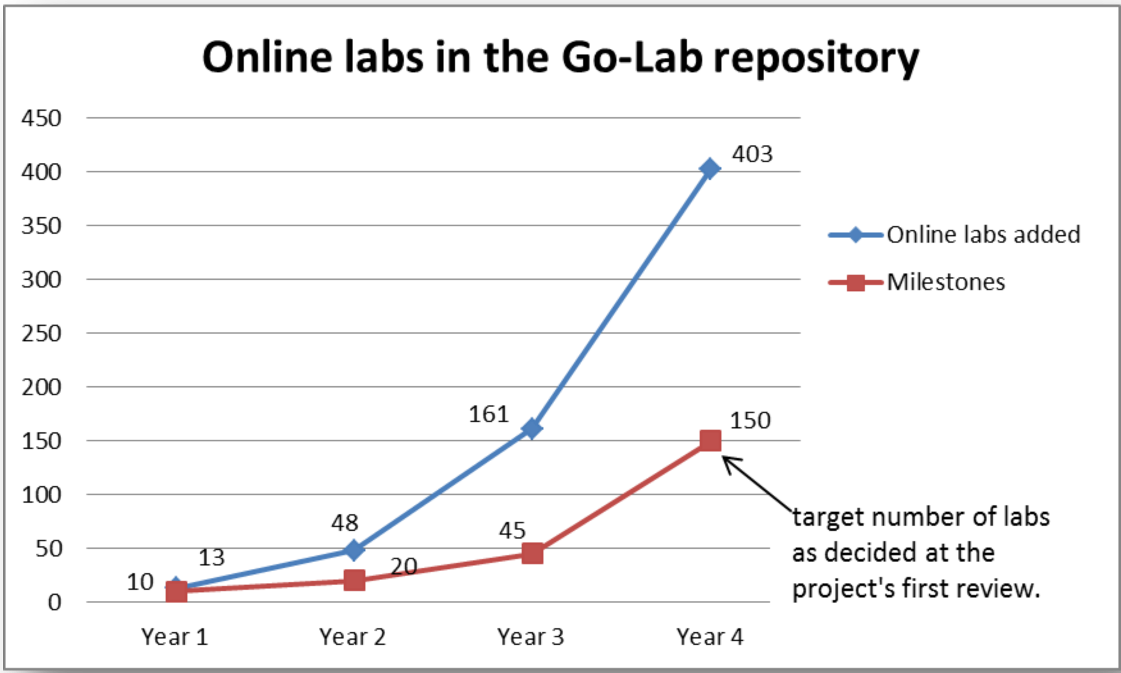

Figure 9. Growth of the Go-Lab repository of online labs.

As mentioned above, these 403 labs come from many different sources. More specifically we present in the table below, the organizations who added their labs in the Go-Lab repository.

Table 2. Origin of labs in the Go-Lab repository.

Lab coming from large organizations and project partners (not university partners)	
CERN	2
EPFL	9
ESA	2
IASA	2
EA	4
Total	**19**
Labs coming from participating universities	
CU	4
CUAS	5
UT	4
UDE	1
UDEUSTO	5
UNED	5
UTE	1
Total	**25**
Labs coming from external parties	
Academo.org	10
Amrita University & CDAC Mumbai	8

The Concord Consortium	36
Kscience	9
New York University	6
PhET Interactive Simulations	40
Physics Aviary	80
RemLabNet	10
Remotely Controlled Laboratories	11
RexLab	9
The King's Center for Visualization in Science	17
University of Nebraska-Lincoln astronomy education	21
University of Saint Andrews	3
Virtual Biology Lab	20
Walter Fendt	28
Xplore Health	8
Other organizations (with one or two labs in the repository)	43
Total	359

When it comes to the additional characteristics of our inventory's profile, like type of labs included, subject domains covered, and so on, we expected since the beginning of the project that these characteristics would not have an even distribution as there would be many different factors that could affect each of them. Indeed, based on the analysis presented in chapter 2, we can see that this is the case for all the metadata investigated.

Having a closer look to the analysis for the online labs' metadata included in the Go-Lab repository we can make the following observations:

a. Lab type*:* Virtual is the dominant type of labs (82%)

Having a much higher number of virtual labs was expected. Compared to remote labs and data sets, virtual labs available for science education are much more widely available. This is due to many reasons some of which are listed below:

- Virtual labs are relatively easy and inexpensive to build and do not require constant maintenance;
- Virtual labs can also be used as tools to help students visualize phenomena that are invisible;
- Virtual labs can simulate experiments that in real life would take a lot of time to do;
- Virtual labs can facilitate multiple users at the same time;
- Remote labs are very costly to build and they require constant maintenance;
- Remote labs cannot easily support multiple users simultaneously;
- Remote labs often require booking so they may not be available when a teacher needs them;
- Data sets often need additional software to be installed in order to be able to manipulate data;

As a result, the project team was able to locate and integrate a significant amount of virtual labs in the inventory, but this was not the case for remote labs and data sets. In many cases, data sets explored were rejected as they were not accompanied by an online processing tool or the data available were not suitable for students to use. Remote labs were quite difficult to find. In addition, in some cases lab owners of remote labs could not be reached, so it was not possible to coordinate with them the integration of their labs.

b. **Age Range:** Ages between 12 and 18 years old are the ones best represented in the Go-Lab inventory. Ages between 10 and 12 years old are also covered by a significant number of labs.

The Go-Lab project targets students between 10 and 18 years old. Thus it is expected that these ages are covered by a larger number of labs compared to ages lower than 10. Although ages 10 to 12 are well covered by the Go-Lab inventory, (more than 145 labs are available for these ages) the number of labs available is less than for ages 12 to 18. This is however expected as for students aged 10-12 the experiments they are expected to do are relatively simple and quite limited in number. Thus the need and in turn the availability of online labs for these ages is lower than for older students.

c. **Subject Domain:** Physics (221) is the most dominant subject domain followed by chemistry (76). Other subject domains include between 21 and 48 online labs.

Physics covers phenomena on multiple scales of the universe; from the microcosm to the macrocosm. To this end the number and variety of phenomena and themes that can be taught using online labs are much higher compared to the other science disciplines. As a result, both teachers' needs and the availability of online labs on physics are higher. This is reflected on the Go-Lab inventory as physics is the most prominent subject, while there is a more even distribution of labs among other disciplines and subjects.

d. **Big Ideas of Science:** The Big ideas of Science covering energy (BIS1), fundamental forces (BIS2) and structure of matter (BIS4) are the most represented ones.

BIS1 and BIS2 cover practically all the scales of our universe so it is expected that they can potentially cover a very wide range of online labs. This is also reflected on the analysis seen above. BIS4 can potentially cover online labs that are used in both physics and chemistry. As these two subjects are the most popular ones in the inventory it only makes sense that BIS4 also included a higher number of labs compared to the rest of the Big Ideas of Science.

e. **Multilingualism:** English covers 99% of the inventory. All languages covered by the consortium are present in the inventory. In total 26 languages have a selection of more than 10 online labs.

In an international inventory it is only expected that the vast majority of labs are available in English. This is also the case with the Go-Lab inventory. In addition to that, the project team tried to include as many multilingual labs as possible focusing mostly on the languages of the implementation countries. Indeed, overall the inventory includes between 25 and 40 labs available in languages that are spoken in one or two countries (for example Greek) and between 60 and 80 labs available in languages that are spoken in multiple countries (for example German).

f. **Level of Difficulty:** Medium and easy difficulty level labs cover 95% of the labs evenly.

Labs with easy to medium level of difficulty are labs that students can use completely on their own or with a little guidance from the teacher. Such types of labs can increase students' confidence and degree of engagement. On the other hand, labs with high level of difficulty are labs that students can use only with the assistance of a teacher and they usually are appropriate for more advanced students. Thus in order to meet the needs of the teaching community and support the effort of mainstreaming the use of online labs it is essential to ensure that the majority of the labs available are apt for use in an average science class where a teacher has to teach 25 to 28 students of different levels.

g. **Level of Interaction:** The majority of the labs have a high interaction level; there are significant numbers of medium and low interaction level labs as well.

Low interaction level means that students manipulate only one variable during experimentation and focus more on observation. Medium interaction level means that students have to manipulate 2 to 3 variables during experimentation while high interaction indicates the manipulation of more than 3 variables. Thus in order to have labs that promote problem solving skills and inquiry skills as much as possible, the Go-Lab online labs would have to be between high and medium level of interaction to their majority. This is indeed the case as presented in the analysis in chapter 2.

Overall, as presented above, the Go-Lab inventory of online labs has by far exceeded the expectation and its final version includes a much higher than expected number of labs covering not only science subjects but STEM as a whole for students aged 6 to 18 years old. The distribution of labs based on their different characteristics is as expected, based on the availability of online labs as well as on meeting the needs of teachers.

4. Conclusion

The Go-Lab project set out to create a federation of science online labs in order to make available to teachers throughout Europe and beyond. To achieve that, WP2 partners (through Tasks 2.3 and 2.4) would have to implement a three-stage deployment cycle by the end of which the Go-Lab inventory would have to include a minimum of 45 online labs which would cover all science disciplines and target students between 10 and 18 years old. During the four years of the project, the team has managed to exceed by far these expectations and create a federation of labs which included not 150 but 403 online labs, which cover not only science subjects but also mathematics, engineering and technology thus covering the entire STEM spectrum. In addition, the labs of the Go-Lab inventory target a wider range of student ages from 6 to 18 years old than originally anticipated. Finally, the analysis presented indicates that labs are not distributed uniformly when looking at different types of categorization based on their different characteristics. Instead, they follow a distribution which varies with each characteristic and that is shaped based on the availability of existing online labs and the needs of the teaching community.